

INFECTION EXPERIMENTS WITH SOME
COMMON OKLAHOMA
PLANT VIRUSES

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By

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INTRODUCTION

The virus diseases of plants constitute one of the great groups of plant afflictions standing distinctly apart from those due to non-parasitic or environmental factors and those in which a visible parasite is the casual agent. The virus troubles with their varied symptomatology have one feature in common which is that they may be transmitted from diseased to healthy plants by an infectious principle, the exact nature of which is unknown.

These troubles agree with the parasitic diseases due to bacteria and fungi in being infectious, but no visible organisms or casual agents are known. The infective principle, whatever it may be, is present in the juice or cell sap of a diseased plant, the different diseases showing varying degrees of infectiousness. Some may be transmitted by mere contact, while in others, less infectious, organic union of a diseased and healthy plant by grafting is necessary for the artificial communication of the disease. Under natural conditions, insects are the most important agents in the transmission of the virus from one plant to another.

The first virus disease to be given definite recognition, tobacco mosaic, was reported in 1886. It was first observed by Swieten in 1857, and was described by the German, Mayer, in 1886, who gave it the name "Mosaikkrankheit." However, it was proven to be transmissible from diseased to healthy plants by Iwanowski in 1892. Beijerinck in 1898 demonstrated the filterable character

of viruses. Takami in 1901 demonstrated insect transmission of virus diseases. Most of the early research in plant viruses was done with the tobacco mosaic virus. From first proof of the mosaic of tobacco as an infectious disease(1888-1892), our knowledge of this group of diseases made slow progress until very recent years, when numerous diseases of the virus type have been described as affecting both wild and cultivated plants. The demonstrations as to the behavior of the virus diseases and the important part which they play in crop losses constitute one of the most important achievements of modern phytopathology.

Virus diseases exhibit different degrees of infectivity and certain individual peculiarities and for this reason are transmitted in different ways in nature or artificially. A virus may be communicated in one or more of the following ways:

1. Transmitted by budding and grafting.
2. By a specific insect or several specific insects.
3. Sap-inoculation, viz., by the juice of a diseased plant.
4. Seed-transmission, viz., perpetuated by the seed from infected parents.
5. Non-specific insect transmissions, viz., no biologic relation between insect and virus.
6. Vegetative propagation.
7. Soil transmission.

The purpose of this paper is to describe an experimental study made of the host reactions and host ranges of some common sap-inoculable plant viruses of this state. This study is concerned mainly with the finding of reliable differential host plants for certain viruses leading to their correct and convenient identification. Moreover, considerable experimental study has been given to two viruses, a mosaic of cowpeas and a mosaic of petunias, which are of uncertain identity and of which there has been very little or no record or description. Also, some original work was done concerning the host reactions, host range, separation and analysis of a mosaic virus complex from potato.

Sap-inoculation methods were used exclusively in these experiments. Inoculations were made by rubbing the infective sap or juice of diseased plants on the leaves of healthy plants with pot labels or cheese cloth. An abrasive such as carborundum powder was occasionally employed to facilitate sap-transmission. These infection experiments involved carrying the viruses to certain members of Solanaceae, Leguminosae, Cucurbitaceae, and Cruciferae.

1. Potato Aucuba Mosaic Virus

Marmor aucuba Holmes

The disease caused by this virus is generally distributed throughout North America, Europe, and Great Britain. It is of comparatively low incidence in both this country and abroad, being encountered only in occasional plantings.

The virus occurs in nature in potatoes, and its host range is confined largely to Solanaceae. The virus, like other potato viruses, is tuber borne. Moreover, it is interesting to note that Elze(10) states that the virus can be borne in the true seed from diseased potato plants.

Potato aucuba mosaic virus is easily sap-transmissible from potato to potato and to certain other solanaceous plants. There are possibly three different strains of the virus; Smith(29) recognized this relationship but classified each strain as a separate entity. Dykstra(3) showed by cross-inoculation immunization experiments that a certain ill-defined yellow mosaic of potato was an atypical form of potato aucuba mosaic. Nevertheless, potato aucuba mosaic is usually a clean-cut highly individualistic virus in its host reactions and aberrant strains are uncommon.

My study of the virus consisted of sap-inoculation experiments on various plants, with the following results.

SOLANACEAE

Solanum tuberosum L. Irish Potato. A systemic brilliant yellow mottle develops in the leaves of this plant. The tubers

become more or less necrotic. The plants lose vitality with a consequent reduction in yield.

Lycopersicon esculentum Mill. Tomato. Using young plants for inoculation, in approximately fourteen days, the virus becomes systemic producing small, scattered, round, yellow spots particularly in the lower leaves. These yellow spots become very faint and often disappear in mature plants, the plants thus carrying a masked infection.

Nicotiana glutinosa L. The symptoms in this host are quite characteristic. In about ten days, whitish irregular lines appear in the leaves following mainly along the veins. These white veinal lines are scattered at random throughout the leaves of the plant. The virus symptoms are at times nearly masked; again, they are quite pronounced. The infection is systemic and ordinarily causes no necrosis.

Petunia hybrida Vilm. Garden Petunia. The potato aucuba mosaic virus does not produce prominent symptoms in this plant, although the infection is systemic. However, a few white irregular spots or streaks occur following along the veins in some of the leaves. At times the virus assumes a masked condition throughout the plant.

Nicotiana tabacum L. Tobacco var. Turkish, and Datura stramonium L. Jimson Weed. In these two species, the virus is carried in a symptomless state.

Capsicum annuum L. Bell Pepper. One of the most striking virus phenomena known is the reaction of peppers to potato aucuba mosaic. In seven days black necrotic areas appear on

the stem and leaves, particularly at the base of the leaves and on the petioles at the points of attachment with the stem. The virus proceeds directly towards the growing point and in ten to fourteen days all of the leaves fall off the plant. Only the necrotic blackened naked stem remains with a meagre spark of life in it. The stem may produce a paltry amount of chlorophyll for a considerable length of time, after which the entire plant dies. Smith(29) says the virus produces very much the same symptoms on Solanum nodiflorum Jacq.

Solanum melongena L. Egg Plant. Through sap-inoculation methods, the virus was not found to be transmissible to this plant.

LEGUMINOSAE

Vigna sinensis(L.) Endl., the common cowpea, was not found to be susceptible to infection with potato aucuba mosaic. The same can be said for French beans, Phaseolus vulgaris L.

CRUCIFERAE

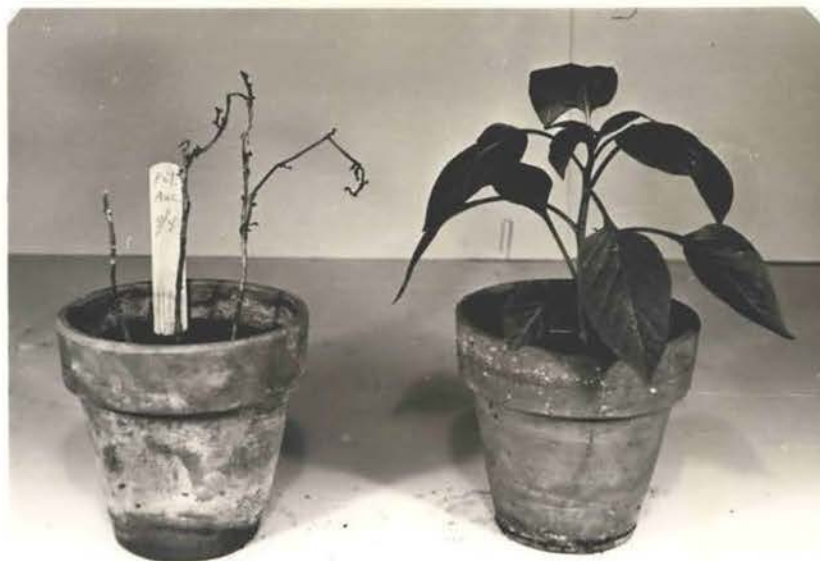
Brassica oleracea L. Cabbage. I was unable to produce infection with the virus in this plant.

Potato Aucuba Mosaic Virus

Explanations to Plate I

- A. Left: potato aucuba mosaic virus in pepper. Note the blackened, necrotic, naked stems. The plant is dead, following a 10-day infection. Right: a healthy pepper plant.
- B. Potato aucuba mosaic virus in Nicotiana glutinosa L.

Plate I



A.



B.

II. Tobacco Mosaic Virus

Marmor tabaci var. vulgare Holmes

The occurrence of tobacco mosaic virus is world-wide. It is found wherever tobacco and tomato plants are grown. The incidence of the virus is high, especially in greenhouses among tobacco plants and tomato plants. It is found to occur rather frequently in petunias.

Due to its extremely infectious nature, unusual stability and power of resistance, wide distribution, and general suitability for experimental work, the virus has attracted much attention and a great deal of information has been compiled in its regard. Tobacco mosaic virus has been subjected to more research work in regard to seed-transmission, physical properties and other characteristics than any other plant virus. I shall not undertake an extensive literature review.

The virus is second to none in its high degree of infectivity. Tobacco mosaic virus is sap-transmissible even by the slightest touch or breaking of a single trichome. The virus has been found not to be seed-transmissible, although there has been much disquisition regarding this subject. Gratia and Manil(11) claim that the virus is absent from pollen grains and anthers; they also contend that the virus does not enter the ovaries or other floral organs of the hosts. Smith(29) says that the virus is present in the ripe fruits of tomato plants and may contaminate the seed coat and in this way infection can arise from the seed. Man is the chief disseminating

agent through smoking tobacco and chewing tobacco. Insects are able to transmit the virus only mechanically, i.e. there is no biological relationship between insect and virus. The virus frequently has the incidence of 100 per cent in greenhouse tomato cultivation due to hand transplanting, pruning, tying, and the use of electric pollinators which spread the disease from one diseased plant to all others.

There are innumerable strains of tobacco mosaic virus, from very mild strains to very severe, with many strains of intermediate degrees of virulence. Also, there are several color strains of the virus. Holmes(13) has succeeded in producing a masked strain of tobacco mosaic by means of heat attenuation of a distorting strain of the type virus. With this masked strain, he has succeeded in producing immunity in tobacco and tomato plants against any other strain of the virus. I carried on similar experiments wherein I produced several attenuated strains from the type virus. However, none of these strains were attenuated sufficiently to produce masked infection in tobacco plants, and therefore were of no value for immunizing plants against other strains.

I transmitted tobacco mosaic virus to several species of plants with the following results.

SOLANACEAE

Lycopersicon esculentum Mill. Tomato. In tomatoes the virus causes an irregular yellow mottle and considerable distortion in the leaves. Distortion is very noticeable in the

younger leaves. The plants do not become stunted and the loss in yield is not readily apparent. According to the calculations of Heuberger and Norton(12), tobacco mosaic reduces the yield of tomato plants 8 per cent.

Nicotiana tabacum L. Tobacco var. Turkish. The symptoms of the virus first appear in the young leaves formed subsequent to the inoculated leaves. The symptoms begin in the young leaves as a vein-clearing which quickly differentiates into a mottle with raised green areas. The young leaves become badly puckered and assume a blistery appearance; as the leaves mature a typical mosaic pattern develops. In many cases, the plants are stunted.

Nicotiana glutinosa L. The well known characteristic of tobacco mosaic virus in this plant is the development of round local necrotic lesions on the inoculated leaves within a period of two to four days. There is no systemic spread of the virus and the localized infection in the inoculated leaves is soon followed by abscission and complete recovery.

Capsicum annuum L. Bell Pepper var. Windsor A. In these plants, tobacco mosaic virus produces local necrotic lesions in a few days. In this variety, the virus shows a slight tendency to spread from the inoculated leaves. However, the plants soon recover completely from the infection following abscission of the infected leaves. Holmes(14) states, in regard to tobacco mosaic, that some varieties of pepper have a tendency toward systemic necrosis and death, while others localize the virus and recover, still others show a systemic chlorosis, and others a delayed necrosis and finally escape

from systemic spread, although the genes for any of these responses are not entirely constant for any one variety.

Datura stramonium L. Jimson Weed., and Solanum melongena L. Egg Plant. In these two species, the virus produces round necrotic lesions which have some tendency to spread to the new leaves. Soon the virus ceases its action toward systemic spread and this is followed by abscission and complete recovery. According to Smith(29), the ordinary European strain of tobacco mosaic virus is much more severe and frequently kills *Datura* plants and also egg plants.

Petunia hybrida Vilm. Garden Petunia. In petunias, the virus causes a pronounced mottling and puckering of the leaves. The picture is one of raised green areas against a background of yellow. The margins of the leaves usually turn upward.

III. Tomato Streak Virus or Single-Virus
Streak Strain of Tobacco Mosaic Virus
Marmor tabaci var. canadense Holmes

So far as I can determine from the available literature, the tomato streak virus, which Holmes(15) calls a single-virus streak strain of the tobacco mosaic virus, has not been previously observed in the United States. I observed the streak condition on tomato plants in the experimental greenhouse of Oklahoma A. & M. College in the spring of 1940, and by infection experiments identified it as single-virus streak. Though apparently not recorded before 1940 in the United States, the viruses are nevertheless of common occurrence in the commercial tomato crops in the British Isles and Canada.

Several strains of the virus have been recorded. Berkeley (1), working in Canada, has obtained what he calls an Ontario strain of the virus, which he asserts like the type virus is merely another strain of tobacco mosaic virus. Smith(28) has isolated a yellow strain of tomato streak virus which he found concurrent with the ordinary streak strain in tomato plants. The yellow strain was isolated by continuous subculturing. Newton and Edwards(24) speak of three serologically identical strains of the virus which were distinguishable by host reactions.

In the identification of the tomato streak virus, it is important to consider that other viruses can produce "streak" symptoms in tomato plants. For example, Smith(29) and also Jones and Burnett(17) indicate that the X virus of potato associated with ordinary tobacco mosaic virus is responsible for the

"streak" tomato disease commonly occurring in America. Moreover, Newton and Edwards(23) have illustrated that a certain strain of the X virus alone has been the cause of a "streak" disease of tomatoes in Victoria. My methods of differentiating the single-virus streak strain of tobacco mosaic from these other possibilities are as follows.

SOLANACEAE

Lycopersicon esculentum Mill. Tomato. The virus starts by producing a mottle on the leaves quite like the symptoms of ordinary tobacco mosaic. The subsequent necrotic patches and spots in the leaves, and the dark longitudinal necrotic lesions or streaks on the stem and petioles, did not appear in the greenhouse until early spring during the month of April when the plants were ripening their first fruits. The disease is a very serious one and sometimes kills the plants. Brown areas appear in the pith and cortex, and the shrivelled leaves give the plants a wilted appearance.

Nicotiana tabacum L. Tobacco var. Turkish. On this variety, the virus produces mottling and distortion symptoms only. Smith(28) says that on tobacco var. White Burley the virus may produce either mottling or necrosis which may be localized or systemic. Holmes(15) reports that the virus causes chlorotic systemic mottling in some varieties of tobacco, and, in others, such as Adcock, necrotic primary lesions with or without subsequent systemic necrosis.

Nicotiana glutinosa L. The virus produces numerous large localized necrotic lesions in this plant. If the tomato streak

symptoms had been due to a complex of two viruses, the X virus in association with ordinary tobacco mosaic, the X virus would have likely become systemic in N. glutinosa and remained in this plant after abscission and recovery from the tobacco mosaic virus. However, such was not the case, because sub-inoculations were made from the recovered N. glutinosa plants to Datura stramonium L., testing thus for the presence of the X virus which may be masked in N. glutinosa. The Datura plants did not show infection, indicating that the streak symptoms on the tomato plants were due to the single-virus streak strain of tobacco mosaic.

IV. Potato X Virus
Marmor dubium var. vulgare Holmes

The virus is almost universally present in the commercial potato stocks of America. However, according to Smith(29), the virus is much less prevalent in Europe. Potato X virus occurs throughout the world, and in some countries is so widespread that no plant of established commercial potato varieties has been found free of it. In some parts of the United States, it is so common and innocuous that it is known as the "healthy-potato virus" or "latent virus."

Although the typical strain of the potato X virus is ubiquitously masked in practically all of the commercial potato varieties of this country, it forms a basis for most of the severe potato mosaic diseases. The virus is carried over in the tubers, but is not transmitted in the true seed. The X virus is easily transmitted by sap-inoculation, and is second only to the tobacco mosaic virus in its high degree of infectivity. No insect vector is known, although thrips have been suspected. Smith(29) has found sap-sucking insect fauna incapable of transmitting the virus. However, using several species of thrips, through 100 transmission tests, he obtained five positive infections. Loughnane and Murphy(19) failed to find an insect vector, but demonstrated very significantly that the virus is transmitted from plant to plant by leaf contact, especially that brought about by air currents.

The X virus of potato exists in a number of closely allied strains. It has been demonstrated by Salaman(26) through sero-

Tomato Streak Virus or Single-Virus
Streak Strain of The Tobacco Mosaic Virus

Explanation to Plate II

- A. Tomato streak virus in tomato. Note the mottle, distortion, and necrotic areas in the leaflets. Note, also, the dark longitudinal necrotic lesion on the stem.

Plate II



A.

logical and immunological reactions that six strains are fundamentally the same virus. The chief difference in the strains of the virus lies in the severity of the symptoms produced in Nicotiana tabacum L., Nicotiana glutinosa L., and Datura stramonium L., which are valuable differential host plants. However, the type strain of the virus, which is the one predominating in the United States, is a mild one, and is the one concerned with in this study.

Certain workers in the United States Department of Agriculture have contributed greatly toward developing virus-disease resistant potato varieties. The variety known as Potato 41956 is X-virus immune and for this reason is indispensable to potato virus research for the purpose of filtering out the X virus from a complex, although it is of no value as a commercial variety. Potato 41956 has been found immune from the X virus by field exposure, leaf rubbing, and grafting; also, the variety Katahdin has been found resistant but not immune (Schultz, Clark, Raleigh, Stevenson, Bonde, and Beaumont 27). Potato 41956 has been found immune from six strains of the X virus even in graft tests (Stevenson, Schultz, and Clark 30).

The following is an account of my infection experiments using the X virus, typical strain.

SOLANACEAE

Datura stramonium L. Jimson Weed. This is one of the most efficient indicator plants for the X virus. Seven days following inoculation, the reaction begins as a mild pepper and salt mottle. Later, as the plant matures, in the new leaves,

large brilliant yellow areas predominate which become fainter as the leaves approach normal size.

Capsicum annuum L. Bell Pepper. This plant is also an excellent indicator for the X virus. I witnessed two types of reactions in pepper plants. In the majority of cases, the virus produces systemic chlorosis accompanied by dark scattered necrotic lesions throughout the leaves of the plants. On the other hand, in a few cases, the virus produced only systemic chlorosis in the plants. This systemic mottling was accompanied by severe leaf distortion and consequent dwarfing of the plants. The respective types of reactions seem to be controlled largely by the varieties of peppers used. However, no one variety exhibits absolute constancy in reacting to the virus.

By subinoculations to *Datura* plants for indicators, I found that this strain of the X virus produces symptomless infections in the following plants:

Solanum tuberosum L. Irish Potato

Lycopersicon esculentum Mill. Tomato

Petunia hybrida Vilm. Garden Petunia

Nicotiana tabacum L. Tobacco var. Turkish

Nicotiana glutinosa L.

Potato X Virus

Explanations to Plate III

- A. The X virus in jimson weed. Note the mild mottling produced in the leaves.
- B. The X virus in pepper. Note the mottling and distortion accompanied by some necrosis, and the tendency toward abscission of the leaves.

Explanations to Plate IV

- A. Leaf-print from leaf of healthy jimson weed.
- B. Leaf-print from leaf of jimson weed infected with the X virus.

Plate III

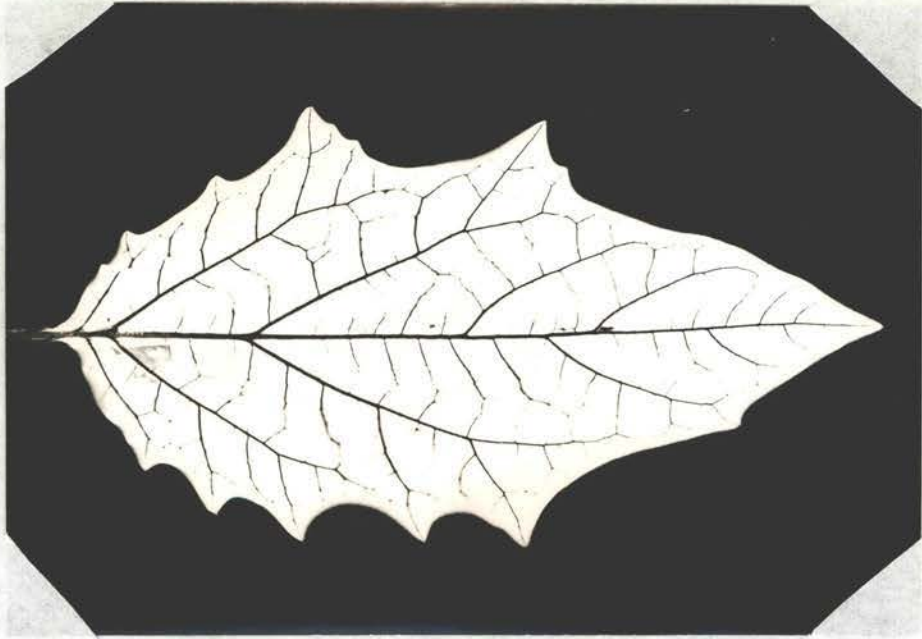


A.

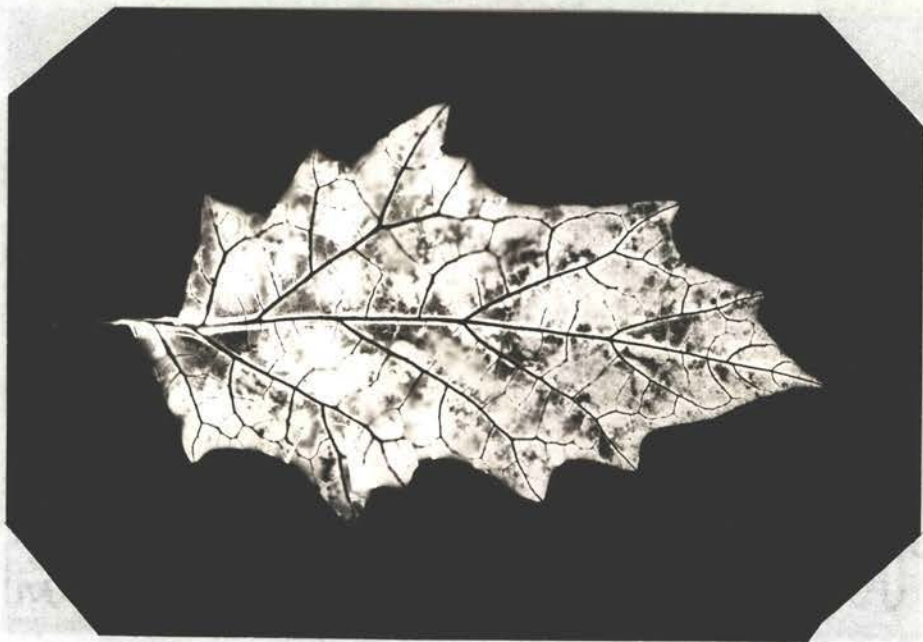


B.

Plate IV



A.



B.

V. Potato Crinkle-Mosaic Virus Complex

The potato crinkle-mosaic disease occurs in the United States, England, and Holland. It is less common than its sister disease, rugose mosaic.

The potato crinkle-mosaic virus complex is sap-transmissible from potato to potato and to certain other solanaceous hosts. The virus complex is sap-transmissible to potato only with difficulty and by persistent effort. The use of an abrasive such as carborundum dust facilitates mechanical inoculation to potato, but even in this case the percentage of infections is low. The complex is best transmitted by grafting methods.

The potato crinkle-mosaic virus complex is composed of two viruses in combination producing characteristic symptoms in its natural host, the potato, and in certain other solanaceous plants. The viruses constituting the complex are the X virus (Marmor dubium var. vulgare Holmes) and the A virus (Marmor solani Holmes). The X virus, though omnipresent in many commercial potato varieties, is not thought to be insect borne, but the A virus has been found to be transmitted by certain insects of the Aphididae, such as Aphis rhamni Boyer in North America and Myzus persicae Sulz. in the British Isles (Loughnane 18). The potato crinkle-mosaic virus complex like the many other potato virus diseases is carried over in the tubers. Also, Dykstra(6) indicates that certain weed hosts such as Solanum spp. and Physalis spp., especially Solanum villosum Mill., can carry the disease in a field and serve as a source of inoculum for

insect vectors. It is interesting to note that Johnson(16) in 1929 assumed that crinkle mosaic and rugose mosaic were diseases due to single viruses, although he fully realized that these diseases were definitely associated with the latent X virus in potatoes. But it is an important fact that potatoes have been known to contract as many as three or even four viruses in natural sequence.

In the past it has been almost impracticable to distinguish crinkle mosaic from rugose mosaic on the basis of host reactions. Crinkle mosaic consists of the X virus coupled with the A virus. Rugose mosaic is composed of the X virus in combination with the Y virus(Marmor cucumeris var. upsilon Holmes). The two diseases are certainly closely related symptomatologically because the A virus and the Y virus belong, according to host reactions, in a group of similar Y-type or veinganding viruses(Smith 29). Murphy and Loughnane (22) suggest that the viruses A and Y are probably identical. However, the fact that there is no immunological relationship between the viruses A and Y seems to be sufficient justification for considering them as independent entities(Smith 29). Chester(2) has shown that the two viruses are serologically unrelated, because the A virus, which he refers to as the potato mild mosaic virus, gives no cross-precipitin tests with the Y virus or the cucumber mosaic virus, and therefore does not antigenically belong in the veinbanding group of viruses. Also by serological methods, Chester(2) has found that the Y virus is definitely related to the cucumber mosaic virus and

has placed both in the beinbanding group of viruses. Concordantly, Holmes(15) considers the Y virus to be a strain of the cucumber mosaic virus in his classification and nomenclature:

Cuc. Mos. Virus, Marmor cucumeris var. vulgare Holmes

Y virus, Marmor cucumeris var. upsilon Holmes.

Moreover, in Holmes' classification, the A virus is an entirely different species:

"A" virus, Marmor solani Holmes.

Johnson(16) says that crinkle mosaic might easily pass for rugose mosaic, and suggests that in order to eliminate confusion, distinctions should be made on bases other than symptomatology. Nevertheless, a number of authorities such as McKay and Dykstra(21) and Smith(29) assert that the symptoms of crinkle mosaic on potato are quite characteristic and easily distinguishable from the disease known as rugose mosaic. But here again doubt arises because much depends on the variety of potato involved. Also, the difficulty is increased by the fact that there are different forms of crinkle mosaic due to different strains of the X virus and the A virus making up the complex, and different forms of rugose mosaic due to different strains of the X virus and Y virus in association(Dykstra 7). Therefore it is not the best practice to attempt to diagnose any virus disease or virus by its reaction or symptoms on one host if it is possible to transfer the infection to several hosts, giving special attention to the reaction on each plant and to the host range.

Practically all of the *Solanum* viruses, due to the general occurrence of the X virus, are composite in nature, but in the

case of the crinkle mosaic virus complex, the presence of the X virus seems actually to revolutionize the effects of the A virus, and vice versa. I have carried the crinkle complex to a number of different host plants making detailed study of the respective host reactions. Also, I have separated the constituent viruses of the complex by means of the X-virus immune clone, Potato 41956, and Datura stramonium L., and have studied each virus independently. Furthermore, I have added one virus to the other in delayed sequence in various hosts, thereby synthesizing the crinkle-mosaic virus complex in its original form. The following topics relate the course and results of this work.

A. Differential Host Reactions of The Crinkle-Mosaic Virus Complex

SOLANACEAE

Solanum tuberosum L. Irish Potato. The most characteristic symptom of crinkle mosaic in potato is a pronounced puckering and downward curling of the leaves. There is no distinct spotting or necrosis, or leaf-drop as sometimes occur in the case of rugose mosaic, but diffuses, slightly yellowish areas appear all over the foliage. The disease is a mild one and does not do the plants serious damage; there is no blighted appearance about the plants as in the case of rugose mosaic. Another strong point in differentiating crinkle mosaic from rugose mosaic is that crinkle mosaic is sap-transmissible from potato to potato with great difficulty, even when an abrasive

such as carborundum dust is employed in the process. This contrasts sharply with the high infectivity of rugose mosaic when sap-inoculated to potato (McKay and Dykstra 21).

Nicotiana glutinosa L. The crinkle-mosaic virus complex exhibits very unique symptoms in this host. In seven days a brilliant vein-clearing appears in the leaves, accompanied by marked crinkling. Quickly following is a severe veinal mosaic turning into myriad irregular small semi-necrotic yellow spots. There is a pronounced downward curling of the leaves. Next, necrosis sets in at the tips of the leaves proceeding back toward the petioles. This progressive necrosis eventually consumes the entire leaf. The virus complex keeps migrating upwards into the new leaves, producing semi-necrotic yellow spots in only three or four days. One by one, the leaves are destroyed by necrosis, their crinkled, brown, dried remains persisting attached to the stalk. Only the uppermost leaves remain alive, dying as new ones are formed. With the continuous column of crisped dead leaves hanging on the stalk below a parasol-like aggregation of young leaves at the summit, the plants have a wretched appearance but survive indefinitely.

Nicotiana tabacum L. Tobacco var. Turkish. At first the virus complex causes a bright-vein-clearing and a crinkled appearance in the leaves of young plants. This vein-clearing quickly becomes a mild ring-spot type of necrosis. The ring-spot soon becomes a ring-chlorosis, a mottle, then a mild mosaic, and eventually becomes entirely masked as the plant approaches maturity.

Lycopersicon esculentum Mill. Tomato. Ten days after

inoculation, the plants develop a severe yellow mosaic. This symptom confines itself largely to the lower leaves and persists without doing the plant any great amount of injury. The affected leaves have a characteristic drooping.

Petunia hybrida Vilm. Garden Petunia. From three to five weeks after inoculation, vein-clearing appears in the new leaves. This symptom gradually differentiates into a striking, yellow, veinal mosaic. The virus complex causes no necrosis. In contrast with this, the rugose mosaic complex does frequently produce necrosis in petunias(Dykstra 6). The crinkle-mosaic virus complex causes no leaf distortion in this species. In petunias the countenance afforded by the virus complex is a characteristic golden mosaic which is almost beautiful to the eye. There is no flower symptom; the plants bloom freely and normally.

Capsicum annuum L. Bell Pepper. Peppers, when inoculated with the crinkle-mosaic virus complex, contract only one of the constituents of the mixture, the X virus. The A virus is filtered out, and composite virus symptoms can not be recovered when subinoculations are made from the peppers to tobacco plants, petunias, or Nicotiana glutinosa L. Only the X virus is recovered in these plants. The symptoms on peppers are the typical X virus symptoms, with systemic chlorosis of the leaves interspersed with many small necrotic spots. The fact that only the X virus can be recovered from peppers inoculated with the crinkle mosaic complex(X and A viruses in association) is an important point. Peppers thus eliminate the A virus, and

in not being susceptible to infection with the A virus establish a strong point of contrast of crinkle mosaic with rugose mosaic. The rugose mosaic complex(X and Y viruses in association) is theoretically transmissible to peppers as a unit, because Dykstra(7) asserts that the Y virus is definitely sap-transmissible to peppers, causing a banding of the veins, which changes to a mottling.

Datura stramonium L. Jimson Weed. Here again we have a species which contracts only the X virus from the crinkle complex. Typical mottling X virus symptoms result on inoculation to this plant. Nothing but the X virus can be recovered when subinoculations are made to other hosts. According to Smith(29), Datura stramonium is, by sap-inoculation methods, immune from the A virus of the crinkle complex, and, also, immune from the Y virus of the rugose mosaic complex.

Solanum melongena L. Egg Plant. The crinkle virus complex, or either of its constituent viruses, did not attack this plant.

LEGUMINOSAE

Vigna sinensis(L.) Endl. Cowpea. Using several varieties of cowpeas and carborandum dust to facilitate inoculation I was unable to induce any infection with the crinkle virus complex. Neither the X virus component nor the A virus component would produce infection in these plants. Using cowpeas var. Black Eye, I made particular efforts to promote an infection with the complex, but found my efforts of no avail. Should the complex have been rugose mosaic, some in-

fections would have been expected from the Y virus. Chester(2) describes the Y virus as being definitely capable of producing red local necrotic lesions on cowpea var. Black Eye.

Phaseolus vulgaris L. French Bean. The crinkle virus complex, or either of its virus components, produced no infection in these plants.

CRUCIFERAE

Brassica oleracea L. Cabbage. The complex, or either of its components, did not infect this species.

B. Separation and Analysis of The Crinkle-Mosaic Virus Complex

Transfers of the composite virus were made to Potato 41956, the X-virus immune variety developed by the United States Department of Agriculture. It is important to use carborundum dust to facilitate the sap-inoculations. Potato 41956 eliminates the X virus from the complex, carrying the A virus in a masked condition. It was my experience to find no difficulty in sap-transmission of the A virus to Potato 41956. The detection of the presence of the A virus will be discussed among the next few topics. Simultaneously, transfers of the composite virus were made to Datura stramonium L., an A virus immune plant. Datura stramonium took the X virus readily, and eliminated the A virus. Potato 41956 and Datura were shown to have divided the complex by testing them for the crinkle complex with certain differential hosts mentioned in the preceding topic. Thus we

have the X virus in *Datura* and the A virus in Potato 41956.

THE A VIRUS COMPONENT. This component is a mild strain of the A virus, and when not coupled with the X virus is apparently powerless to produce symptoms in any tested host. This strain of the A virus produces masked infections in Potato 41956 and in the following plants:

Nicotiana tabacum L. Tobacco var. Turkish

Nicotiana glutinosa L.

Petunia hybrida Vilm. Garden Petunia

Lycopersicon esculentum Mill. Tomato.

It is interesting to note that the ordinary strains of the A and Y viruses will produce vein-banding symptoms in the above plants (Smith 29 and Dykstra 7), and in this respect are very similar. However, the only convenient way to detect the masked presence of this strain of the A virus in these plants is to add the X virus to it, the X virus also being a masked-symptom strain in the above plants when carried alone. Moreover, by re-combining the X virus with the A virus in the above plants, striking, characteristic symptoms of the original crinkle-mosaic virus complex can be obtained. These symptoms have already been described. The A virus is sap-transmissible with difficulty to commercial potato varieties. I was not able to transmit the virus to Capsicum annuum L., bell pepper, by sap-inoculation methods. In this respect, the A virus differs markedly from the Y virus which is sap-transmissible to peppers (Dykstra 7).

THE X VIRUS COMPONENT. The symptoms on Datura stramonium L.

are quite characteristic of the X virus. Here there is the typical pepper-and-salt mottle becoming more pronounced in the upper leaves. On Capsicum annuum L., the reaction in the plant is also characteristic of the X virus. Systemic chlorosis interspersed with small necrotic lesions appears on the leaves of this plant. This strain of the X virus produces masked infections in the following hosts:

Nicotiana tabacum L. Tobacco var. Turkish

Nicotiana glutinosa L.

Lycopersicon esculentum Mill. Tomato

Petunia hybrida Vilm. Garden Petunia.

C. The A Virus Component of Crinkle Mosaic
versus The Y Virus Component of Rugose Mosaic

At this point it is well to summarize the information leading to the identification of the virus as the A virus component of crinkle mosaic rather than the Y virus component of rugose mosaic. (1) The A virus is sap-transmissible only with difficulty to commercial varieties of potatoes, the percentage of infections being low. Quite in contrast, the Y virus is readily and efficiently sap-transmissible to commercial potato varieties, causing rugose mosaic due to the ubiquitous nature of the X virus (Dykstra 7). (2) The A virus in association with the X virus in potatoes (crinkle mosaic) produces a mild mosaic with slight downward curling of the leaves. There is no necrosis or dropping of the leaves and the plants are not badly harmed by the infection. By way of

contrast, when the Y virus is in association with the X virus (rugose mosaic), very severe symptoms frequently result in potatoes. The symptoms consist of a distinct mosaic in the leaves, and the leaves become ruffled. Necrosis sets in along the veins enlarging into prominent necrotic areas; eventually the lower leaves die and fall (McKay and Dykstra 21). (3) I was unable to infect Capsicum annuum L. with the A virus. In contrast, the Y virus is sap-inoculable to peppers producing a banding of the veins which changes to a mottling (Dykstra 7). (4) The A virus and the Y virus have a characteristic in common in that neither can be transmitted by mechanical inoculation to Datura stramonium L. (5) Although I made numerous attempts, using sap-inoculation methods facilitated by carborundum powder, I was not able to induce any type of infection with the A virus in the species, Vigna sinensis (L.) Endl., cowpea var. Black Eye. I repeated this inoculation using several other varieties of cowpeas, with no results. In contrast, the Y virus following sap-inoculation produces pronounced red necrotic lesions on the leaves of cowpeas var. Black Eye. (Chester 2).

D. Synthesis of The Crinkle-Mosaic Virus Complex

1. Synthesis in Nicotiana glutinosa L.

ADDING THE X VIRUS TO THE A VIRUS. I selected five healthy young N. glutinosa plants for this part of the experiment. Each virus by itself is masked in this species. Several N. glutinosa plants carrying the X virus and the A virus separately were set aside as controls. Transfers of the A virus were made

from five respective Potato 41956 plants to the five selected healthy young N. glutinosa plants. Four weeks later, the X virus from Datura stramonium L. was added to these same plants. Typical crinkle-mosaic virus complex symptoms appeared in one of the plants in three weeks; in seven weeks two more of the plants showed typical symptoms. Two out of the five plants remained with atypical symptoms. At a later date, I repeated this experiment a second time, using five N. glutinosa plants. In two weeks, typical crinkle-mosaic virus complex symptoms appeared in three of the plants, and in three weeks typical symptoms appeared in all five of the plants.

ADDING THE A VIRUS TO THE X VIRUS. I selected four young healthy plants. To these I transferred the X virus from Datura stramonium L. Three weeks later, I added to these plants the A virus from Potato 41956. All four of the N. glutinosa plants showed typical crinkle virus complex symptoms within three weeks.

MIXING X AND A VIRUSES. Here I used two N. glutinosa plants. I crushed host leaves of the X virus and host leaves of the A virus together in a mortar. I rubbed the mixture on the leaves of the N. glutinosa plants with pot labels. Typical symptoms of the complex appeared on the plants in two weeks.

2. Synthesis In Nicotiana tabacum L.

In the case of tobacco var. Turkish, I used four plants. First the A virus was inoculated into these plants, then after a lapse of three weeks, the X virus was added. In approximately three weeks, the X virus was added. In approximately three weeks,

all but one of the plants manifested quite typical symptoms of the crinkle-mosaic virus complex.

I mixed viruses A and X at the outset, using three N. tabacum plants, and obtained the usual composite symptoms in two weeks.

3. Synthesis In Petunia hybrida Vilm

In these plants, the two viruses when added in delayed sequence do not evidence symptoms of the complex for about three months. Setting aside for controls several plants carrying the A and X viruses separately, transfers of the A virus from Potato 41956 were made to three petunias. One month later I added the X virus. After a prolonged period of time, some three months, typical crinkle-mosaic virus complex symptoms appeared in the three plants.

4. Synthesis In Lycopersicon esculentum Mill.

Selecting two young healthy tomato plants, I made transfers of the A virus from Potato 41956. In three weeks, I added the X virus from Datura stramonium L. Composite symptoms appeared in both plants in two weeks.

Potato Crinkle-Mosaic Virus Complex

Explanations to Plate V

- A. A healthy petunia plant.
- B. A petunia infected with the crinkle-mosaic virus complex.

Explanations to Plate VI

- A. Leaf-print from leaf of healthy Nicotiana glutinosa L.
- B. Leaf-print from leaf of Nicotiana glutinosa L. infected with the crinkle-mosaic virus complex.

Explanations to Plate VII

- A. Synthetic crinkle-mosaic virus complex in Nicotiana glutinosa L.
- B. Same plant from top view.

Explanations to Plate VIII

- A. Crinkle-mosaic virus complex in petunia. Note the brilliant diffuse mottling.
- B. Synthetic crinkle-mosaic virus complex in Nicotiana glutinosa L. Note the crisped leaves hanging to the stalk.

Plate V



A.



B.

Plate VII



A.



B.

Plate VIII



A.



B.

VI. Cowpea Mosaic Virus

With the increasing use of cowpeas in soil improvement programs, cowpea mosaic is becoming an important factor in Oklahoma production. Chester(5) states that cowpea mosaic first attracted attention in this state in the experiment station plantings of Oklahoma A.&M. College in 1937, where it had become quite serious. In 1939, the disease was found frequently in commercial fields of cowpeas, with losses as high as 30 per cent in some cases(5).

A mosaic of cowpeas was reported as common in Arkansas in 1921(Elliott 9), but there is no evidence pro or con as to this virus being the same as the cowpea mosaic virus of Oklahoma.

The cowpea mosaic virus is sap-transmissible to cowpeas and to certain members of Solanaceae. The cowpea mosaic virus differs from the majority of legume viruses in being inoculable to solanaceous plants. On the other hand, like certain of the other legume viruses, the cowpea mosaic virus is seed-transmissible in the natural host. The virus is 5 per cent transmissible by the seed from infected cowpea plants(Chester 4). From an original 5 per cent seedling infection, 100 per cent infection may result in a field in a few weeks, evidently due to efficient insect transmission(4). The insect vector has not been determined(Chester 5). I have observed natural infections of the virus in Nicotiana glutinosa L. plants grown under greenhouse conditions. The virus causes systemic infection

in all known hosts. It is possible that the cowpea mosaic virus may be a strain of the common cucumber mosaic virus (Marmor cucumeris var. vulgare Holmes), although host reactions and the host range are somewhat the contrary.

The following is an account of my infection experiments with the cowpea mosaic virus using sap-inoculation methods.

SOLANACEAE

Nicotiana glutinosa L. Using young plants, symptoms begin ten days after inoculation as a distinct vein-clearing in the leaves. This symptom soon graduates into a diffuse blistery yellow mottling which may or may not be accompanied by scattered areas of necrosis, particularly at the edges of the leaves. The leaves curl downward and are usually much reduced in size. Occasionally, in very vigorous plants, the symptoms, except for a ruffled downward curling of the leaves, become almost completely masked, cropping out at intervals in some of the uppermost leaves. Smith(29) describes a somewhat similar disease caused by the cucumber mosaic virus in this species.

Nicotiana tabacum L. Tobacco var. Turkish. Following inoculation, the symptoms begin as a pronounced vein-clearing in the leaves of young plants. As the plants grow, this soon changes to a mild mosaic symptom which may persist or eventually disappear so that the virus is carried in a masked condition. Smith(29) describes the cucumber mosaic virus as producing a mottle and leaf malformation in this species.

Capsicum annuum L. Bell Pepper var. Windsor A. A shiny

yellowish mottle is produced in this plant by the cowpea mosaic virus. The leaves become variously distorted, and the plants are markedly dwarfed. Usually, there is no necrosis. The cucumber mosaic virus produces similar symptoms in this species (Smith 29).

Solanum tuberosum L. Irish Potato. I was not able to infect this species with the virus.

Datura stramonium L. Jimson Weed. It was not possible for me to infect this species with the virus. According to Smith(29), Datura stramonium is a good differential host for the type strain of the cucumber mosaic virus which produces a ring-chlorosis in these plants. It seems logical that certain allied strains of the cucumber mosaic virus would also be transmissible to this species.

Solanum melongena L. Egg Plant. Unlike the type strain of the cucumber mosaic virus, cowpea mosaic virus was not, by my efforts, capable of attacking these plants.

Lycopersicon esculentum Mill. Tomato. I found the cowpea mosaic virus incapable of producing infection in tomatoes. Smith (29) describes the cucumber mosaic virus as producing mottling and "fern leaf" symptoms in the leaves of these plants.

Petunia hybrida Vilm. Garden Petunia. The cowpea mosaic virus produces a mild mosaic with no leaf distortion or necrosis when inoculations are made to petunias. The cucumber mosaic virus produces necrotic primary lesions followed by systemic chlorosis and stunting in petunias(Smith 29).

LEGUMINOSAE

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Vigna sinensis(L.) Endl. Cowpea. The virus is sap-transmissible to varieties of this species with considerable difficulty. It is important to use carborundum powder to facilitate inoculation. The virus causes a very severe disease in cowpeas. The disease begins as a brilliant yellow mosaic in the young leaves. The succeeding leaves have a striking veinal mosaic which is accompanied by a severe downward crinkling. The plants are badly dwarfed, become decumbent, and the yield is greatly reduced below normal. Often the plants are short lived, but may survive indefinitely. Price(25), on using several varieties of cowpeas, found that the various strains of the cucumber mosaic virus produce only a localized infection of circular red necrotic lesions three or four days after inoculation. Price(25) has also isolated a yellow strain of the virus which does become systemic in the cowpea. This strain produces yellow lesions which are not necrotic, but which have a necrotic periphery. Systemic infection takes the form of a green and yellow mottle in the subsequent uninoculated leaves accompanied by severe stunting and distortion.

Cowpea var. Black Eye. I was not successful in transmitting the cowpea mosaic virus to this variety by sap-inoculation methods. Nevertheless, this variety is probably not immune, especially when insect transmission is involved. It is interesting to note that Price(25) describes cucumber mosaic virus and its allied strains, with the exception of the yellow mottling strain mentioned in the above paragraph, as giving a characteristic

reaction of red local necrotic lesions on cowpea var. Black Eye.

Phaseolus vulgaris L. French Bean. I was unable to infect this species with the cowpea mosaic virus.

CUCURBITACEAE

Cucumis sativa L. Cucumber. Using several varieties of this species, I could not induce any infections with the cowpea mosaic virus. This is a natural host for the cucumber mosaic virus, and it is reasonable to assume that any of the closely allied strains of the virus would infect cucumbers through sap-inoculation methods.

Cucurbita maxima Duchesne. Squash. The virus caused no infection, when attempts were made to inoculate these plants. This is a common host for the cucumber mosaic virus and certain of its allied strains.

CRUCIFERAE

Brassica oleracea L. Cabbage. The results on attempting to infect this species were negative.

Cowpea Mosaic Virus

Explanations to Plate IX

- A. The cowpea mosaic virus in cowpea.
- B. A healthy cowpea plant.

Explanations to Plate X

- A. The cowpea mosaic virus in cowpea.
- B. The cowpea mosaic virus in Nicotiana glutinosa L.
Compare with Plate XIII A.

Explanations to Plate XI

- A. The cowpea mosaic virus in pepper.
- B. Top view of same plant. Compare with Plate XII A.

Explanations to Plate XII

- A. Healthy pepper plants.
- B. Cowpea mosaic virus in young Nicotiana glutinosa L.
plants.

Explanations to Plate XIII

- A. A healthy Nicotiana glutinosa L. plant.
- B. The cowpea mosaic virus in Nicotiana glutinosa L.

Explanations to Plate XIV

- A. A leaf-print from a leaf of a healthy tobacco plant.
- B. Leaf-print from a leaf of a tobacco plant infected
with the cowpea mosaic virus.

Plate IX



A.



B.

Plate X

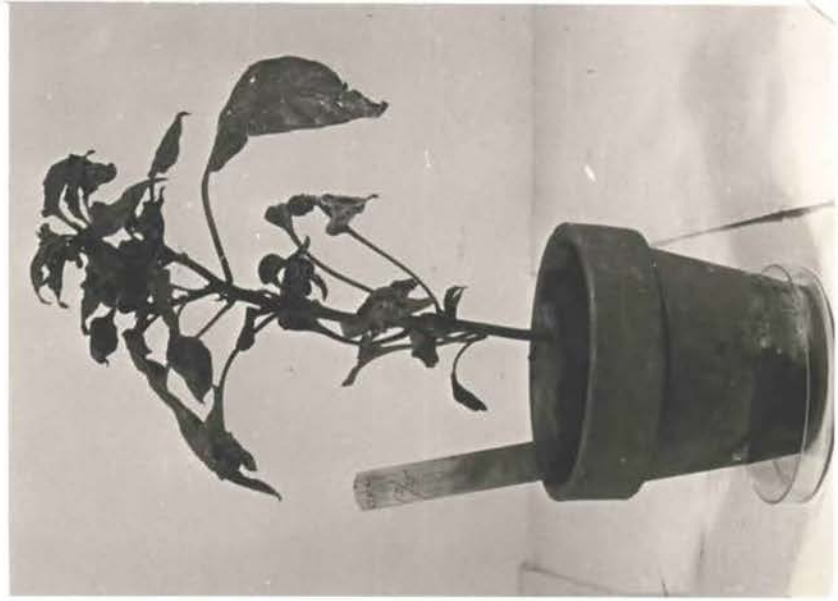


A.



B.

Plate XI



A.



B.

Plate XII



A.



B.

Plate XIII

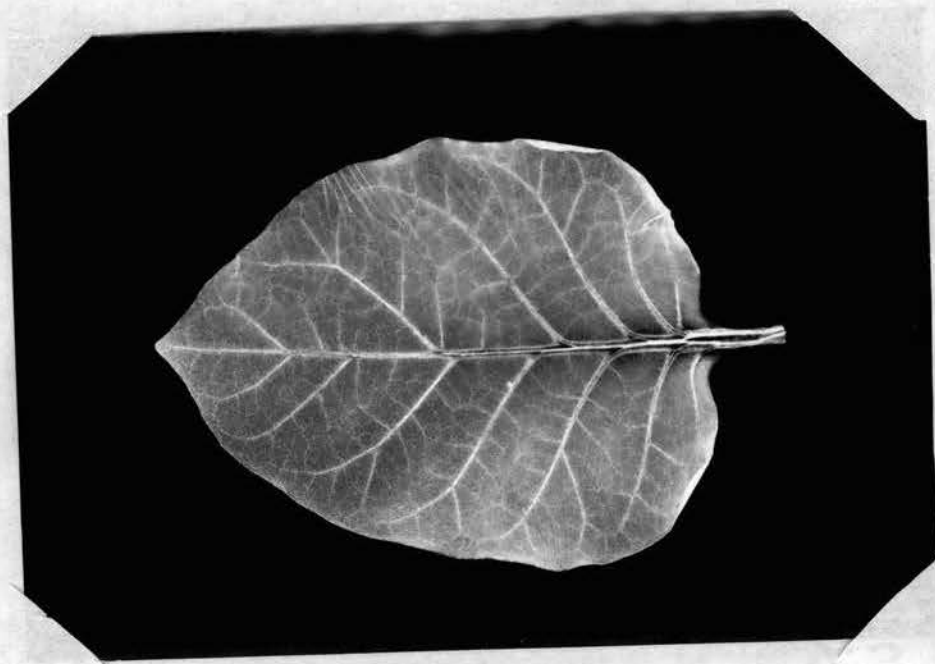


A.

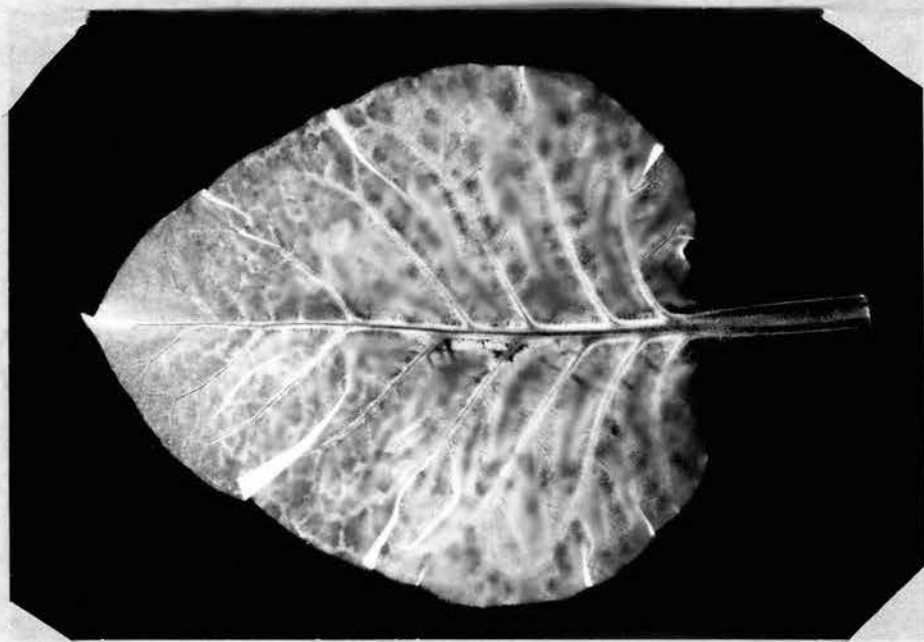


B.

Plate XIV



A.



B.

VII. Petunia Mosaic Virus

Garden petunias in Oklahoma show a surprisingly high incidence of mosaic due to a certain virus which I have isolated from petunias growing in both gardens and greenhouses. The number of infections reaches as high as 30 per cent in some outdoor flower plots. I have observed 100 per cent infection in petunias grown in greenhouses, where the plants were propagated vegetatively by cuttings.

I have found this petunia mosaic virus to be identical with a virus which Chester(5) has found causing natural infections in field cowpeas, and has since been kept growing in culture plants in the experimental greenhouse of this institution. Although the virus produces a systemic mild or green mosaic in cowpeas, Chester(5) considered the disease to be due to a strain of the cucumber mosaic virus. I have observed natural infections of the petunia mosaic virus under greenhouse conditions in tobacco plants var. Turkish and in Nicotiana glutinosa L.

The identity of the virus is uncertain. Apparently, no one has undertaken the identification of the virus or attempted to describe its host reactions and host range. Chester(3) reported the cucumber mosaic virus as causing 100 per cent infection in petunias in a greenhouse in Ardmore, Oklahoma. It is known that the cucumber mosaic virus and the tobacco mosaic virus do occur rather frequently in petunias. However, my experiments indicate that the petunia mosaic virus which I have studied is neither a strain of the cucumber mosaic virus nor a strain of

the tobacco mosaic virus.

Matsumoto and Hirane(20), in 1939, working in Formosa, Japan, isolated a virus from petunias which caused systemic mottle when inoculated to petunias and Nicotiana spp. They did serological work with the virus which indicated that it is not related to the cucumber mosaic virus. There is insufficient information as to whether or not the virus is the same as the petunia mosaic virus herein reported.

The petunia mosaic virus causes systemic infection in all known hosts. It is sap-transmissible to cowpeas, and to certain members of Solanaceae. The insect vector has not been determined.

SOLANACEAE

Nicotiana glutinosa L. The petunia mosaic virus produces very characteristic symptoms in this species. The leaves become irregularly mottled and strap-shaped to thread-like. This "strap leaf" or "thread leaf" symptom is especially pronounced in the upper leaves. There is no necrosis. The plants become dwarfed and spindling. According to Smith(29), the cucumber mosaic virus produces a severe blistery mottling which may be accompanied by some necrosis in the leaves of this species.

Nicotiana tabacum L. Tobacco var. Turkish. The symptoms begin in young plants as a mild mosaic. This mosaic soon differentiates into a blistery distortion in some of the leaves. Occasionally, the symptoms become almost masked cropping out again in some of the new leaves. Those leaves that become disfigured may be round, strap-shaped, fiddle-shaped, obtuse, spatula-shaped,

or double. The most common symptom is the production of strap-shaped leaves. The plants are not badly dwarfed. There is no necrosis. Smith(29) describes the cucumber mosaic virus as producing a mottle and leaf malformation in this species.

Petunia hybrida Vilm. Garden Petunia. In petunias the symptoms take the form of a blistery green and yellow mottle in all of the leaves. The leaves become ruffled and variously distorted. There is no necrosis or flower symptom. The plants are markedly dwarfed. Smith(29) describes the cucumber mosaic virus as producing primary necrotic lesions followed by systemic chlorosis and stunting in petunias.

Capsicum annuum L. Bell Pepper var. Windsor A. The petunia mosaic virus causes a dull grayish green mottle and considerable distortion in the leaves of these plants. There is no necrosis. The plants are badly dwarfed. The cucumber mosaic virus produces a somewhat similar condition in this species(Smith 29).

Datura stramonium L. Jimson Weed. The petunia mosaic virus produces a type of ring-chlorosis in this species. The picture is a coarse green network against a yellow background in the leaves of these plants. Smith(29) describes a similar condition caused by the cucumber mosaic virus in this species. I find the petunia mosaic virus difficult to transmit to this species.

Lycopersicon esculentum Mill. Tomato. The petunia mosaic virus causes a mild chlorosis and a unique type of leaf malformation in tomato plants. However, the virus is difficult to transmit to this species. The outstanding symptom caused by the virus is the malformation which results in the compound leaves.

The leaflets of the uppermost compound leaves become thread-like and twisted. In the older leaves the leaflets are very abnormally narrow and irregular in shape. The leaflets are thinner than usual and have a marked tendency to curl up in spirals or twist round in a corkscrew fashion. Smith(29) describes a somewhat similar disease caused by the cucumber mosaic virus in tomato, which is known as "fern leaf."

Solanum tuberosum L. Irish Potato. I was unable to induce infection with the petunia mosaic virus in this species.

Solanum melongena L. Egg Plant. I could not accomplish any infection with the virus in egg plant.

LECUINOSAE

Vigna sinensis(L.) Endl. Cowpea. The petunia mosaic virus is sap-transmissible to varieties of cowpeas with difficulty. It is important to use carborundum powder to facilitate inoculation. The infection starts as a vein-clearing and soon develops into a systemic mild mosaic. I was not successful in attempts to infect the cowpea var. Black Eye, although this variety is probably not immune, especially when insect transmission is involved. Price(25) describes the cucumber mosaic virus and several of its strains as producing red local necrotic lesions on varieties of cowpeas including cowpeas var. Black Eye. Price(25) has isolated a yellow strain of the cucumber mosaic virus which does become systemic in cowpeas. This strain causes a yellow mottle, severe stunting and distortion.

Phaseolus vulgaris L. French Bean. I was not able to infect this species with the petunia mosaic virus.

CUCURBITACEAE

Cucumis sativa L. Cucumber. My results indicate that the petunia mosaic virus is not sap-transmissible to cucumber varieties. The plants were tested for masked infection. It is reasonable to assume that the cucumber mosaic virus and its closely allied strains would be transmissible to cucumbers.

Cucurbita maxima Duchesne. Squash. The virus is evidently not sap-inoculable in this species. The plants were tested for masked infection. This is a common host for the cucumber mosaic virus and certain of its allied strains.

The most substantial evidence to the effect that the petunia mosaic virus is distinct from the cucumber mosaic virus is my inability to transmit the petunia mosaic virus to Cucurbitaceae.

CRUCIFERAE

Brassica oleracea L. Cabbage. I was not able to transmit the virus to this species by sap-inoculation.

The petunia mosaic virus may be easily differentiated from the cowpea mosaic virus by the reactions of the respective viruses on N. glutinosa and tobacco. The petunia mosaic virus produces narrow strap-like leaves and blistery mottling in these two species. The "strap leaf" symptom is more pronounced in N. glutinosa. On the other hand, the cowpea mosaic virus produces in N. glutinosa a blistery mottling, downward curling of the leaves, and frequently some necrosis at the tips and edges of the leaves. In tobacco, the cowpea mosaic virus produces a mild mosaic which may later become masked; there is no

distortion. Furthermore, the petunia mosaic virus is transmissible to tomato, whereas the cowpea mosaic virus evidently is not. Moreover, the petunia mosaic virus is transmissible to jimson weed, whereas this species is evidently not a host for the cowpea mosaic virus.

Petunia Mosaic Virus

Explanations to Plate XV

- A. The petunia mosaic virus in petunias.
- B. The petunia mosaic virus in pepper.

Explanations to Plate XVI

- A. Side view of the petunia mosaic virus in Nicotiana glutinosa L. Note the narrow strap-like leaves. Compare with Plate XVIII B.
- B. Top view of the petunia mosaic virus in Nicotiana glutinosa L. Note the strap-like and thread-like leaves. Compare with Plate XVIII B.

Explanations to Plate XVII

- A. The petunia mosaic virus in tobacco. Note the narrow blistered leaves. Compare with Plate XVIII A.
- B. A leaf print made from a leaf of a tobacco plant infected with the petunia mosaic virus.

Explanations to Plate XVIII

- A. A healthy tobacco plant.
- B. A healthy Nicotiana glutinosa L. plant.

Explanations to Plate XIX

- A. Top view of a healthy tomato plant.
- B. Top view of a tomato plant infected with the petunia mosaic virus. Note the pendulous attitude of the compound leaves, and the narrow leaflets.

Plate XV



A.



B.

Plate XVI



A.



B.

Plate XVII



A.



B.

Plate XVIII



A.



B.

Plate XIX



A.



B.

SUMMARY

1. The potato aucuba mosaic virus was transmitted by sap-inoculation to Irish potato, tomato, Nicotiana glutinosa L., petunias, tobacco, peppers, and jimson weed. The virus produces a masked infection in tobacco and jimson weed. In pepper plants the virus produces systemic necrosis and death in a few days. In the other hosts mentioned, the virus produces systemic mottling of various types. N. glutinosa and peppers are useful indicator plants for this virus because of their characteristic reactions.
2. The tobacco mosaic virus was transmitted by sap-inoculation to tomato, tobacco, Nicotiana glutinosa L., peppers, jimson weed, egg plant, and petunias. The virus produces systemic mottling in tomato, tobacco, and petunias. The virus may produce systemic mottling, systemic necrosis, local necrotic lesions, or various combinations of these three types of reactions in peppers. The virus produces local necrotic lesions in N. glutinosa, jimson weed, and egg plant. The best differential host plant for the tobacco mosaic virus is N. glutinosa.
3. The tomato streak virus or single-virus streak strain of the tobacco mosaic virus was differentiated from the "streak" complex of tomato which is composed of the X virus of potato in association with the ordinary tobacco mosaic virus by

making transfers to Nicotiana glutinosa L. On N. glutinosa the virus produced only large local necrotic lesions with no tendency toward systemic spread. The leaves subsequently formed on these N. glutinosa plants were tested for masked infection of the X virus by attempting transfers to jimson weed plants. The jimson weed plants gave no reaction, indicating that the streak symptoms on the tomato plants were due to the single-virus streak strain of the tobacco mosaic virus. Although common in the British Isles and Canada, the virus has not been heretofore recorded in the United States. It causes mottling and distortion in tobacco Var. Turkish.

4. The strain of the potato X virus common in this state is masked in Irish potato, tomato, petunias, tobacco, and Nicotiana glutinosa L. Peppers are good indicator plants for the virus, although the symptoms are variable. The jimson weed is also a convenient indicator plant for the virus.
5. A composite virus disease on potato was found to be due to the crinkle-mosaic virus complex(X and A viruses in association) rather than the rugose-mosaic virus complex(X and Y viruses in association). The crinkle complex was carried to a number of different host plants making detailed study of the respective host reactions. Also, the constituent viruses of the complex were separated by means of the X-virus immune clone, Potato 41956, and the jimson weed, and each virus was studied independently. Furthermore, one virus was

added to the other in delayed sequence in various hosts, thereby synthesizing the crinkle-mosaic virus complex in its original form.

6. Little has been recorded of the cowpea mosaic virus common in this state. The virus is apparently undescribed. Detailed study was made of the host reactions and host range of the virus. The results indicate that the cowpea mosaic virus is not a strain of the cucumber mosaic virus. It differs from the majority of the legume viruses in being transmissible to Solanaceae. Evidently, the virus is not transmissible to Cucurbitaceae.
7. The petunia mosaic virus apparently has not been hitherto recorded or described. It was submitted to detailed study in regard to its host reactions and host range. The results indicate that the virus is not a strain of the cucumber mosaic virus. It is readily sap-transmissible to Solanaceae, and it produces systemic mottle in cowpeas. Evidently, the petunia mosaic virus is not transmissible to Cucurbitaceae.

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