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The Endless Struggle of Man with Plant Viruses

by J. L. Ladipo

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INTRODUCTION

Man has been a struggling being against the menace of viruses on his person, his animals, his crop plants and other plants useful to him from the beginning of history. The skin lesions on the mummified body of an Egyptian king (Ramese V) who died around 1100 BC at the age of 40 years suggested that he died of smallpox (Goodheart, 1969). Before the development of a vaccine against Smallpox, it was one of the world's most devastating human diseases. Those who escaped the fatal effect of the disease invariably had their faces disfigured. Poliomyelitis is another viral disease of man that dates back to the earliest times. The leg deformity of an Egyptian who died about 3000 BC suggested that he must have died of paralytic poliomyelitis (Goodheart, 1969). Since the interest in this lecture is not in the struggle of man against viruses that attack him directly, the two examples cited above are sufficient to show man as a direct victim of such.

Man's domesticated animals have not been spared either. Rabies, a central nervous system disease of animals, especially dogs, is caused by a virus. Rabies in dogs and other domestic animals was recognized by Democritus in 500 BC and by Aristotle in 322 BC (Shope, 1976). Rabies is a highly dreaded disease because of its fatal effect on man. The foot-and-mouth disease of cattle and other livestock is another viral disease of animals which is highly infectious and highly dreaded. One example of a viral disease of animals which man has converted to his own advantage through science is the cowpox disease. Edward Jenner discovered in 1798 that dairy maids who were exposed to the virus by milking cows that were so diseased became immune to smallpox (Frobisher, 1968). This was possible because the cowpox virus is immunologically related to the smallpox virus. Edward Jenner's work marked the beginning of successful immunization against smallpox. Viral diseases reduce the productivity of the affected animals, and in fatal and epidemic cases, reduce their numbers drastically with man standing the loser at the end. Again, the intention is not to see man as struggling against viruses that attack his animals; the examples are given only to show that his animals are also afflicted.

Man depends on plants for food, shelter and many other conveniencies and luxuries of life. Among the living forms, only plants are able to utilize solar (sun) energy through the process of photo-synthesis to convert simple elementary substances into complex organic substances that are used by man and his animals for growth and metabolic processes. Supplementing the food plants are those that satisfy other human needs such as those medicinal plants that had served humanity from the earliest beginning. The early medical men were herbalists; they prescribed plant decoctions or infusions to treat human discomfort and diseases. With the advent of chemistry as a science, plant products with specific medicinal properties were identified and methods were developed to extract and purify them into drugs now in use. Large quantities of fruits and cereals are being converted into beverages such as cocoa and coffee, and alcoholic drinks like beer and wine, to mention a few. Sap from oil palm trees is tapped, fermented and taken as palm-wine; in fact, bottled palm wine is a commercial product from Nigeria Institute of Oil Palm Research (NIFOR) and it is sold in cartons just as beer is sold. Man also gratifies himself by smoking, chewing or snuffing processed tobacco leaves.

The world economic fibres are products of plants; they include cotton, hemp, jute, flax and ramie. Even the modern synthetic fibres owe their existence in part to fossil plants since they are largely products of coal and petroleum. Plants in the fossil forms are the basis of the world's fuel reserve. The Nigerian oil situation is here relevant. Wood is an important item in the construction of human dwellings. It is used in making household furniture and other items of equipment for man's comfort in his dwellings. Indeed, wood is the single most important building material the

world over; a look at this magnificent edifice that is Oduduwa Hall, will, I am sure, prove the point. Industrial products from plants are also many. One of such is rubber which has contributed significantly to the development of modern transportation systems. Other plant products such as paper pulp, acetone, tannins, dyes, oils and flavourings are quite useful to man. Man uses plants to beautify his environment; for instance, a blend of carefully selected and well positioned ornamentals with aesthetic architectural designs at the University of Ife makes it the beauty of a campus that is great Ife.

Animals are used by man as food, while the wool of animals is used in the production of warm clothing and these animals owe their existence to plants, especially those that are herbivores. Even the carnivores indirectly depend on plants since they prey on animals which in turn depend on plants. Plants are fed to animals as forage. Other plant products such as groundnut cake and cotton seed meal are used as supplements in livestock ration formulations, with corn grains constituting the major component of poultry feed and cassava the main item in swine ration formulation.

From the accounts given above, I believe it is appropriate to regard man as a guest of the plant kingdom, at least here on earth. The numbers therefore, of man and animals, I believe, will be governed, by and large, by the availability of the right type of plants. You can imagine the fate of man and animal if plants were to disappear from the surface of the earth today. In the recognition of his near absolute dependence on plants for existence, man constantly makes deliberate and concerted efforts to grow the right type of plants for food and cash, replanting forests for lumber and fuel and establishing plantations of medicinal plants. Unfortunately, however, his efforts are constantly frustrated by hazards such as unfavourable weather conditions, pests and diseases. I leave the discussion on weather conditions to an agroclimatologist and the pests come under the purview of the entomologists. Even with regard to the diseases, I am limiting myself to those caused by plant viruses.

THE NATURE OF VIRUSES

One of the issues that had generated a lot of debate among virologists is the nature of viruses. Two questions are frequently asked:

i) are viruses organisms ?

ii) are viruses living ?

In a definition by Lwoff (cited by Luria and Darnell, 1967) an organism was said to be "an independent unit of integrated and interdependent structures and functions". An infectious virus particle is not independent but depends on a living cell to replicate itself and maintain its genetic continuity. A virus is therefore not an organism. In another definition, "A material is living if after isolation, it retains a specific configuration that can be reintegrated into the cycle of a genetic matter" (*ibid*). The specific base sequence of the nucleic acid component of a virus particle can be isolated and be integrated into other cells and can replicate within them. The virus particle is therefore a living entity. In summary, viruses are no organisms but are living entities.

PLANT VIRUSES

a. *Brief History of Plant Virology*

Many of the plant diseases that are now known to be caused by plant viruses did not attract attention as diseases until the nineteenth Century. Adolf Mayer (1886), an agricultural chemist, investigated a disease of tobacco which for many years past had been a source of worry to the tobacco growers in the Netherlands. He called the disease *Mosaikkrankheit*, a Dutch word meaning mosaic disease. From several experiments, he demonstrated that the causal agent could be transmitted to healthy plants by inoculation with extracts from diseased plants. That process is now known as mechanical, sap or contact transmission of plant viruses. In 1892, Dimitri Ivanowski (1892) demonstrated through experiments that the agent of tobacco mosaic disease could be transmitted to healthy plants after passing sap from diseased plants through filters that would retain all bacteria that were then known. The conclusion was drawn that the agent was not a bacterium and in fact smaller than it. In 1898, Beijerinck (1898) found that the filtrable agent of tobacco mosaic disease would diffuse through an agar gel just as a fluid would do. Consequently, he called the agent *Contagium vivum fluidum* meaning a living infectious fluid. It was in Beijerinck's work that virus was used to describe the agent of the disease.

The period 1900–1935 witnessed a lot of activities in the field of Plant Virology. Attention was focussed on the description of virus diseases on the bases of symptomatology and cytological evidence, as could be revealed by the limited efficiency of the light microscope. Attention was also focussed on the host range studies and transmission methods. The types and extent of investigations were governed by the techniques and equipment that were then available. Also during the period, some of the important characteristics of viruses became known:

i) Viruses exist and multiply or replicate in living cells only (this indicated the obligate parasitic nature of viruses)

ii) they are host specific

iii) they can mutate to different strains (the significance of this characteristic in man's unending struggle against plant viruses will be highlighted later in this lecture)

iv) they are antigenic (this characteristic was later employed in serological tests for precise identification of viruses and their quantitative assays)

v) they are transmissible by insects in which they could multiply.

A major contribution to the science of Plant Virology came in 1935 when Stanley crystalized tobacco mosaic virus. In 1936, Bawden *et al* (cited by Corbet, 1964) showed that the crystalline preparation of tobacco mosaic virus consisted of protein and nucleic acid; the nucleic acid forming the inner core and the protein making up the external protective coat.

b. Naming of viruses

There is yet no agreement among plant virologists on the species concept. Therefore, most plant virus names are, in general, descriptive as they are derived from the most conspicuous symptoms in the first or major host with the word 'virus' added at the end. Thus, we have, for instance, tobacco mosaic virus indicating a virus which produces mosaic symptom in tobacco as its first host; similarly we have cucumber mosaic virus, cowpea mosaic virus, tomato ringspot virus, etc. Identical viruses from other hosts will be strains or isolates of the original virus. Thus, a tobacco mosaic virus from cowpea will be named tobacco mosaic virus cowpea strain.

c. Symptoms of virus diseases in plants

Symptoms of virus disease may be divided into two broad groups, namely: local symptoms and systemic symptoms. The local symptoms are in form of localized lesions (Figures 1 & 2) that develop near the sites of virus entry. They are usually not of economic significance but are important for biological assays in the laboratory. The systemic symptoms, on the other hand, include foliage symptoms which are the commonest of virus symptoms. They are expressed in form of colour deviations resulting in mosaic, mottle, veinbanding (Figure 3) or veinclearing; and reduction in leaf size which sometimes results in the leaf appearing like a shoe-string. There are also the stem symptoms – the stem may be swollen as in the case of cacao swollen shoot disease; the internodes may be greatly reduced as the case with the bunchy-top disease of tomato (Figure 4) or the stem may be necrotic as in tomato streak (Figure 5). The flowers, the fruits and roots may also show symptoms.

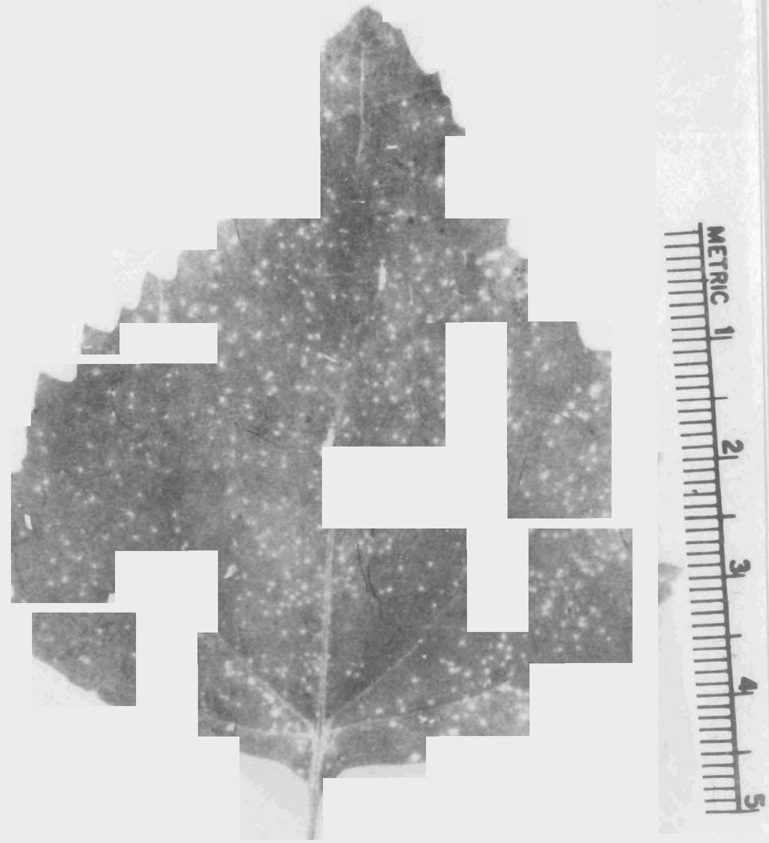

Figure 1

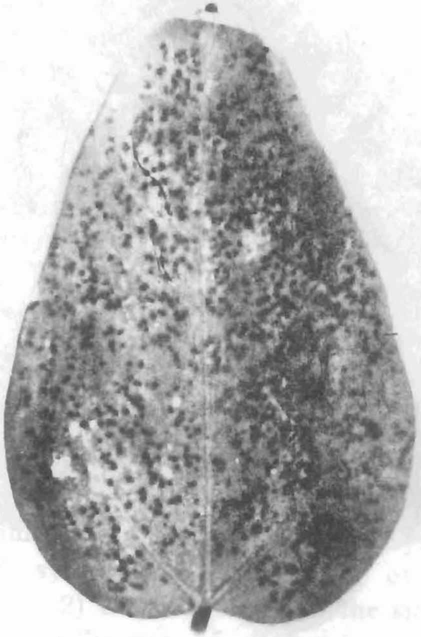

Figure 2

Figure 3

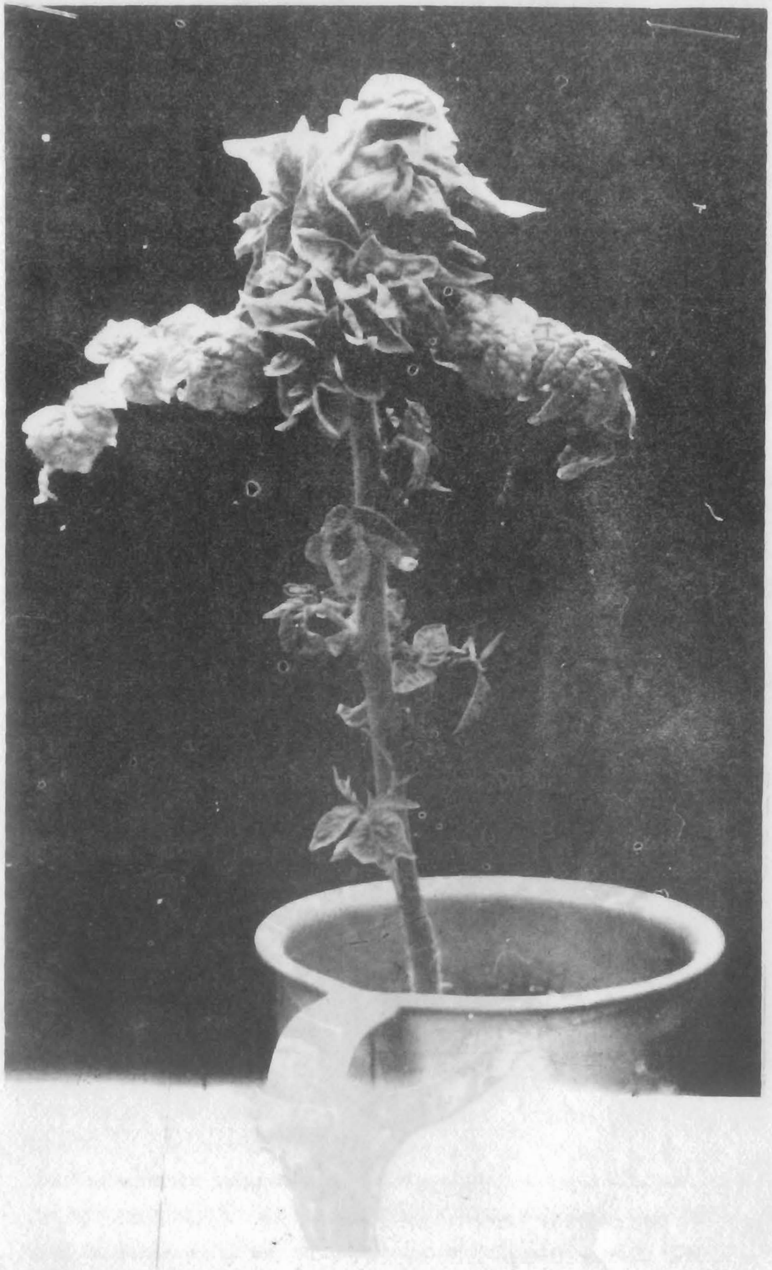

Figure 4

Figure 5

d. Economic importance of virus diseases

Nearly all forms of plant life including fungi suffer from plant virus diseases. The economic importance of any disease depends on the value of the plant. It must be recognized that it is very difficult if not impossible to obtain reliable data on losses attributable to virus diseases alone since they occur in the field with diseases caused by other pathogens like fungi, bacteria and nematodes. In general, the losses may be qualitative when the market values are reduced or quantitative when losses are associated with yield reduction such as fewer or smaller fruits as in the case of the bunchy—top disease of tomato. Sometimes virus diseases may impose restrictions on the type of crops that can be grown in a particular area; for instance, some years ago when the menace of the cacao swollen shoot disease was at its peak in areas of mass infection in the former Western Nigeria, it was suggested that food crops should be planted instead of cacao.

Some important virus diseases

The examples are chosen from among those of cash and food crops, forage and ornamental plants.

1) Cash crops

Before the discovery of petroleum in commercial quantities in Nigeria, Agriculture was the mainstay of the country's economy. The major sources of foreign exchange were products like coco beans, groundnut, cotton and palm produce. The yield potentials of these cash crops have never been attained due to the devastating effects of pests and diseases. Prominent among the diseases are those caused by plant viruses. The following are some examples:

Cacao *(Theobroma cacao* L.): After the blackpod disease caused by a fungus *(Phytophthora palmivora* Butl.) the next most important disease of cacao is the cacao swollen shoot disease and indeed it is one of the most economically important diseases in the world. It was first reported in

Ghana in 1936 and in 1944, it was discovered in Nigeria. By the late 1950s, the disease had become so wide-spread in Abeokuta and Ibadan provinces of the then Western Region of Nigeria that they were designated Areas of Mass Infection (AMI). Similar diseases were reported from Ivory Coast (now Cote d'Ivoire), Trinidad and Ceylon (Thresh & Tinsley, 1959). In Nigeria alone, some 20 strains of the virus were recognized, based on the type and severity of symptoms. Symptoms are found on the leaves, the stems (which are characteristically swollen), the fruits and roots. The virus is spread by mealybugs, three of which are *Planococcoides njalensis* Laing, *Planococcus citri* Risso and *Ferrisiana virgata* Ckll in the order of their importance (Thresh, 1958b). Because infected plants cannot be cured of the disease, the only possible means of control was to remove and destroy such. Based on this, Thresh (1958a) proposed a method of control that involved the removal and destruction of the infected plants. Also based on the knowledge that there may be a period of latent infection, plants within a radius of definitely infected plants were similarly recommended for destruction.

Following these recommendations, almost two million trees were removed and destroyed between 1946 and 1956 in Nigeria and more than 60 million trees in Ghana between 1945 and 1957 *(ibid.)*. For the control programme, government employees were used. Because of the economic value of the crop and the extensive destruction of trees involved, the measure did not go well with the farmers. They showed their resentment by becoming hostile to the government agents. Consequently the measure had to be abandoned not only in Nigeria but also in Ghana and Ivory Coast. Also suggested as a measure of control was the destruction of wild hosts like wild cola *(Cola chlamydantha* K., Schum.) baobab tree *(Adamsonia digitata)* and silk cotton tree *(Ceiba pentandra* Gaertn) which are known to be common in forests in West Africa (Thresh, 1958a). In theory it would sound good, but in practice it was difficult as some of these are big forest trees. Other viruses of cacao are cacao necrosis virus and cacao yellow mosaic virus. They are of less economic importance.

Groundnut *(Arachis hypogaea* L.) is an export crop of some African countries including Nigeria. It is afflicted by a number of virus diseases caused by groundnut rosette, groundnut clump, groundnut mosaic and groundnut eyespot viruses. The most devastating of them is the groundnut rosette virus especially in Nigeria and Sudan (Lana & Adegbola, 1977). It is transmitted efficiently by the groundnut aphid *(Aphis craccivora* Koch.) (A'Brook, 1964; Booker, 1963).

Cotton *(Gossypium* spp) another cash crop is not spared. It suffers from such virus diseases as cotton leaf curl, cotton leaf mottle, cotton virescence and cotton yellow vein (Lana and Adegbola, 1977). Cotton leaf curl is the most destructive and the causal virus is transmitted by the whiteflies *(Bemisia tabaci* L.).

Industrial crops like soybean and tobacco are equally afflicted; soybean by soybean mosaic and African soybean dwarf viruses and tobacco by tobacco leaf curl, tobacco mosaic, tobacco etch, tobacco rattle, tobacco vein mottling, tobacco ringspot and pepper veinal mottle viruses to mention a few.

2) Food crops

Cassava *(Manihot esculenta* Cranz) is a major source of carbohydrate for millions of Africans. It is also a major component of swine feed. A yield potential of 15–20 tons/hectare is never realized due largely to virus diseases such as is caused by cassava mosaic, cassava latent and common cassava mosaic viruses. Since cassava is propagated vegetatively by cutting, perpetuation of the diseases is assured. Indeed, most peasant farmers who produce the bulk of the crop have come to accept the disease condition as normal and will regard as abnormal any cassava plant that

does not show the symptoms. The viruses are each transmitted by the whiteflies which have several alternate hosts. The control of the vector through the application of insecticides is therefore difficult. Some tolerant varieties are now available (Rossel and Thottappilly, 1985) but for how long will this tolerance last, is the question which the struggling man is asking.

Yam *(Dioscorea* spp) is another good source of carbohydrate for Africans especially West Africans. It also suffers from virus attack manifested by mosaic symptoms. The mosaic disease which may be serious is present in Nigeria, Ivory Coast (Cote d'Ivoire) and Togo (Reckhaus, 1979). It has been observed in white yam *(Dioscorea rotundata* Poir.), water yam *(D. alata* L.) and yellow yam *(D. cayenensis* Lam.).

Cocoyam *(Colocasia esculenta* (L.) Schott (old cocoyam)) and *(Xanthosoma sagitifolium* L.) Schott (new cocoyam)) is another staple food in humid tropics which is attacked by Basheen mosaic virus (Rossel and Thottappilly, 1985, transmitted by *Myzus persicae* and *Aphis gassypli* Glov.

The importance of maize *(Zea mays* L.) to man and the poultry industry is well known and therefore requires no amplification. Virus diseases such as maize streak, maize mottle/chlorotic stunt, maize stripe and maize dwarf are its common ailments. The most important is the maize streak which is transmitted by leafhoppers *(Cicadulina* spp) among which *C. mbila* appears to be the most important. Varieties (TZSR-yellow and TZSR-White) have been developed at the International Institute of Tropical Agriculture (IITA) with high levels of resistance (Rossel & Thottappilly 1985). Again, for how long will this resistance last?

Cowpea *(Vigna unguiculata* (L.) Walp. subsp. *unguiculata)* is a cheap source of plant protein. It is plagued by a number of virus maladies which include cowpea mosaic, cowpea aphid-borne mosaic, cowpea mottle, cowpea mild mottle and one caused by cucumber mosaic virus. Each of them affects the yield potential of the crop especially when they occur together to produce synergistic effects, situations that are quite common.

Vegetable crops such as tomato, peppers, eggplants, okra and the cucurbits are also victims. Tomato for instance is attacked by such viruses as tobacco mosaic virus, pepper veinal mottle virus, tomato leaf curl virus, cucumber mosaic virus and potato virus Y, to name a few.

3) Forage crops

Alfalfa *(Medicago sativa* L.) is a perennial forage crop used as hay, pasture or silage for livestock. It suffers from a number of virus diseases such as alfalfa mosaic, alfalfa dwarf and alfalfa witches broom (Barnett, 1974).

Clover *(Trifolium* spp) is perhaps the most nutritious of all forage legumes. It is grown alone or in combination with other legumes or grasses. Viruses reported from clover include alfalfa mosaic, bean yellow mosaic, clover yellow mosaic, clover yellow vein and peanut stunt viruses (Barnett and Gibson, 1975). Apart from causing yield reduction, infection weakens the plants and makes them more susceptible to other diseases and stresses. Mention must also be made of Centrosema *(Centrosema pubescens* Benth.), a component of grass-legume mixture for the grazing animals. Its potential in the mixture is reduced by virus diseases such as those caused by centrosema mosaic and groundnut crinckle viruses (Dubern, 1981).

4) Ornamental plants

One of the oldest plant diseases is the tulip mosaic. It attracted attention as far back as the sixteenth century but not as a disease. The affected plants produced flowers that were variegated, a condition that was termed 'colour break' and was greatly admired since people regarded it as a special variety, sought after it and paid high prices for it. The condition was perpetuated by vegetative propagation of infected

plants. It was not known that a virus was responsible until 1926 when McKay and Warner (cited by Corbet, 1964) proved the involvement of a virus. With that knowledge, the demand for tulips with colour break dropped and growers started to destroy them so as not to infect the self-coloured healthy plants.

Another ornamental plant of interest is the gladiolus. The economic value of the plant is reduced by virus diseases which cause white break of the foliage and flowers. The inflorescences become unsightly and in severe cases, unmarketable. Viruses that cause diseases in gladiolus include bean virus 2, cowpea mosaic, cucumber mosaic, tobacco rattle, tobacco ringspot and tomato ringspot virus (Ladipo, 1971).

As it was in the past, it is possible even now that some of the highly admired vegetatively propagated ornamentals in our environment are diseased plants afterall.

e) Transmission of viruses

The knowledge of how a virus is transmitted is important from the practical point of view of preventing or circumventing its natural spread. Viruses are transmitted by fungi, nematodes, dodder, mechanical method (as mentioned earlier) grafting and vegetative propagation, through seeds and by insects. Because of their relevance to the formulation of disease control, the last four will be discussed.

(i) **Mechanical transmission:** Earlier in this lecture, it was mentioned that Adolf Mayer (1886) transmitted the agent of tobacco mosaic disease by the inoculation of healthy plants with extracts from diseased plants. It was also mentioned that the method later became known as mechanical, sap or contact transmission. It is a very important method of virus transmission in the laboratory but only moderately important in the field accounting for natural spread of diseases caused by viruses that are stable and occur in their hosts at fairly high concentrations. Indeed, the most studied viruses are those that are easily transmitted by the mechanical method. Tobacco mosaic virus, for instance, is spread among tobacco and tomato plants in the field through contact. This is possible when leaves of infected plants are rubbed against those of adjacent healthy plants by wind or during the process of debudding of tobacco or staking of tomato plants by the attendants. Tobacco mosaic virus can remain infective in dry tobacco leaves for some years even when processed; thus, cigarette smokers can spread it through their contaminated hands and clothing. Care should be taken.

(ii) Grafting and vegetative propagation: Viruses are economically important when they become established systemically in their hosts; and more so if such hosts are perennial or are vegetatively propagated. Vegetative propagation ensures the perpetuation of such viruses and contributes to their spread. For instance, tubers, corms, bulbs, stem cuttings or suckers from infected parents are very likely to produce sprouts that are virus-infected. The effect is a continuous loss of yield from generation to generation. Examples include various viruses of Irish potato *(Solanum tuberosum* L.) such as potato leaf roll and potato virus Y and cassava mosaic virus in cassava, to mention just a few.

(iii) Seed transmission: A virus is said to be truly seed–borne if it is carried internally in the seed. Heat treatment of such seeds has not succeeded in inactivating the virus without destroying the seed embryo. Such viruses are of significance in that they are spread over long distances across nations through the international exchange of materials. In this way, viruses that would have remained localized have extended their international boundaries. In addition, such viruses become available in the field as soon as the infected seeds germinate. The seedlings then serve as early sources of infection to other plants in the population or vicinity

especially if they are vectored and the vectors are available. The rate of seed transmission depends on a number of factors such as the temperature of the environment in which the infected plant is grown (Crowley, 1957), the stage of plant at the time of infection and more importantly virus–host combination; for instance, tobacco ringspot virus is transmitted 100% in seeds of infected individual soybean plants (Athow & Bancroft, 1959) whereas the rate of transmission of lettuce mosaic virus in lettuce is 3–10% (Couch, 1955).

(iv) Insect transmission: Most plant viruses that cause severe economic losses are spread on the field by insects which feed transiently on plants such as (1) aphids which constitute the group of insects that transmit the largest number and variety of plant viruses (Watson & Plumb, 1972) e.g. potato leaf roll, potato virus Y and pepper veinal mottle virus which are transmitted by the green peach aphid *(Myzus persiae* Sulz.) and groundnut rosette transmitted by the groundnut aphid *(Aphis craccivora* Koch.) (A' Brook, 1968); (2) Leafhoppers such as *Cicadulina* spp. that transmit maize streak virus in Africa and *Nephotettix* spp. as vectors of ricetungro virus in the Philippines (Ling & Tiongo, 1977); (3) Whiteflies *(Bemisia* spp.) which are responsible for the transmission of viruses that cause cotton leaf curl, tobacco leaf curl, tomato leaf curl and cassava mosaic in the tropical countries like Nigeria (Costa, 1969); (4) Mealybugs species like *Planococcoides njalensis* Laing., *Planococcus citri* Risso, and *Ferrisiana virgata* Ckll. are vectors of cacao swollen shot virus (Thresh, 1958b).

f. Principles of plant virus disease control

Many fungal diseases are controlled by the application of fungicides; no such chemicals are available for the control of plant virus diseases. Available measures are designed to reduce sources of infection, limit spread by vectors and minimize yield losses. Controlling plant virus diseases is therefore a continuing struggle as it has to be an exercise that is carried out on a yearly basis except in cases where the sources of resistance have been located and incorporated into useful varieties to obtain varieties that are good agronomically and meet consumer preference. Even here, protection is not permanent as new strains of the virus may arise that will attack a previously resistant variety. The cycle of finding the source of resistance to the new strain will begin, concluded by the development of yet another variety that is resistant and terminated with another strain arising that will attack the new variety. In addition, a completely new virus may surface that will attack the new variety. The result is an endless struggle.

The available control measures include:

(i) Removal of infection sources

It is logical to believe that there will be no virus disease if planting materials such as seeds, cuttings etc., are virus-free when planted into the field and no sources of infection are available. Unfortunately, this perfect situation is not always the case. Virus-free material may be grown but resulting plants will become infected through infection sources like weeds or wild hosts and volunteer plants from a previous crop. In theory, it will appear simple to recommend that such sources should be eliminated, but in practice, it is difficult, especially if the sources are widespread, varied and are difficult to detect early after infection. If the source is from within the crop, few and readily detectable early in the season, roguing may be effective.

(ii) Planting virus-free seeds and other planting materials

Where infected seed is the main source of the virus, growing crops in isolation to obtain virus-free seeds may be an effective means of control provided there are no other sources of infection. For plants propagated vegetatively, e.g. cassava, the main source of virus will be the chronically infected plant. Control is possible if virus-free clones can

be developed. Even when developed and planted, they can still be re-infected. For such a control to be effective, there must be a regular and adequate supply of virus-free planting materials so that using re-infected materials for planting can be avoided. Virus-free materials can be obtained by identifying individual plants that are virus-free. Heat therapy may be used to free plant materials from virus; a temperature range of 35° – 40°C for a period of weeks is commonly used (Mathews, 1970; Nyland and Goheen, 1969). The cassava plant for instance was freed of cassava mosaic virus through heat therapy (Kaiser and Louice, 1982). Meristem tip culture may be employed.

(iii) Control of vectors

In deciding on whether controlling the insect vectors will be worthwhile or not in controlling virus diseases, the virus-vector relationship must first be determined. There are three types, namely: non-persistent or stylet-borne, semi-persistent or circulative and persistent or propagative relationships. A non-persistent virus is acquired and transmitted by its vector within a short time, a matter of minutes or even seconds. The vector loses the ability to transmit unless it acquires the virus anew. For such viruses, eliminating the vectors through the use of insecticidal chemicals will be of little effect because transmission will have been achieved before the vector is killed. In the case of the semi-persistent, the virus particles are ingested, pass through the insect tissues and are introduced into plants through the mouth-parts of the insect. For such viruses, killing the vectors with chemicals may help. If the relationship is the persistent type, the virus is acquired, multiplies inside its vector and in fact the vector retains the ability to transmit the virus as long as it lives. In that case, controlling the vector with insecticidal chemicals especially systemic insecticides have been found to be effective as in the case of potato leaf roll disease which has been controlled by the use of insecticide to control its aphid vector *Myzus periscae* in which it is carried persistently (Bawden, 1964).

(iv) *Use of resistant varieties*

The best of solutions to the problem of virus disease is the use of resistant varieties. Three categories of resistance are clearly recognized, namely: immunity in which the plant does not get infected at all (it is the highest level of resistance); hypersensitivity in which the host responds to infection by the localized death of cells at the site of infection without spreading further. Such a reaction gives an effective field-resistance and serves no risk of infection of other varieties that may be susceptible. Thirdly, there is tolerance where the virus multiplies and spreads through the plant but the effect of the disease is mild and it may serve as a source of infection to susceptible crops around.

MY CONTRIBUTION TOWARDS MAN'S STRUGGLE WITH PLANT VIRUSES

It all started some twenty years ago during a long vacation employment on Moor Plantation, in Ibadan. I worked with Dr. J. Craig who was a plant pathologist in the U.S.A.I.D. team in Nigeria. One day he asked me if I would be interested in specializing in Plant Virology, an area he said had no Nigerians then. He further stressed the fact that diseases caused by plant viruses were enormous in Nigeria and other countries in the humid tropics. It was not difficult for me to get convinced since I had already developed an interest in Plant Pathology. This was as a result of my concern for the toiling farmers in Nigeria who lost substantial parts of their crops to pests and diseases annually. When, in 1965/66 session, the time came to choose what to do for our final year projects in the Department of Botany of this University, I chose to investigate the possibility of cultivated cola being a host of cacao swollen shoot virus since evidence from literature showed that the virus originated, among other wild hosts, from wild cola *(Cola chlamydantha)* in the lower storey of West African forests. The result of that investigation (Esenam & Ladipo, 1967) showed that cultivated cola

was not susceptible to the strain of cacao swollen shoot virus used. That was the beginning of my systematic interest in Plant Virology as a discipline.

For many years now, the staff of the Department of Plant Science have devoted a substantial part of their research efforts to the development of improved varieties of crops like cowpea, tomato and maize. The approach is multidisciplinary and this makes the Department a unique one. The crops I have had to work on therefore had to be dictated by the research interests of the Department. I have, since 1971, concerned myself with investigating virus diseases of the above named crops and other members of the plant families to which they belong. The approach is in three stages:

Stage 1 – This involves the isolation of viruses from field-infected plants. The viruses so isolated are either kept frozen or diced. dehydrated over calcium chloride in the cold and stored dry; some others are maintained in living hosts by regular transfers in the screenhouse. We have several virus isolates at this stage waiting for further studies.

Stage 2 – In this stage, attempts are made to biologically purify each virus isolate especially where mixed infection is suspected and this is commonly encountered. After the biological purification, each virus isolate is characterized with a view to identifying it. We have identified cowpea mosaic virus, cowpea aphid-borne mosaic virus (Ladipo, 1976), southern bean mosaic virus, cucumber mosaic virus, pepper veinal mottle virus (Ladipo and Roberts, 1977 & 1979), tobacco mosaic virus and bunchy-top virus (Ladipo, 1973) from crops grown in Nigeria.

Stage 3 – It is our considered opinion that research activities should not stop at identifying the problems, in this case, the viruses menacing our crops, but should extend to finding solutions to the problems. We also recognize the fact that the most effective and realistic approach to virus disease control is the use of disease resistant plants that have desirable agronomic characteristics and also meet the consumer preference. The third stage of our research approach aims at achieving these goals. At this stage, we screen plant accessions to locate sources of resistance to each of the identified viruses.

The International Institute of Tropical Agriculture (I.I.T.A.) has a rich collection of cowpea germplasm, and through some cooperation with Dr. D. J. Allen of thae Institute, we obtained materials for our Screenhouse screening programme in cowpea. We have located sources of resistance in cowpea to cowpea mosaic, cowpea aphid–borne mosaic and southern bean mosaic viruses (Ladipo & Allen, 1979a, 1979b). These sources are now available to plant breeders for their use in our cowpea improvement programme.

Selection of lines of Ife Brown that are resistant to cowpea aphid-borne mosaic virus was carried out (Fatunla & Ladipo, 1982). One of the lines has become a valuable tool to the breeders in their inheritance studies. From out-crosses that resulted when Ife Brown cowpea was planted in the field side by side with two cowpea accessions that possess multiple resistance to cowpea mosaic and cowpea aphid-borne mosaic viruses, eight cowpea segregants have been obtained. Two of them possess multiple resistance to cowpea mosaic virus which is the most commonly encountered virus in cowpea in Nigeria and cowpea aphid-borne mosaic virus. Their field performance is being closely monitored and they show some promise in terms of growth habit and grain yield. They may enter the list of cowpeas for national trial with a view to releasing them eventually to the Nigerian farmers. They will also be subjected to tests of consumer acceptability.

SPECIALIZED FACILITIES FOR PLANT VIRUS RESEARCH

Plant Virology is a special branch of Plant Pathology and it is required that specialized facilities be made available to

prosecute research in that field. They include transmission electron microscope, refrigerated low speed centrifuge and ultra-centrifuge; ultraviolet spectrophotometer, functional greenhouse, cold room (4°C) etc. There are not many laboratories in Africa where these facilities are available. The lack of them in most laboratories has made it necessary for scientists in that field to seek collaboration with laboratories in Europe and the U.S.A. that have adequate facilities for virus research. This arrangement is with problems brought about by long distant separation and therefore considerable delay in getting samples to their destinations. Many times, the samples arrive in very bad conditions and are therefore useless for any laboratory studies. This is capable of frustrating even the most enthusiastic researcher in the field. Indeed, some have deflected to other areas of Plant Pathology that are less demanding in terms of facilities.

If I have succeeded in this lecture in bringing into a clear focus, and to your appreciation, the negative and devastating effects of plant viruses on man's efforts to live and be comfortable, the need to stop the drift must equally be appreciated. With the adoption of modern agricultural technology such as large scale mechanization, irrigation and heavy fertilization aimed at increasing crop production, more virus problems will be encountered and there will be the need to further intensify research on plant virus diseases.

SUGGESTION

Attention is drawn to the existence in East Africa of a virus research unit within the set-up of the East African Agriculture and Forestry Research Organisation (EAAFRO) at Muguga near Nairobi, Kenya. The unit has adequate facilities for virus research and serves the East African Community of Kenya, Tanzania and Uganda. It is suggested that a similar virus research centre be established under the auspices of Economic Community of West African States (ECOWAS) to serve the countries of West Africa. The establishment of such a centre will greatly reduce the distance between the centre and any of the participating countries. Nigeria should initiate the establishment of the centre.

Functions of the Centre

The centre will be expected to:

1. Receive small samples from virus research workers based in the participating countries for final identification
2. Compile and make available, periodically, information on the identity, incidence and distribution of economically important plant viruses in areas of mandate of the Centre.
3. Compile and distribute to plant virologists in the participating countries the list of indicator hosts for viruses that occur naturally in plants in its area of mandate.
4. Prepare antisera to selected viruses and distribute same to scientists on request.
5. Encourage contact among scientists in the Centre and plant virus workers in its area of mandate.

CONCLUSION

It will be saying the obvious to conclude that scientific research is expensive in terms of facilities needed to prosecute it and unless we realize this and provide the needed facilities for research, the expected impact may be far from forthcoming. If Nigeria will develop scientifically, she must be prepared to fund scientific research, and adequately too. We must stop making statements of intent; rather, we must begin to actualize our intentions.

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