REPORT ON SURVEY OF VIRUS DISEASES OF FOOD CROPS IN THE TERRITORY OF PAPUA AND NEW GUINEA WITH SPECIAL REFERENCE TO PLANT QUARANTINE—PART II

C. J. MAGEE, M.Sc., D.Sc. (Agr.)

(Chief Biologist, N.S.W. Department of Agriculture.)

This survey was carried out in the course of travels in the Territory for the purpose of reporting on the incidence of bunchy top of *Musa* spp. in that region (see Part I) and was undertaken at the suggestion of Mr. R. E. P. Dwyer, Director of Agriculture, Stock and Fisheries, who was desirous of having the general virus disease position examined, particularly in relation to certain Native food crops, e.g. taro, kaukau (sweet potato), Cassava (tapioca), peanuts, corn, etc., as a guide to future quarantine action. The survey should be regarded as a cursory one and as being quite incomplete. The impressions were obtained from it, however, that the Territory has so far escaped a number of important virus diseases which are present in other countries and that the adoption of rigid quarantine would be of great value in the future development of agriculture in the Territory.

Special interest is attached to virus diseases because of the rather insidious means by which they may take control of a crop and the drastic measures which are usually required to deal with them once they have obtained the upper hand. Compared with blights and rots caused by fungi and bacteria which are usually conspicuous, virus infections may escape early notice and only become clearly evident when they have reached an epiphytotic phase or the whole of the planting stock of a crop is affected. Virus diseases are carried on from season to season by vegetative propagation which causes them to accumulate gradually and, in addition, most of them are transmitted from diseased to healthy plants by one or more insect vectors, which at times may allow them to spread with alarming rapidity. Transmission of viruses by true seed is the exception rather than the rule. Plant health authorities have come to regard virus diseases with special concern and the introduction of vegetative parts of plants to new territory now receives special scrutiny.

Plant Virus Diseases Seen in the Territory.

1. Aibika (Spinach) Mosaic.
2. Banana Mosaic or Infectious Chlorosis.
3. Canna Mosaic.
4. Cassia Mosaic.
5. Centrosema Mosaic.
6. Crotalaria Mosaic.
7. Corn Mosaic.
8. Cucumber Mosaic.
9. Pandanus Yellow Spot Mosaic.
10. Papaw Mosaic.
11. Peanut Mosaic.
12. *Piper Betle* Mosaic.
13. Potato Leaf Roll.
14. Taro Mosaic.
15. Tobacco Mosaic.
16. Tomato Mosaic.
17. Yam Mosaic.

Aibika (Spinach) Mosaic.—

A mosaic disease of Native spinach was noticed at Paragum, Gazelle Peninsula, New Britain, causing a light and dark green mottle and malformation of the leaves. Affected plants were also somewhat stunted. The relationship of the virus responsible for the mosaic is uncertain, but both tobacco plants affected with tobacco mosaic and bananas showing symptoms caused by the cucumber mosaic virus were present nearby in the same Native garden. No reference to a mosaic disease of aibika has been found in the literature.

Fig. 1.

Kaukau or sweet potato, one of the most important Native food crops, was found to be free from virus diseases. The " rosette " or " leaf curl " of this crop which is common in some parts of the Territory is believed to be caused by insect attack. A mosaic of sweet potato can be caused by the cucumber mosaic virus, but no sign of this disease was seen.

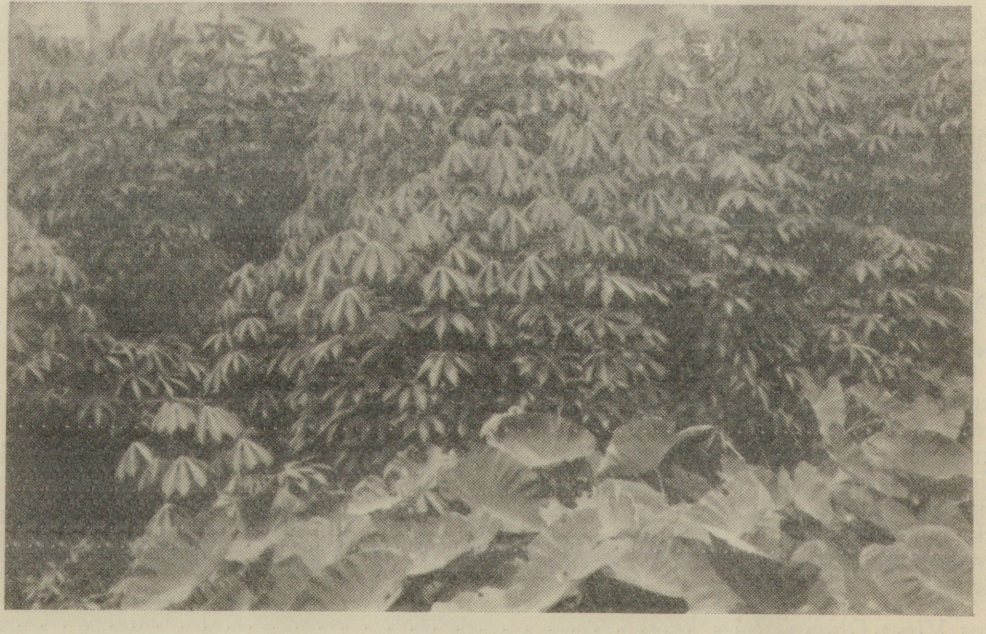

Fig. 2.

Cassava (or tapioca) in background, taro in foreground. In many parts of the tropics (e.g. Gold Coast, Congo, Cameroons, Liberia, Madagascar, Java), cassava is severely attacked by a virus disease. No sign of a virus disease was seen in this crop in the Territory, where it grows luxuriantly.

Fig. 3.

Mosaic disease of Centrosema. This is a valuable cover crop in many parts of the tropics, but is severely affected by mosaic throughout Papua and New Guinea and reduced in vigour.

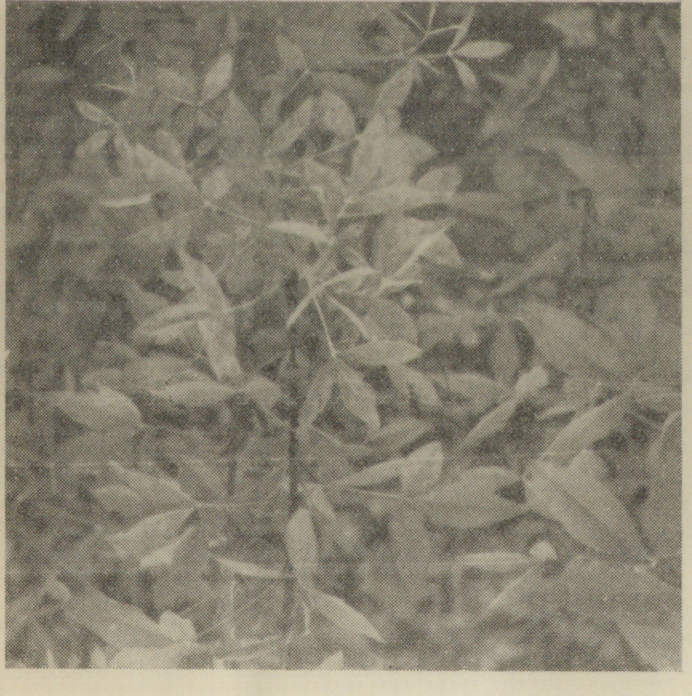

Fig. 4.

Mosaic disease of Crotalaria, healthy foliage on right of photo. Crotalaria is widely used as temporary shade for plantation crops throughout the Territory but is almost universally infected with mosaic.

Banana Mosaic or Infectious Chlorosis.—

The occurrence of this disease in the Territory is referred to on page 21 of Part I of this Report. The disease is considered to be caused by one of the strains of cucumber mosaic virus and to be identical with that described in the literature by Wellman (12), Ocfemia (7) and the writer (5). It is regarded as unlikely that this virus will ever create a serious problem in this important food crop, although severe local outbreaks of the acute form of the disease may occur at intervals in areas where vegetable crops, particularly cucurbits, are interplanted with bananas. The chronic form of the disease generally has a minor effect only on plants and is probably not very infectious. It is the practice in New South Wales not to propagate from plants that carry even mild forms of the chronic infection and the adoption of a similar procedure in the Territory is suggested. It is not recommended, however, that banana plants showing mild symptoms of chronic infection be destroyed, but plants showing the acute form of the disease should be dug out when encountered.

Canna Mosaic.—

This disease is another manifestation of the cucumber mosaic virus (2, 10) but was encountered only once during the survey, namely, at Vunapope Mission, New Britain. It is recommended that affected plants be destroyed. In the Philippines (7) *Canna* spp. are regarded as important reservoirs of the cucumber mosaic virus.

Mosaic of Cassia, Crotalaria, Centrosema and other Leguminous Plants.—

Mild to severe mosaic mottling of the foliage, sometimes accompanied by pronounced stunting, is widespread in leguminous shade and cover crops (Figs. 3, 4), in most parts of the Territory. This disease is common in both highland and lowland areas.

It is not known whether one virus is the cause of the symptoms in all species or whether several viruses are involved. It is considered probable, however, that a single virus is responsible for most, if not all, the infections and that it manifests itself with a variety of symptoms according to the species attacked. In a series of adjacent plots of different leguminous plants at Mageri Agricultural Officers' Training School, Papua, mosaic symptoms were seen on *Centrosema plumeri, Desmodium* sp., *Uraria lagopodioides, Tephrosia* sp., *Crotalaria stiata* and *Dolichos hosei,* while *Calopogonium* sp., *Indigofera* sp., *Cajanus* sp. and peanut had escaped infection or were resistant to infection. Minor and doubtful symptoms were seen on *Stylosanthes* sp., *Clitoria ternatea, Stizolobium* sp. and *Poinciana* sp.

There was no evidence that the virus (or viruses) affected plants outside the Family *Leguminoseae* in any of the many localities where it was observed. It seemed also to have a somewhat restricted range even amongst leguminous plants. Thus, in some localities there was almost 100 per cent. infection in *Crotalaria striata, C. anagyroides* and *Desmodium* sp., while nearby peanuts (*Arachis hypogaea*) and beans (*Phaseolus* spp.) were unaffected.

A mosaic of Crotalaria has been described in the literature (3) but the causal virus has not been studied in detail. It is considered possible that the virus, which is widespread in many leguminous plants in the Territory, is that which is known as common pea mosaic virus (14). This virus has a fairly wide host range among leguminous plants, is transmitted by several species of aphids (*Macrosiphum gei, M. pisi, Aphis rumicis*) but is not transmitted through seed.

Corn Mosaic.—

Mosaic disease of corn was seen in only one locality, namely, in a plot of young corn at the Teachers' Training School, Sogeri, Papua. A portion only of the plot was affected. There are two mosaic diseases of corn and the symptoms of mottling resemble those carried by the cucumber mosaic virus in corn (13) rather than those of leafhopper-transmitted corn mosaic (4). A colony of aphids, presumably *Aphis maidis,* was present on some of the affected plants and there were no signs of leafhopper feeding marks.

Cucumber Mosaic.—

The host plant range of this virus is very wide (2, 10) and it is the writer's opinion that the virus is fairly widespread

in the Territory where it causes a number of diseases, e.g. mild cucumber mosaic, acute and chronic banana mosaic, corn mosaic, canna mosaic, mild mosaic of papaw and mild mosaic of passionfruit. In no instance, however, were serious outbreaks attributable to this virus seen. The outbreaks were mainly local ones and indicated that a few infective aphids had spread from a restricted infection centre. This position is different from that which obtains in some tropical countries, e.g. Hawaii, North Borneo, Florida, Mindanao, where it is usual to find common weeds such as *Commelina nudiflora* and wild grasses infected with this virus. As a result epiphytotics of diseases caused by different strains of cucumber mosaic occur from time to time in neighbouring crop plants. It is thought that it is inevitable, as European settlement expands, that the weeds and grasses of the Territory will also become widely infected with cucumber mosaic virus. The virus is known to be disseminated by the seeds of a number of its host plants and several different species of aphids are capable of transmitting it with high efficiency.

Under tropical conditions, cucumber mosaic virus appears to have a less destructive effect on some of its host plants than it does in temperate regions. Although symptoms are present they are mild or masked. This applies particularly to cucumber and passionfruit and evidence of this was seen in both the lowlands and highlands of the Territory. Special interest attaches to passionfruit where the symptoms of infection are so slight that they would escape notice except by one familiar with the variations of symptoms of this virus in this host with seasonal conditions. In Australia, cucumber mosaic virus causes the widespread mosaic or woodiness disease of passionfruit and the severity of symptoms fluctuates greatly between winter and summer because of the masking action of temperature. In both the lowlands and highlands of New Guinea the virus appears to be always masked and because of the suitability of the Highlands, e.g. Wahgi Valley, for fruit production by this vine and masking of the virus, the Highlands of New Guinea could prove in the future to be a very favourable area for passionfruit culture.

Pandanus Yellow Spot Mosaic.—

A striking yellow ring-spot mosaic was noticed in the Native school grounds at Matupit near Rabaul in small plantings of pandanus which were grown for basket work. The relationship or importance of this virus is not known.

Papaw Mosaic.—

The papaws of the Territory are surprisingly free from virus disease, but in one planting in the Saiho area near Popondetta, several plants which showed a mild mosaic of the younger leaves were encountered. The papaws were interplanted with cucumbers and corn and it is considered that the mosaic symptoms seen may have been another manifestation of the cucumber mosaic virus.

In the Highlands of New Guinea, at Nondugl and Mount Hagen, almost every papaw plant showed a conspicuous mottling (of light and dark green areas) of the younger foliage. The vigour of the plants was unaffected. This mottling, which superficially resembles a mosaic of virus origin, is caused by infection of young foliage by the powdery mildew fungus (*Erysiphe* sp.).

Peanut Mosaic.—

Special attention was paid to peanut crops with a view to determining whether peanut rosette (11), a serious virus disease of this plant, occurred in the Territory. No sign of the disease was seen.

A single plant which showed a severe leaf mottle and was stunted, was found in a crop of Virginia Bunch at Bubia Experiment Station, near Lae. The symptoms bore no resemblance to those of peanut rosette and are considered most likely to have been caused by a chance infection by the virus which is common in Crotalaria and Centrosema in the Territory. Even if this is so, peanuts must still be regarded as highly resistant to this virus.

Mosaic of Piper Betle.—

The occurrence of a virus disease of this plant in the Territory is of interest since the betel vine (*Piper betle*) is closely related to pepper (*Piper nigrum*) which is a possible crop of the future. A mosaic disease of *Piper betle* was seen in Native gardens

near Rabaul. Although the mottling of the foliage was conspicuous, the vigour of the affected plants was still satisfactory. No reference to a virus disease of *Piper* spp. has been noticed in the literature, but it is thought likely that *Piper nigrum*, which is propagated vegetatively is commonly affected with a virus disease in Java. Last year, canes of the broad leaf and narrow leaf pepper from Java were intercepted in quarantine in Sydney and all canes in the consignment were found to be affected with mosaic.

Potato Leafroll.—

This disease (10) which is one of the serious "degeneration" diseases of potato, is to be seen in most crops in the Highlands of New Guinea. The disease is carried in the tubers and is spread by a number of species of aphids. Presumably, the disease has been introduced to New Guinea in seed potatoes from Australia. A crop of potatoes being grown at Wau from New South Wales certified seed contained a percentage of leafroll plants. The Department of Agriculture, Stock and Fisheries is developing a potato seed raising project at Aiyura Experiment Station (altitude 5,500 feet) using virus free stock. Most of the important varieties of potatoes have been imported and as soon as sufficient seed for distribution is available from this project it would be advisable to restrict further importations of seed potatoes to the Territory with the object of retarding entry of the spotted wilt virus (which has a wide host range) and potato blight (*Phytophthora infestans*).

Mosaic of Taro.—

Taro (*Colocasia antiquorum*) is important as a Native food crop in most parts of the Territory, and in most areas is affected with a mosaic disease. The disease appears to have an acute form and a chronic form and the different varieties, which are usually intermixed in Native plantings, seem to vary in sensitivity to the virus. The acute form causes marked stunting of affected plants, with chlorosis, twisting and malformation of the central leaves. The symptoms of the chronic form are variable, ranging from a prominent yellow mottling or streaking of the leaves without much malformation (Fig. 5) to an almost imperceptible minor streaking of the foliage. In some districts, e.g. Lae, the Native women in propagating, avoid severely affected plants and succeed in establishing improved stands. This disease is regarded as an important one, being somewhat equivalent in its degenerating effect to leafroll and the mosaic diseases of potato in European countries and it is thought that means of overcoming it should be investigated, for instance, at Keravat Experiment Station.

A search of the virus disease literature has not revealed any investigation of a virus disease of taro. The possibility should be entertained, however, that the disease is caused by the cucumber mosaic virus. Many monocotyledonous plants are susceptible to this virus and such infections frequently have an acute and chronic phase. Further, this virus is fairly widespread in the Territory on other hosts.

Some attempt is being made at Keravat Experiment Station to improve taro crops by roguing out severely affected plants. It is suggested that this system be modified to one of selection of apparently mosaic-free planting stock for replanting in isolation.

Reference should be made here to the disease which is reported to have wiped out taro crops in Bougainville and the British Solomons in 1946 and which was at first considered to be a virus disease (1). The disease has since been identified (8) as leaf spot and blight caused by *Phytophthora calocasiae*. During a brief visit to Buka Agricultural Experiment Station an endeavour was made to examine this disease but it was reported that the phythophthora disease had also "wiped out" the taro crop of Buka. Phytophthora leaf spot and blight occurs also in Hawaii (9) where a fair degree of control of it is obtained by spraying at intervals of about ten days with 4.4.50 Bordeaux mixture. Kongkong taro, *Xanthosoma macrophylla*, is resistant (15) to this disease and observations in the Territory indicated that this taro is also highly resistant to mosaic. Natives are reported, however, not to favour the variety, but it is being used successfully for Natives at Vunapope Mission, New Britain. There the crop is widely spaced and grown sufficiently long for the roots to become tuberous (about 15 months).

Tobacco Mosaic.—

This disease (2, 10) was present in almost all plants of tobacco seen in Lowland areas, particularly in the Gazelle Peninsula. It was seen also in the Central Highlands but symptoms there were milder as a result of masking by lower temperatures. The disease probably occurs in every part of the world where tobacco is grown. Although the virus is one of the most infectious it is apparently not regularly transmitted by any species of insect, nor by seed. Man seems to be the chief agent in disseminating the virus, since it is readily transmitted if healthy plants are handled after handling diseased ones, or if the operative is a smoker. The virus is a most refractory one and is not inactivated in the processing of tobacco. Since it is present in most tobacco crops it is also present in most brands of tobacco.

The tobacco mosaic virus has a relatively wide host range, particularly among solanaceous plants and is potentially important as the cause of a number of crop diseases.

Tomato Mosaic.—

Plantings of tomatoes were examined in a number of parts of the Territory and it was pleasing to observe that the spotted wilt virus (2, 10) has apparently not so far established itself in any of the areas visited. The tobacco mosaic virus, however, was seen causing a mosaic and a fern-leaf type of malformation in two crops of Bonny Best tomatoes grown by a European at Kubanga, Gazelle Peninsula. Control of this disease could be obtained by thorough washing of the hands with soap and water or allowing only non-smokers to transplant and attend to tomato crops.

Mosaic of Yams.—

A mosaic disease of yams (*Dioscorea* spp.) was encountered in a Native garden at Bumbi, near Lae. Time did not permit a survey of the Sepik District where yams are so important as a food crop. The disease caused mottling, vein clearing and distortion of the leaves with some reduction in vigour of the plants (Fig. 6). Apparently the disease has never been investigated, although there are scant references in the literature to the occurrence of a mosaic disease of the yellow yam in Sierra Leone in 1935 and in *Dioscorea* sp. in Puerto Rico in 1936. In the garden at Bumbi a small percentage only of the plants was affected by the mosaic so that it should be possible, by selection of planting material, to build up disease-free stocks.

Plant Quarantine in the Territory.

As mentioned earlier, the plant health position in the Territory is regarded as surprisingly good, particularly when one realizes that a great many introductions of plants have been made over the years. In addition to inspecting food crops, some observations were made on coconuts, cacao, coffee, quinine and tea and the impression of these crops, too, was that no serious introduced disease was causing losses. Most of these crops were subject to root and bark rots which have spread to them from the jungle and the few other diseases seen appeared to the writer to be caused by the use of unsuitable localities for the crops. In the case of a leaf malformation and yellowing of Robusta coffee at Keravat Experiment Station, an undetermined soil nutritional factor seemed to be involved.

Most countries of the world have established a plant quarantine service in order to avoid or slow down the entry of new diseases, pests and weeds and while there are the beginnings of such a service in the Territory, there is a need for precise legislation as a basis for future development. The *Quarantine Ordinance* 1931-1938 of the Territory of New Guinea and the Plant Diseases Ordinance of the Territory of Papua provide a suitable framework on which a plant quarantine organization could be built up, but there is need for a supporting series of Proclamations declaring ports of entry and naming specific diseases for the purposes of the Ordinances, plants which are prohibited as well as drafting of Regulations governing procedure in connection with seeds or parts of plants to which it is desired the Ordinance should apply.

The exclusion of plant diseases from an importing-exporting country presents many problems. In some regions, e.g. North America, an elaborate, highly restrictive and costly quarantine has been devised to achieve this end, but few countries can afford the luxury of staff to operate such a

Fig. 5.

Taro, one of the favourite Native food crops, is affected with an acute and a mild form of mosaic in most parts of Papua and New Guinea. The central leaf in the photo is showing the mild form of the disease, which has only a slight effect on vigour. The acute form dwarfs the plant and malforms the leaves.

Fig. 6.

Showing left, mosaic disease of yam and right, healthy foliage. The disease causes mottlimg and severe malformation of the leaves.

scheme or are sufficiently self-supporting to bear the interference with commerce the restrictions involve. It is doubtful, too, whether the best organized schemes do not sometimes break down, through first-class mails or by surreptitious imports.

It is considered that the most publicly-acceptable and workable quarantine scheme is one aimed at protecting the principal crops of the country and which prohibits imports of such plants, or allows entry of them only from sources where a disease of importance does not occur. Plant pathology is becoming well developed in most countries and accurate records of the geographical distribution of the more important diseases are now available from the Distribution Maps of Plant Diseases issued, and kept up to date, by the Commonwealth Mycological Institute, London.

A system of plant quarantine based on the above principle is the one advocated for the Territory, with care being taken to interfere as little as possible with the free movement of items of commerce and food. The main export crops which need protecting are well defined, possible future export crops can be envisaged and the principal Native and European food crops are well known. For practical purposes, and until disease surveys are more complete, it can be assumed that existing crops of the Territory are free from important diseases.

The present provisions of the *Quarantine Ordinance* 1931-1938 does not distinguish between plants (all plant parts) whether principal crops or merely items of commerce or food. If this Ordinance was enforced all plant material entering the Territory would have to enter through certain ports (not yet specified) and be submitted to the prescribed inspection. It is considered that this section should be modified or suitable Proclamations issued, prohibiting entry of specified plants, e.g. coconut, rubber, cacao, coffee, tea, cotton, sugar-cane, banana, abaca (Manila hemp), papaw, sweet potato, taro, cassava, peanut and other principal crops. Provision should be made for entry of limited quantities of seed or propagative parts of the above crop under permit from the Director of Agriculture in order to keep the Territory supplied with new or improved varieties. It is doubtful whether control of entry of fruit, seed and propagative parts of temperate-climate fruits, vegetables and ornamentals should be restricted at this stage, because of interference with commerce and food supplies, unless there is a specific reason. Thus, potato and dahlia tubers might be prohibited from countries where the spotted wilt virus occurs, e.g. Australia, because of the danger of introducing this virus which affects a very wide range of herbaceous plants. An important part of quarantine is public acceptance of the principles on which it is based and such acceptance is more easily obtained if quarantine is aimed at protecting specific and important crops.

The establishment of the Plant Introduction Station at Laloki, Papua, has been a step in the right direction. The Station is an irrigated farm in a dry area, is relatively isolated and well suited to the purpose for which it was designed. Entry of limited quantities of prohibited plants could be safely managed through this Station. Port Moresby would appear to be the most suitable Port for quarantine entry for both air and sea traffic because it is close to Laloki, but it will probably be wise to make Rabaul a port of entry also for certain areas. If this is done an isolated area at the Keravat Experiment Station should be demarcated as a plant introduction garden.

The above discussion takes into consideration only plant diseases, but the same general principles would apply to quarantine of insect pests and weeds except that closer port inspection must be maintained. One advantage of the prohibition system of principal crops is that a good deal of the port inspections can be carried out as a Customs routine.

LITERATURE CITED.

1. Badcock, W. J.—Annual Report British Solomons Islands Protectorate 1946, 13 pp. 1947.

2. Holmes, F. O.—Handbook of Phytopathogenic Viruses. Burgess Publishing Company, U.S.A., 1939.

3. Johnson, H. W. and Lefebvre, C. L.—Crotalaria Mosaic. Abs. Phytopathology 27, pp. 10-11, 1938.

4. Kunkel, L. O.—The Corn Mosaic of Hawaii District from Sugar Cane Mosaic. Phytopathology 17, p. 41, 1927.

5. Magee, C. J.—Transmission of Infectious Chlorosis or Heartrot of the Banana and Its Relationship to Cucumber Mosaic.

6. Murphy, D. M. and Pierce, W. H.—Common Mosaic of the Garden Pea (*Pisum Sativum*). Phytopathology 27, pp. 710-721, 1937.

7. Ocfemia, G. O.—The Rapid Dissemination of the Mosaic Disease of Abaca or Manila Hemp Plant (*Musa textilis Nee*) in the Field. Philippine Agric. 33, 2. pp. 142-144, 1949.

8. Parham, B. E. V.—Economic Botany Notes 3; Diseases of Taro. Agric. J. Fiji 18, p. 80, 1947.

9. Parris, G. K.—Diseases of Taro in Hawaii. Circ. Hawaii Agric. Exp. Sta. 18. 29 pp., 1941.

10. Smith, Kenneth.—Textbook of Plant Virus Diseases. J. and A. Churchill Ltd., London, 1937.

11. Storey, H. H. and Bottomley, A. M.—The rosette disease of peanuts (*Arachis hypogaea*). Ann. Appl. Biol. 15, pp. 26-45, 1948.

12. Wellman, F. L.—A Disease of Banana, markedly similar to Bunchy Top, produced by Celery Virus 1 in U.S.A. Phytopathology 24, pp. 1032-1034, 1934.

13. ————Infection of *Zea mays* and various other Gramineae by the Celery Virus in Florida. Phytopathology 24, pp. 1035-1037, 1934.

14. Zaumeyer, W. J. and Wade, B. L.—Pea Mosaic and its relation to other Legume Mosaic Viruses. Jour. Agr. Res. 53, pp. 161-186, 1936.

15. Plant Pathology—Rept. Hawaii Agric. Exp. St., 1937. 33-45, 1938.