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VIRUS DISEASES OF CACAO: THE WORLD SITUATION

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INTRODUCTION

Throughout the cacao growing areas of the world pests and diseases act as an important check on production. Yield records and assessments of the extent of damage are so inadequate that an accurate estimate of the loss in crop is impossible. Nevertheless Hale (1953) suggested that 200,000 tons of dry cacao were lost each year through pests and diseases and this amounts to a substantianl proportion of the average world production of 840.000 tons during each of the last five years.

The relative importance of the various pests and diseases varies between countries and in the West Indies and South America fungus diseases cause the chief loss in crop, whereas in West Africa capsids are more important. However the losses due to these causes varies widely with season and can at least be partially controlled by measures which increase productivity and give a financial return for the outlay involved. By comparison virus diseases tend to cause steadily increasing although less spectacular losses, which are likely to become relatively more important in the future with the adoption of more general control measures against the other pests and diseases. Furthermore, trees infected with virus cannot be cured and eradication methods are the only control measures which it is possible to adopt on a widespread scale and these can do no more than check further spread. At best therefore they can only maintain the present position and can make no positive contribution to production.

Detailed reviews of the literature on the spread and control of cacao virus diseases have recently been prepared (Thresh, 1958a, 1958b). The present paper summarizes the available information on the distribution of cacao viruses throughout the world. An attempt is also made to assess the relationships between the numerous isolates of virus which have been made from infected cacao and to estimate their importance in the various growing areas.

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Ghana:

In 1936 cacao trees in the New Juaben District of the Eastern Province of Ghana were found to be affected by a disease which caused abnormal swellings to appear on the branches (Steven, 1936). The disease became known as cacao swollen shoot and all attempts to find its cause were unsuccessful until Posnette (1940) used grafting methods to demonstrate that it is due to virus infection. Subsequent detailed surveys of the all important growing areas in Ghana and Togoland revealed that infection must have been present in the country for many years, because infection was widespread in the Eastern Province and numerous scattered outbreaks occurred in Ashanti, Western Province and Togoland. The Department of Agriculture are responsible for the eradication control measures in Ghana and their records indicate the extent of the virus problem. By the end of 1957, 1,400,722 infected trees had been eradicated in Ashanti, 61,568,178 in the Eastern Province, 4,123,780 in Western Province and 111,990 in Togoland. Not all these trees were mature, but assuming an average tree density of 600 to the acre, this indicates that 112,000 acres of cacao have been destroyed in disease control operations in a country where a total of 4,079,000 acres have been recorded. These are not the only losses due to swollen shoot disease and many other infected trees must have died before control measures were started, while losses continue in untreated areas.

In these circumstances it is hardly suprising that 80% of the total expenditure of the Department of Agriculture, on cacao in Ghana should be on control measures against swollen shoot disease. Indeed this work has until recently dominated the work of the whole Department and has probably delayed the introduction and extension of control measures against other cacao pests and diseases. Nevertheless, the eradication control measures have achieved considerable success and only limited numbers of infected trees are now being found and cut out in Ashanti, Trans-Volta & Togoland, the Nkawkaw Division of Eastern Region and the Eastern and Central sections of the Western Provinces. Swollen shoot is being controlled in these areas but many infected trees remain to be destroyed elsewhere in the Eastern and Western Regions where trees are still being cut out at a rate of 797,000 per month (Hammond, 1957).

Nigeria:

Swollen shoot disease was first recognized in Nigeria in 1941, soon after the start of the first detailed survey of the growing areas. This survey was completed in 1949 and revealed that the disease was not present in the limited cacao areas in the Northern and Eastern Regions of the country and that in the Western Region most of the diseased trees were in Ibadan Province, although scattered outbreaks also occurred in Abeokuta, Ijebu Ode and Oyo Provinces. One and a half million infected trees were destroyed by June 1950 in an unsuc-

cessful attempt to eradicate swollen shoot disease from the country. Control measures were then abandoned in one heavily infected part of Ibadan Province in 1950 and in part of Abeokuta Province in 1953. These two areas contain 142,000 of the 989,000 acres of cacao which have been recorded in the Western Region and within them infection is spreading without check and causing a progressive decline in yield. Moreover the two abandoned areas are acting as incresingly dangerous foci of infection from which virus is apparently spreading at an increasing rate into the adjacent and hitherto healthy cacao. Nevertheless, these areas are being maintained free or relatively free from infection by limited cutting out operations involving the destruction of an average of 61,000 trees in each of the last four years. (Lister & Thresh, 1957; Thresh, 1958d).

Ivory Coast:

Virus disease of cacao in the Ivory Coast was discovered during the first survey of the growing areas which was started at the end of 1943. Outbreaks were at first thought to occur only in the east, around Abengourou in areas alongside Ashanti and the Western Provinces of Ghana, from which virus appeared to have spread. However a more detailed assessment of the position later revealed numerous outbreaks in the western cacao areas around Issia and Daloa. These were remote from the nearest sources of infection in Ghana and Ivory Coast. In 1946 it was already estimated that 1,950 acres were infected in a recorded acreage of 122,000 and only limited control measures have been practised in subsequent years, so that the position has inevitably deteriorated (Renaud, 1957). However, the rate of spread has been limited by the scattered nature of the farms particularly in the western localities.

Other Parts of West Africa:

Cacao virus diseases have not been reported from Sierra Leone, Liberia, French Togoland, Dahomey, French Cameroons or Saint Thome; while the suggestion that the vein-clearing disease of cacao in British Cameroons is caused by a virus has not been confirmed by transmission tests (Thorold, 1957). Nevertheless it is possible that a more intensive search may reveal infection in one or more of these areas, particularly as they contain known potential hosts of some of the West African cacao viruses.

The West Indies:

Dale (unpublished information) could find no evidence of virus infection in cacao in Grenada, St. Vincent or St. Lucia but virus in Trinidad cacao was noted in 1943 (Posnette, 1944) at River Estate near the western end of the Northern Range. Subsequent surveys showed that infection was apparently confined to this part of the island and leaf symptoms were found at all the outbreaks, but no swellings. No outbreaks have been discovered in the main cacao areas

of eastern, central and southern Trinidad. However in the north, additional scattered outbreaks were found at Diego Martin and more extensive infection in the Maracas and Santa Cruz valleys where infected trees were found in almost every plantation.

Additional observations on the distribution of virus in Trinidad are presented by Baker & Dale (1947) and Kirkpatrick (1951), but there has been no recent assessment of the extent of infection. Nevertheless, in the absence of any general control measures the number and extent of the original outbreaks must have increased.

South America:

There are no fully substantiated reports of virus infection in cacao in South America, although there are indications that this may occur. Thus, Posnete & Palma (1944) found trees in Venezuela with symptoms of a type caused by virus infection, but were unable to carry out transmission tests. Similarly, in Colombia and Dominica, Ciferri (1948) observed symptoms which may have been caused by virus and reported occasional transmissions to seedlings inoculated by grafts. These results have not been substantiated or confirmed.

A further suggestion that virus may be present in South America was made by Kevorkian (1951). However, the only evidence for this statement appeared to be that an abnormal condition of the flowering cushions on trees in Nicaragua, Costa Rica and Panama is systemic in that it affects the whole tree.

The Pacific:

Only limited acreages of cacao are present in the various growing areas in the Pacific, but leaf symptoms similar to those caused by West African viruses were reported in Ceylon by Urquhart (1951) and subsequently described with photographs by Peiris (1953). The presence of virus in Ceylon was eventually demonstrated by Carter (1956) who infected young seedlings by mealybugs which had fed on material from affected trees. Only leaf symptoms were found at the earliest recorded outbreaks, but swellings were later noted at two estates naear Kandy (Arellana & Peiris, 1957). There appear to have been no detailed assessments of the extent of infection in Ceylon cacao. However, the indications are that virus has been present at least since 1951 and spreading without check for a period of several years.

Elsewhere in the Pacific, Thung (unpublished information) has recorded virus-like leaf symptoms in Java, but the remaining cacao growing areas including Malaya and New Guinea appear to be free from infection.

The movement of Planting Material Between Growing Areas:

The limited distribution of the most virulent types of cacao virus, and the complete absence of virus disease from certain areas emphasise the importance of strict quarantine arrangements for the

movement of planting material between countries. None of the cacao viruses are known to be seedborne, but cuttings, buds, and pods taken from infected trees are likely to contain virus, which may be moved between growing localities and countries in this material. This may already have occurred in the past and everything possible should be done to prevent any further movement of virus in this way. Obvious precautions are to take pods, cuttings or grafting material only from trees growing in areas remote from the nearest source of infection, and which are thoroughly inspected for virus symptoms at regular intervals. It is also important to hold cuttings under quarantine conditions both in the country of origin and in the receiving country. Moreover, intact pods should only be transported between countries if they had been carefully treated with insecticide to destroy any possible mealybugs occuring on them and if they are destroyed immediately they are broken and the seed removed.

Cuttings derived from some of the selected Amazon parents present a particular quarantine problem as they may tolerate infection and show limited and inconspicuous symptoms even when infected with virulent forms of virus (Posnette & Todd, 1951). This means that they are difficult to check for the presence of virus, particularly if they are fan cuttings which may make little growth with symptoms during the conventional quarantine period. For these reasons it is suggested that clonal material should, be moved between countries not as cuttings but as budwood, which is multiplied on susceptible indicator stocks in the country of origin and in the receiving country.

GENERAL FEATURES OF CACAO VIRUSES AND CRITERIA FOR THEIR CLASSIFICATION

At an early stage of the virus investigations in West Africa it was realised that major differences occurred between some of the isolates obtained from the different outbreaks (Posnette, 1943). For example some of them consistently failed to cause swellings and many others could be distinguished by their leaf symptoms. Nevertheless all the isolates which have been made have certain features in common with each other and with vruses obtained from cacao elsewhere. These are discussed in the present section with particular reference to the features which are of diagnostic value in the classification of the various isolates.

Symptoms:

All the viruses which have been described from cacao have been characterized by the symptoms they cause on young plants or cuttings inoculated by grafts or mealybugs. This work has shown that some isolates cause stem and root swellings, which may be large and produced at early stage of infection, or small and produced infrequently after a long delay. They are caused by a localized increase in the amount of secondary phloem and xylem within the affected tissues and the tracheids are larger and the zone of cambium tissue wider than usual (Knight & Tinsley, 1958).

Leaf symptoms are caused by all the cacao viruses, and appear during the expansion of the leaves and take their final form when these have matured. At an immatur stage of the leaf the symptoms take the form of a reticulate red pattern, referred to as red vein banding, which is caused by an abnormal accumulation of anthocyanin in the tissues immediately alongside the minor veins. These transient symptoms become masked as the leaves harden and the chlorophyll pigments appear, but at this stage the permanent symptoms become obvious. These are due to a clearing of the veins or to a limited development of chlorophyll in the tissues immediately adjacent to them. The leaf symptoms may be extensive, affecting a large portion of the leaf or they may be limited to a few of the smaller veins. Moreover they may vary according to the virus, the host and the stage of infection. Thus quite dissimilar isolates may resemble each other at particular phases of infection and it is essential to keep test plants under observation for a period of several months, otherwise the full details of the sequence of symptom expression are missed.

Some of the isolates of virus from cacao in West Africa and at least one of those occurring in Ceylon, cause infected trees to produce abnormally small and rounded pods, the surface of which may be mottled. Other symptoms caused by cacao viruses are of less diagnostic value as they may be due to other factors. For example, stems may show premature defoliation and dieback, while infected trees also tend to flush less regularly than comparable healthy ones. The yield of infected trees is also adversely affected to an extent depending upon the virulence of the virus they contain and on the environmental conditions. The virus found at New Juaben in Ghana is the most severe in its effects and in one experiment reduced yield by 25% in the first crop after inoculation, 50% in the second and stopped production in the third, by which time most of the trees were dead. (Crowdy & Posnette, 1947).

Already more than 100 isolates from cacao in various parts of the wold have been characterized in greater or lesser detail by the symptoms they cause on cacao and there seem to be no limit to the number which could be found and described if sufficiently detailed attention is given to the finer aspects of symptom expression. However, symptoms are of limited value as an indication of the relationship between different viruses. This has become apparent from the work with virus diseases of other crops, where it has been found that similar symptoms may be caused on a particular host by different viruses, while a range of symptoms may be caused by different strains of one particular virus on the same host.

Transmission:

Numerous attempts have been made to transmit viruses from cacao in West Africa by sap inoculation, but these have been uniformly unsuccessful. Consequently it is hardly surprising that antisera

have not been prepared against any of the cacao viruses, that there is a complete lack of information on their physical and chemical properties, and that they do not appear to be spread by contact. Similarly there is no evidence that any of the viruses are soil-borne, or that natural root grafts occur between trees. Indeed all the evidence indicates that the natural spread of cacao virus diseases takes place by the movement of mealybugs (Pseudococcidæ) from infected trees. This has been demonstrated in West Africa (Posnette, 1950) West Indies (Kirkpatrick, 1950) and Ceylon (Carter, 1956) with all the viruses which have been adequately tested, except the unique group of isolates from adjacent localities in south west Nigeria. These appear to be spreading in the field but all attempts to transmit them by mealybugs and some other sucking insects have so far been unsuccessful.

Detailed experiments have shown that the probability of mealybugs transmitting virus from plants infected with a virus from Mampong in Ghana, increased with the number of vectors used an the lenght of time they spent on the source plants up to an optimum period of several hours (Posnette & Robertson, 1950). The infection rate also increased with the time spent on test plants up to a period of 50 minutes. Starved insects were more efficient than unstarved ones in transmitting virus from infected plants on which they had spent less than 10 hours. However the virus persisted for less than 36 hours in mealybugs which were starved after an infection feed and was non-persistent in insects which were allowed to feed. Similar results have been obtained in the only other detailed transmission experiments which have been done. These involved the New Juaben virus also from Ghana (Dale, 1955) and a virus from Trinidad (Kirkpatrick, 1950). There is no evidence therefore that the different isolates which have been transmitted by mealybugs may be grouped according to the conditions under which they are transmitted by the vector.

Of greater significance is the observation that viruses are not uniformly transmitted by all members of the mafily *Pseudococcidæ* and some species are able to transmit certain viruses but not others. For example *Ferrisiana virgata* Ckll. will transmit some West African viruses but not others and the only viruses to be transmitted by *Pseudococcus adonidum* (L.) fall into the second group (Posnette, 1950).

Host Range Investigations:

Host range studies were started at an early stage of the virus investigations in West Africa, with the object of obtaining information on which to base a classification of the various isolates and on their possible indigenous hosts. Similar studies have not been undertaken with viruses from elsewhere. Consequently generalisations are impossible on the available information, which indicates that the host range of the eight isolates which have been studied is limited

to a number of closely related families in the Tiliales and Malvales (Tinsley & Wharton, 1958; Dale & Attafuah, 1957). Thus five isolates from Ghana and three from Nigeria infected at least some of the species of the Tiliaceae, Bombacaceae and Sterculiaceae with which they were tested, using mealybugs to carry out the inoculations.

Moreover, at least one of the Ghana viruses will also infect species in the Malvaceae of the order Malvales. Of the many other tested species, which belong to a wide range of families, none has yet been infected.

Different isolates did not always cause the same symptoms on a particular host. Furthermore the different hosts were not uniformly susceptible to all the isolates with which they were tested, and none of them infected exactly the same group of species. Indeed, the isolates could be divided into three groups according to their ability to infect certain key species and an extension of this work may give important information on which to base a detailed classification.

Several of the hosts which are known to be susceptible to West African cacao viruses are indegenous or have been introduced to many of the most important cacao growing countries, and may act as natural sources of infection. This has already been demonstrated in Ghana where virus has been transmitted to cacao by mealybugs which had fed on samples from *Adansonia digiatata* L. trees on the Accra Plains, Togoland and the Guinea Savannah areas (Attafuah & Tinsley, 1958), from *Cola chlamydantha* K. Schum. trees in the West Province and from a *Cola gigantea* var *glabrescens*, Brenan *et* Keay seedling and *Ceiba pentandra* Gaertn. trees in the Eastern Province (Posnette, Robertson & Todd, 1950). Further work will probably reveal additional infected wild hosts, although it is not always easy to demonstrate the presence of virus in trees which are difficult to sample or which tolerate infection. Nevertheless the existing information on the extent of infection in *A. digitata* and *C. chlamydantha* trees miles away from the nearest cacao indicates that virus was present in the hosts before the crop was introduced to Ghana at the beginning of the century. Virus may also have spread from indigenous hosts to cacao in other countries. However, there is no evidence on this possibility except that an infected *C. pentandra* tree was discovered in an outbreak in Nigeria (Posnette, Robertson & Todd, 1950).

Protection Tests:

It has been established that certain viruses are able to recover from the initially severe effects of infection and eventually make symptomless growth, even though this may contain virus. Plants which recover in this way are subsequently either totally or partially immune from the effects of an additional inoculation with the same virus or with related strains.

In the same way plants which are systemically infected with one virus may resist subsequent infection with related viruses but not with different ones.

The ability of viruses to interfere with the establishment and multiplication of related strains has been used as a basic criterion for determining relationships and protection tests with certain viruses give definite results and indicate affinities which have been substantiated by serological tests. With other viruses the results of the experiments have been equivocal and protection may be incomplete or even absent between closely related viruses. In general the results indicate that viruses are usually closeley related when one will protect plants from the effects of subsequet inoculation with the other. However the inability of a virus to protect plants from the effects of a second one does not necessarily mean that the two viruses are unrelated.

The possibility of using protection tests to indicate relationships between the various isolates from cacao were appreciated at an early stage of the investigations in West Africa and many tests have been carried out in which grafting methods were used for most of the inoculations. Various degrees of protection were noted between the different isolates. Some were able to protect plants completely from the effects of subsequent inoculation with other viruses, which either failed to infect or caused no recognizable symptoms. A striking example of this type is the protection afforded by the mild New Juaben virus against the severe form and also against similar viruses from Konongo in Ashanti and from Kongodia in Ivory Coast. Thus the New Juaben virus rarely causes symptoms on trees already infected with the mild virus and has no detectable effect on the yield of these trees (Posnette & Todd, 1955). With another combination of viruses partial protection has been noted. For example the New Juaben virus can infect plants already infected with a virus from Bisa, but there is an unusually long latent period and the symptoms of the challenging virus may be mild or even absent (Crowdy & Posnette, 1947). An additional phenomenon was noted when plants infected with the New Juaben virus were inoculated with one from Mampong.

The symptoms of each virus occurred independently on some leaves but occasional leaves were formed with a characteristic mosaic, quite unlike the symptoms caused by either virus alone (Posnette & Robertson, 1950). The formation of a complex in this way has not been noted with other combinations of viruses. Indeed, interference between cacao viruses is unusual and in general the characteristic symptoms of a challenging virus are produced in the usual way on plants previously infected with other viruses (Thresh & Tinsley, 1958).

This may mean that a large number of distinct viruses are present in West African cacao, but it is more likely that the grafting methods usually used in these protection experiments are too critical a test of the ability of the basal virus to protect plants from the

effects of a challenging one. Further work may elucidate this point and also give information on the relationship between the viruses from cacao in West Africa and those occurring elsewhere, none which have yet been used in protection tests. Meanwhile, the available results from West Africa clearly show that some isolates from cacao are more closely related than others.

THE VIRUSES OCCURRING ON CACAO

Numerous isolates of virus have been made from cacao in various parts of the world and the variation and relationships between them have recently been discussed in detail (Thresh & Tinsley, 1958). On the available evidence it is suggested that at least three distinct viruses occur in West Africa. Their distribution and principal features are presented in the following sections, together with the range of viruses present elsewhere.

West Africa:

Cacao Necrosis Virus:

This name is ascribed to unique group of isolates which is characterised by an early necrotic phase of infection, followed by a chronic, recovery phase in which only limited leaf symptoms are produced. Moreover the isolates differ from all the others which have been adequately tested in that they have not been transmitted by mealybugs and do not cause red vein banding.

All the isolates of cacao necrosis virus have been made from small outbreaks found at a number of localities near Asalu in adjacent parts of Ijebu Ode, Abeokuta and Ibadan Provinces of Nigeria. The infected trees are in badly maintained farms and it is impossible to estimate the effect of infection on their vigour, but leaf symptoms are common and take the form of translucent distorted patches along the midrib and principal veins. These symptoms are quite different from those caused by any other isolates of cacao virus, but the necrotic symptoms which appear soon after seedlings are infected by means of grafts are even more unusual. The flush leaves are severely affected by a vein necrosis and commonly wilt and fall before maturing. Moreover whole shoots wilt and die back and at this stage severely affected plants which have been cut back at the time of inoculation, look almost dead. Nevertheless, plants usually recover and then show leaf symptoms of the type noted in the field.

These is some evidence that isolates of cacao necrosis virus differ in the severity of the necrotic symptoms they cause and in their effects on the growth of seedlings. However, there is no indication of major variation within the group and plants which have recovered from the acute stage of infection do not show necrosis on subsequent inoculation with the same isolate or with similar ones. By comparison isolates of cacao necrosis virus will infect plants already showing symptoms of infection with any of the mealybug transmitted viruses

from Ghana and Nigeria with which they have been tested. Also mealybugs or grafting methods can be used to introduce these viruses into plants already infected with cacao necrosis virus (Thresh, 1958c).

Nothing is known of the host range of any of the isolates causing necrosis, although it may be significant that all the outbreaks have been found in areas devoted to the extensive cultivation of *Cola acuminata* (P. de Beauv) Schott et Endl. and *Cola nitida* (Vent) Schott et Endl. These trees are related to cacao and are commonly found with symptoms resembling those caused by virus infection. It is therefore feasible that infection occasionally spreads into cacao from this possible alternative host and a vector may be involved which is not usually found on cacao.

Cacao necrosis virus appears to be confined to localities around Asalu and has not been reported from elsewhere in Nigeria. However, the inconspicuous symptoms may have been overlooked by the survey parties in the routine inspections for cacao swollen shoot disease. Outside Nigeria, Posnette & Palma (1944) found trees in Venezuela which showed spmytoms similar to those produced by cacao necrosis virus. Similarly leaf symptoms noted on one tree in Ceylon are apparently similar to those caused by the viruses from Asalu (Orellana & Peiris, 1957).

Cacao Mottle Leaf Virus:

The name cacao mottle leaf virus was originally ascribed to an unusual isolate from cacao at Kpeve in Togoland (Posnette, 1947). The name is now used for this virus and also for apparently similar ones from cacao in the same area and from the baobab *A. digitata*. Defined in this way the cacao mottle leaf virus group is restricted to isolates causing a red mottle on the flush leaves, which is particularly intense along the midrib and secondary veins. These symptoms are followed by clearing and banding of the veinlets between the mottled areas and consequently not closely related to the principal veins. None of the isolates within the group cause swellings and they are transmitted by mealybug species excluding *F. virgata*.

Most of the viruses of the cacao mottle leaf type have been obtained from baobabs on the Accra Plains in localities 10-15 miles from the nearest cacao and in the northern savannah areas 50-100 miles from the main producing areas. Consequently the indications are that cacao mottle leaf virus is primarily one of baobabs and only affects cacao in the occasional localities where the two hosts occur together and infection spreads into the introduced crop. This appears to have occurred in Togoland where baobabs have been found in close proximity of diseased farms. Elsewhere in West Africa there has been no detailed search for infection in baobab, but a virus of the mottle leaf type has been found in cacao in Nigeria at Alaparun. It is probably significant that this locality is near the edge of the lowland rain forest and near areas where baobabs are common.

Minor variation has been noted between the symptoms caused by some isolates of cacao mottle leaf virus from different baobabs and from different outbreaks in cacao in Ghana, but there is no evidence that any of them fail to protect each other. However, the virus from Kpeve will infect plants already inoculated with the one from Alaparun and this may indicate that some isolates within the cacao mottle group are more closely related than others. Differences have also been noted between the host ranges of the viruses from Kpeve and Alaparun. None of the isolates ascribed to the cacao mottle leaf virus group will protect plants from the effects of subsequent inoculation with any of the other mealybug transmitted viruses from cacao or other wild hosts with which they have been tested. Moreover these isolates fail to protect plants from the effects of subsequent inoculation with viruses causing mottle symptoms.

Cacao Swollen Shoot Virus:

The first isolates of virus to be taken from cacao were of the swollen shoot complex (Posnette, 1940) which is now known to cause most of the loss in crop due to virus infection in West Africa. Isolates which are ascribed to this complex have been prevalent in many of the most important growing areas and are still common in some of them. All the viruses within the complex cause red vein banding symptoms which are usually restricted to the veinlets immediately alongside the principal veins. Moreover they all cause clearing and banding of the veinlets between the principal veins and also alongside them. Most of the isolates also cause stem and root swellings and they are transmitted by mealybug species which usually include *F. virgata*.

At an early stage of the virus investigations in West Africa it was realized that the leaf symptoms shown by trees infected with viruses causing swellings, often varied widely between outbreaks. At some outbreaks the leaf symptoms were very mild, or not even present on most of the trees, whereas at others they were very conspicuous and severe. Moreover at certain outbreaks the usual types of leaf symptoms were found on all the trees, but no stem symptoms were noted. These differences in symptom expression were maintained when uniform groups of seedlings were inoculated in experimental transmissions and the symptoms produced were usually typical of those present on the trees from which the inoculum was taken.

The variation between isolates from different localities has received considerable attention and differences have been noted not only in the type and severity of the symptoms which are caused, but also in effects on growth and other properties. For example, none of the six different isolates which were tested infected exactly the same range of hosts (Tinsley & Wharton, 1958) and variation has also been noted in the ability of the different mealybug species to transmit them (Posnette, 1950). Furthermore, different isolates rarely protect against each other unless they have been obtained from the

same outbreak or from closely ralated otubreaks. Clearly some isolates within the cacao swollen shoot complex are more closely related than others and they may eventually be ascribed to various groups or even distinct viruses on a basis of protection tests or other criteria. Another possibility is that the cacao swollen shoot virus isolates may be grouped according to the indigenous hosts from which they have spread. It already known that the viruses occurring in the Western Provinces of Ghana are very similar to the ones in nearby *C. chlamydantha* trees and further work may indicate an association between the viruses and wild hosts occurring elsewhere.

In all the outbreaks of swollen shoot disease which have been studied in detail, considerable variation has been noted between the symptoms present on different trees. Typically these show leaf symptoms and swellings but swellings are the only symptom present on certain trees and leaf symptoms are the only ones to be found on others. Moreover, the leaf symptoms vary considerably in type and severity and may be extensive and conspicuous, or so mild that the trees are virtually symptomless and apparently healthy. Some of the trees with inconspicuous symptoms are in an early stage of infection, while others tolerate even the most virulent strains. However, variation has also been noted between the viruses present in different trees and also between viruses which were simultaneously infecting particular trees. Variation of this type has received relatively little attention, but appears to be due to the occcurrence of minor variants. These may be recognised by the severity of the symptoms they cause and by their effects on growth. The milder ones usually protect plants from the effects of subsequent inoculation with more virulent viruses from the same area, which either fail to infect or cause no recognizable symptoms. Indeed is has been suggested that mild strains may be used to infect the healthy trees around virus outbreaks or new planting material, as a method of reducing the spread of virulent strains (Posnette & Todd, 1951, 1955).

The Viruses Occurring Outside West Africa:

There is so little information on the viruses occurring outside West Africa that it is impossible to assess their relationships to the three discussed in the previous section. For example in Ceylon it is merely known that leaf symptoms occur on trees in all the outbreaks, but swellings have been found only in certain localities. Moreover, there is information on only two of the isolates of virus from Trinidad, where the symptoms they cause have been followed on clonal plants (Posnette, 1944; Baker & Dale, 1957). This makes it impossible to compare the published descriptions with the observations on the West African viruses, which have almost exclusively been in Amelonado seedlings. Thus it is not known whether the apparent absense of swellings caused by the viruses from Trinidad is due to a property of the host or of the virus.

It is clearly desirable that a detailed comparison of the viruses from cacao in various parts of the world should be made under the

same conditions and on the same hosts. Moreover, information is also required on the relationship between the viruses as indicated by protection tests, host range and vector studies. There are obvious dangers in assembling the viruses in a tropical country, particularly one in which cacao is grown. One possibility is to carry out the work in a tropical glasshouse in a temperate country. Until the results of a study of this type are available it seems reasonable to assume that the viruses occurring in Ceylon and probably also those in Trinidad, fall within the range of the cacao swollen shoot complex as observed in West Africa.

SUMMARY

The available information on the distribution and importance of virus infection in cacao is summarised. Cacao viruses are known to occur in Ghana, Ivory Coast, Togoland, Nigeria, Trinidad and Ceylon while symptoms which may be caused by virus infection have also been noted in Java, Venezuela and Colombia. Elsewhere, there is no evidence that viruses occur on cacao and this limited distribution emphasizes the importance of the strictest quarantine control on the movement of planting material between countries.

The general properties of cacao viruses are also discussed together with the available criteria for their classification. There is only limited information on the viruses occurring outside West Africa, but at least three have been distinguished in Ghana and Nigeria by the symptoms they cause in cacao and by the ability of mealybugs to transmit them. Cacao necrosis and cacao mottle leaf virus do not cause swellings and are apparently limited in distribution and importance, but the various forms of cacao swollen shoot virus are widespread and are a major factor influencing production.

There is little information on the viruses occurring in the cacao areas outside West Africa, but the isolates from Ceylon and probably also the ones from Trinidad apparently fall within the cacao swollen shoot virus complex. It is suggested that the viruses from cacao in different parts of the world should be compared under the same conditions, on the same host, and also used in protection tests to give more reliable information on the relationships between them.

RESUMEN

Se da un resumen de la información disponible sobre la distribución e importancia de la infección causada por virus en cacao. Se sabe que se encuentran virus en cacao en Ghana, Costa de Oro, Togolandia, Nigeria, Trinidad y Ceilán; del mismo modo se hace notar que en Java, Venezuela y Colombia se encuentran síntomas que pueden ser causados por infecciones virosas. De otra parte, no hay evidencia de que se encuentren virus en cacao y su limitada distribución hace ver la importancia de una estricta cuarentena que controle el movimiento de material vivo entre los países.

Las propiedades generales de los virus del cacao son también discutidas junto con el criterio existente para su clasificación. La información disponible sobre los virus que existen fuera del Africa Occidental es muy limitada; en Ghana y en Nigeria se han distinguido por lo menos tres, según los síntomas que ellos causan en cacao y de acuerdo con la habilidad de las chinches harinosas para transmitirlos. El "cacao necrosis virus" y el "cacao mottle leaf virus", no causan hinchamiento y aparentemente su distribución e importancia son limitadas. En cambio las varias formas de "swollen shoot virus" están muy esparcidas y son un factor importante que afecta la producción.

Hay muy poca información acerca de afecciones virosas o de virus en áreas de fuera de Africa Occidental, pero los casos aislados de Ceilán y también de Trinidad aparentemente caen dentro del complejo viroso causante de la enfermedad del "swollen shoot". Se sugiere que los virus del cacao de las diferentes partes del mundo sean comparados bajo las mismas condiciones, en los mismos huéspedes y también sean usados en pruebas de protección para proveer más información aprovechable sobre las relaciones existentes entre ellos.

REFERENCES

ATTAFUAH, A. & TINSLEY, T. W. 1958).—Virus diseases of *Adansonia digitata* L. (Bombacaceae) and their relation to cacao in Ghana. *Ann. appl. Biol. 46,* 20.

BAKER, R. E. D. & DALE, W. T. (1947).—Notes on a virus disease of cacao. *Ann. appl. Biol. 34,* 60.

CARTER, W. (1956).—Notes on some mealybugs (Coccidae) of economic importance in Ceylon. *F. A. O. Plant Prot. Bull. 4,* 49.

CIFERRI, R. (1948).—A virus disease of cacao in Colombia and Santo Domingo. *Rev. Fac. Nac. Agron. Colombia, 8,* 79.

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

DALE, W. T. (1955).—Virus research. *Annual Report of the West African Cocoa Research Institute,* 1954-1955, 33.

DALE, W. T. & ATTAFUAH, A. (1957). Virus Research. *Annual Report of the West African Cocoa Research Institute,* 1955-1956, 28.

HALE, S. L. (1953). World Production and Consumption-1951 to 1953. *Proceedings of Cocoa Conference,* London, 3.

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

KEVORKIAN, A. G. (1951). The cushion-gall disease of cacao. Abstr. *Phytopath. 41,* 562.

KIRKPATRICK, T. W. (1950).—Insect transmission of cacao virus disease in Trinidad. *Bull. ent. Res. 41,* 99.

KIRKPATRICK, T. W. (1951).—Insect pests of cacao and insct vectors of cacao virus disease. *A report on cacao research* 1945-1951. *Imperial College of Tropical Agriculture, Trinidad.*

KNIGHT, R. & TINSLEY, T. W. (1958).—Some histological observations on virus infected *Theobroma cacao* L. *Ann. appl. Biol. 46,* 7.

LISTER, R. M. & THRESH, J. M. (1957). The history and control of cocoa swollen *shoot disease in Nigeria. Proceedings of the Cocoa Conference,* London. (In Press).

ORELLANA, R. G. & PEIRIS, J. W. L. (1957).—The swollen shoot phase of the virus disease of cacao in Ceylon. *F. A. O. Plant Prot. Bull. 5,* 165.

PEIRIS, J. W. L. (1953).—A virus disease of cacao in Ceylon. *Trop. Agriculturalist, 109,* 135.

POSNETTE, A. F. (1940).—Transmission of swollen shoot. *Trop. Agriculture, Trin. 20,* 116.

POSNETTE, A. F. (1943).—Swollen shoot disease. *Report on the Central Cocoa Research Station, Tafo,* 1938-1943, 56.

POSNETTE, A. F. (1944).—Swollen shoot in Trinidad. *Trop. Agriculture, Trin. 21,* 105.

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

POSNETTE, A. F. (1950).—Virus diseases of cacao in West Africa. VII virus transmission by different vector species. *Ann. appl. Biol. 37,* 378.

POSNETTE, A. F. & PALMA, M. (1944).—Observations on cacao in the Paria Pennisula, Venezuela. *Trop. Agriculture, Trin. 21,* 104.

POSNETTE, A. F. & ROBERTSON, N. F. (1950).—Virus diseases of cacao in West Africa. VI Vector investigations. *Ann. appl. Biol. 37,* 363.

POSNETTE, A. F., ROBERTSON, N. F. & TODD, J. M. (1950).—Virus diseases of cacao in West Africa. V. Alternative host plants. *Ann. appl. Biol. 37,* 229.

POSNETTE, A. F. & TODD, J. M. (1951).—Virus diseases of cacao in West Africa. VII. The search for virus resistant cacao. *Ann. appl. Biol. 38,* 785.

POSNETTE, A. F. & TODD, J. M. (1955).—Virus diseases of cacao in West Africa. IX. Strain variation and interference in virus. 1A. *Ann. appl. Biol. 43,* 433.

RENAUD, R. (1957).—Distribution en Cote D'Ivoire des maladies a virus du cacaoyer. *Preceedings of the Cocoa Conference,* London. (In Press).

STEVEN, W. F. (1936).—A new disease of cocoa in Gold Coast. *Gold Coast Farmer, 5,* 122, 144.

THOROLD, C. A. (1957).—A chlorosis disease of cocoa in the Southern Cameroons. *Jour. West African Sci. Assoc. 3,* 96.

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

THRESH, J. M. (1958b).—The spread of virus disease in cacao. *Technical Bulletin No. 5 of the West African Cocoa Research Institute.*

THRESH, J. M. (1958c).—Virus research. *Annual Report of the West African Cocoa Research Institute,* 1956-1957, 71.

THRESH, J. M. (1958d).—Further aspects of the control of cacao swollen shoot disease in Nigeria. (In Press).

THRESH, J. M. & TINSLEY, T. W. (1958).—The viruses of cacao. *Technical Bulletin Nº 6 of the West African Cocoa Research Institute.*

TINSLEY, T. W. & WHARTON, A. L. (1958).—Studies on the host ranges of viruses from *Theobroma cacao* L. *Ann. appl. Biol. 46,* 1.

URQUHART, D. H. (1951).—Prospects of the growing of cacao in the British Solomon Islands with notes on Malaya, Ceylon and Java. *Report Cadbury Brothers Limited.*

WELLMAN, F. L. & ORELLANA, R. G. (1954).—"Buba" or Cushion Gall of cacao in Nicaragua. *Vth Meeting of the Inter-American Technical Committee on Cacao.* Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica.