A TEXTBOOK OF PLANT VIRUS DISEASES

By

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PREFACE TO SECOND EDITION

SINCE the first edition of this book was published the number of known plant viruses has increased greatly, and in the present edition over 300 separate viruses, not counting strains, are dealt with.

The method of presenting each virus, its properties and the diseases it causes, etc., is similar to that in the first edition, but the arrangement is different. The controversial question of the nomenclature of plant viruses has been avoided by using only the English popular names. These are arranged in alphabetical order under the names of the *viruses* and not the *virus diseases*. This avoids much needless repetition because one virus may cause many diseases.

Since the viruses are arranged in alphabetical order, and since all the references are collected at the end in the Bibliography, also in alphabetical order, there is no need for either a subject or author index. However, in order to facilitate finding a given virus by any of the names by which it may be known an Index of Synonyms is included. In addition, in the text of the book, careful cross-references are inserted whereby it is possible to find a particular virus under its alternative names. For example, Passion Fruit Woodiness and Pineapple Yellow Spot are listed in their correct alphabetical order, but the reader is referred to the viruses of cucumber mosaic and tomato spotted wilt respectively, since these viruses are now known to be the cause of the diseases in question. In some cases the name of the insect vector given may not be the latest one, but I have tried so far as I could to follow the ever-changing nomenclature which so handicaps the study of entomology.

I am greatly indebted to many friends and colleagues with whom I have discussed this book, but the final arrangement and interpretation of the virus relationships are my responsibility.

I am especially grateful to Dr. I. Harpaz for much assistance in reading the proofs; Miss M. E. Short kindly helped in checking the references; and Mr. Simon Frey prepared and mounted the plates.

I am also grateful to many friends who lent me either photographic prints or blocks for the illustrations: the names of these authors are given under each borrowed illustration.

Acknowledgment is due to the East Malling Research Station for the blocks of Figs. 4, 5, 6, 36, 37, 56, 57, 58, 59, 62, 63, 64, 65 and 68; to the Editors of the *Journal of the Royal Agricultural Society* for the blocks of Figs. 8 and 71; to the Editors of the *Annals of Applied Biology* and the Cambridge University Press for the block of Fig. 73 and to the

Editors of the *Journal of Horticultural Science* for permission to reproduce Figs. 59, 64, A, B and C and 65. Finally, I would once more acknowledge my indebtedness to the *Review of Applied Mycology* for the great assistance rendered in reviewing the world's literature on plant virus diseases.

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CAMBRIDGE.

PUBLISHERS' NOTE

As the arrangement of the causative viruses in alphabetical order obviates the need for a Table of Contents the reader's attention is drawn to the list of addenda on pages 641–645 and to the Index of Synonyms commencing on page 647.

ABACA BUNCHY-TOP VIRUS

SYNONYMS : *Musa Virus* 2, Smith ; *Marmor abacá*, Holmes.

The Virus and its Transmission. There has been some question in the past as to whether this virus was not the same as that causing bunchy-top of bananas, but in view of the failure to infect bananas experimentally with the virus from Manila hemp, the two viruses are treated here as separate entities, but the possibility must still be considered that the two viruses are closely related (Ocfemia and Buhay, 1934).

Abacá bunchy-top virus is not transmissible by mechanical methods of inoculation and there is in consequence no information on its properties. The insect vector is the aphid, *Pentalonia nigronervosa* Coq. The shortest time required by adult aphids to obtain the virus is twelve hours. In addition to this time, between twenty-four and forty-eight hours must elapse before the insects are capable of causing infection on healthy seedlings, that is to say, there is a delay in the development of infective power within the insect of twenty-four to forty-eight hours. The incubation period of the disease in fast-growing seedlings is shorter than in slow-growing seedlings, thirty to thirty-two days as compared to sixty to seventy-two days.

Disease caused by Abacá Bunchy-top Virus

Musaceæ

Musa textilis Née. Abacá or Manila hemp. *Bunchy-top.* The general symptoms of bunchy-top in abacá include reduction in leaf size and narrowing of the blade, sometimes down to a few centimetres from the midrib ; irregular and more rapid unfurling of young rolled leaves ; darkening of the green colour in the leaf sheaths comprising the trunk ; shortening of the leaf sheaths so as to produce congestion and rosetting at the crown of the plant and degeneration of the root system (Wardlaw, 1935).

Ocfemia (1930) describes the leaf symptoms as follows : delicate, thin and transparent, membrane-like areas of varying shapes and sizes may develop on the thin chlorotic portions of the youngest leaf either before it unfurls or immediately after. In transmitted light the main veins of leaves showing the symptoms may be seen as transparent lines. These transparent streaks are continuous on the main veins from the midrib to the margin and about $\frac{1}{2}$ mm. in width, but broken into 1 to 5 mm. dashes on the secondary veins. On both surfaces of the leaves these dashes appear yellow. If the leaf is furled the streaks sometimes appear water-soaked. The transparency of the primary and sometimes secondary veins is always to be noticed in aphid transmission of abacá bunchy-top. Dark green streaks, varying from mere dots to

lines several millimetres long, or starting from the midrib and disappearing as they reach the yellowed borders, are of great diagnostic value in some varities of abacá. The dark green lines are about $\frac{1}{2}$ mm. wide and are occasionally present on the midrib, petiole and leaf blades.

Host Range. Abacá bunchy-top virus appears to be confined to *Musa textilis* and its different varieties and is not transmissible to the banana.

Geographical Distribution. The only record of bunchy-top of abaca seems to be from the Philippine Islands, where the disease is serious and widespread.

Control. The methods recommended for the control of banana bunchy-top are also applicable in the case of bunchy-top of abaca. Ocfemia considers that if infected land is rested for nine to twelve months, if only suckers known to be virus-free are used, and if young plantations are regularly inspected, it should be possible to rehabilitate the abacá industry in areas where the disease is serious.

ABACA MOSAIC VIRUS

See Cucumber Mosaic Virus, p. 208.

ABUTILON MOSAIC VIRUS

SYNONYMS : Abutilon Infectious Variegation Virus (Baur) ; *Abutilon Virus* 1, *Marmor abutilon* H.

The Virus and its Transmission. The virus is not sap-inoculable and there is no information on its properties. It can be transmitted by grafting and it appears to be also transmitted through the seed of certain species only ; notably some hybrids of *Abutilon* spp. (Keur, 1933).

For many years *Abutilon* mosaic was known as an " infectious variegation " and put in a category of its own. It has now, however, been shown (Orlando and Silberschmidt, 1946) that the insect vector is the whitefly, *Bemisia tabaci* (Genn.) and the reason why the virus in Europe was transmissible only by grafting was the absence of the specific insect vector. There is little information available on the relationship of virus and vector but a single individual, either male or female, is capable of infecting a plant. The female appears to be slightly more efficient in transmission than the male.

Diseases caused by Abutilon Mosaic Virus

Malvaceæ

Abutilon spp. The attractive bright yellow and green variegation in various species of *Abutilon* is well known and is the chief reason for the propagation of the species as an ornamental plant. There appear to be two types of symptoms, that occurring in *Abutilon thompsonii*,

A. mulleri and *A. megapotamicum variegatum* being the more intense. There seems to be no information as to whether these two types of symptoms are due to two distinct strains of the virus.

Abutilon plants sometimes recover from the disease, either wholly or in part, but such plants or parts of plants are susceptible to reinfection. The mottling tends to disappear if the plants are grown in darkness or subdued light. When variegated plants of *A. thompsonii* are kept in total darkness for varying periods of a few days to a fortnight there is no trace of variegation in the new foliage formed while the plants are in obscurity, and subsequently matured in the light. On the other hand, variegation occurs in the leaves which develop after the plants are restored to the light.

Host Range. In addition to the various species of *Abutilon*, already mentioned, the virus has been transmitted experimentally by means of the whitefly vector to *Abutilon striatum* var. *spurium* and *Sida rhombifolia* (Orlando and Silberschmidt, 1946). Owen (1946) has described mosaic diseases infecting a number of species of Malvaceæ in Trinidad, including *S. rhombifolia*. In the absence of further evidence, however, it is not possible to say whether the mosaic diseases described by Owen are due to *Abutilon* Mosaic virus.

In a recent paper, Costa (1955) has shown that the virus is transmissible by means of *B. tabaci* to *Phaseolus vulgaris*, *Glycine* (*Soja*) *Max*, *Althæa rosea*, *Hibiscus cannabinus*, *H. esculentus*, *Cyamopsis tetragonoloba*, *Nicandra physaloides*, ground nut, lentil, white lupin and potato. Furthermore, the virus occurs naturally in cotton in which it causes a mosaic disease. (See also Silberschmidt and Tommasi, 1956.)

Geographical Distribution. The virus occurs naturally in Brazil and probably in Trinidad. It has been sent all over the world in the " variegated " *Abutilon* spp. which are grown as ornamental plants.

ALFALFA DWARF DISEASE VIRUS

SYNONYMS : Lucerne dwarf disease virus ; virus of Pierce's disease of the grape ; virus of Anaheim disease ; *Medicago Virus* 3, Smith ; *Morsus suffodiens*, Holmes.

The Virus and its Transmission. The virus is not sap-inoculable but can be transmitted by grafting. The insect vectors are all Cicadellid leafhoppers belonging to the subfamily *Amblycephalinæ* ; the following species have been identified as vectors : *Draculacephala minerva* Ball, *Carneocephala fulgida* Nott., *C. triguttata* Nott., *Helochara delta* Oman, *Neokolla circellata* (Baker), *N. gothica* (Sign.), *N. confluens* (Uhler), *N. hieroglyphica* (Say), and *Cuerna occidentalis* (Oman and Beamer).

Freitag and Frazier (1954) have conducted tests to determine the percentage of leafhopper vectors that were carrying the virus under natural conditions in a number of different habitats. In these tests particular emphasis was placed on the three economically important

vectors, the green sharp-shooter, *Draeculacephala minerva*, Ball; the red-headed sharp-shooter, *Carneocephala fulgida* Nott; and the blue-green sharp-shooter, *Hordnia* (*Neokolla*) *circellata* (Baker). The results suggest that generally the virus occurs naturally wherever the three important vectors are found. Eleven of the fifteen species of leafhopper vectors tested for natural infectivity were found to be carrying the virus under natural conditions. Altogether twenty species of leafhoppers are known to be capable of acting as vectors of the alfalfa dwarf disease virus.

Diseases caused by Alfalfa Dwarf Disease Virus

Leguminosæ

Medicago sativa. Alfalfa, Lucerne. Dwarf Disease. The earliest stages of the dwarf disease cannot be detected by the symptoms above ground, since the disease is already well advanced in the root before it becomes evident in the top. The first signs of the disease in the tops are a shortening of the stems and a slight reduction in the size of the leaves. Blossoming is often retarded or inhibited. Usually no chlorosis or other colour change occurs in the leaves or stems until the last few stems die. In the final stages of the disease only one or at most a very few stems are produced, and these reach an ultimate height of only a few inches. These stems remain upright and for the most part turgid until death ensues. Not infrequently the leaves of diseased plants appear to be of a darker green than those of healthy plants. The leaves of affected plants are not mottled, crinkled or deformed, although commonly they are somewhat rounded at their apices, resembling more closely the basal than the terminal leaves of healthy plants. The stems of diseased plants are reduced more or less uniformly in size.

Root Symptoms. The first evidence of the disease in the root is a small yellow streak in the wood, apparent only when the bark is removed. This streak, which varies in size, may occur anywhere in the root, especially in the upper foot of the taproot. As the disease develops the yellowing spreads until it eventually involves the entire circumference of the root. When the root is cut across the yellow colour is found in the outermost part of the woody cylinder just beneath the bark. This discoloured tissue forms a definite ring or band which is narrow at first, but becomes wider as the disease develops, until at the time the plant dies the root is frequently discoloured throughout its entire diameter. The yellowing extends into the main divisions of the crown and into the base of the green stems, but does not penetrate very far into the latter (Weiner, 1931).

Vitaceæ

Vitis vinifera L. Grape Vine. Pierce's Disease of the Grape. In 1939 this disease was severe in the grape-growing district of California where losses ranged up to 30 per cent. of the vines. The symptoms are similar to those of the so-called California Vine Disease described by

Newton B. Pierce in 1892. The disease varies somewhat according to the variety. On the variety Emperor the leaves show a dark green vein-banding and a puckering of the tissue between the veins. The vines usually die the season following the first appearance of leaf symptoms. On the variety Ribier there are no distinct leaf symptoms, but the vines wilt and dry up in mid- and late summer, usually with a heavy crop. In early autumn most varieties show dying of the leaf margins and tissues between the large veins. In late summer some of the canes show a dying back from the tips and the unkilled portions of the cane mature only in irregular dark brown patches. The fruit often becomes soft and may shrivel and dry up (Hewitt, 1939).

Host Range. Under the synonym of Pierce's disease virus of grapes, Freitag (1951) has made a systematic study of susceptible plants using three species of leafhoppers in the experimental transmissions. The virus was transmitted to 75 species of plants belonging to twenty-three plant families. The new host plants discovered include Johnson grass, Bermuda grass, rye grass, timothy, canna, toyon, Scotch broom, Hubam clover, alsike clover, crimson clover, red clover, Ladino clover, carrot, periwinkle, mint, vetch and species of *Œnothera*, *Godetia*, *Hedera*, *Coprosoma*, *Sambucus*, *Lonicera*, *Symphoricarpos* and *Artemisia*. Thirty-six species of plants belonging to eighteen families were demonstrated to be naturally infected with the virus. These include Bermuda grass, Dallis grass, California blackberry, acacia, Boston ivy, rosemary, fuchsia, Ladino clover and species of *Sambucus*, *Eugenia*, *Artemisia*, and *Baccharis*. Symptoms of the disease developed on only a few species of plants. The great majority of plants susceptible to the virus were symptomless carriers. Thirteen species of legumes were experimentally infected and those, as would perhaps be expected, were among the few susceptible plants which developed symptoms of the virus.

The grasses are readily susceptible and twenty-two species were experimentally infected. Eight species were found naturally infected with the virus.

A species of sedge and nineteen species of weeds were susceptible. Sixteen species of plants grown as ornamental were experimentally infected. Nine species were found naturally infected.

Geographical Distribution. United States of America.

ALFALFA MOSAIC VIRUS

SYNONYMS : *Alfalfa Virus* 1, Pierce. *Medicago Virus* 2, Pierce. Zaumeyer and Wade ; *Marmor medicaginis*. H. *Marmor medicaginis*. H. var. *typicum*. Lucerne Mosaic Virus.

The Virus

Thermal Inactivation Point. There is a slight uncertainty in the literature as to the exact temperature at which the virus is inactivated and this is probably due to the fact that different strains of the virus

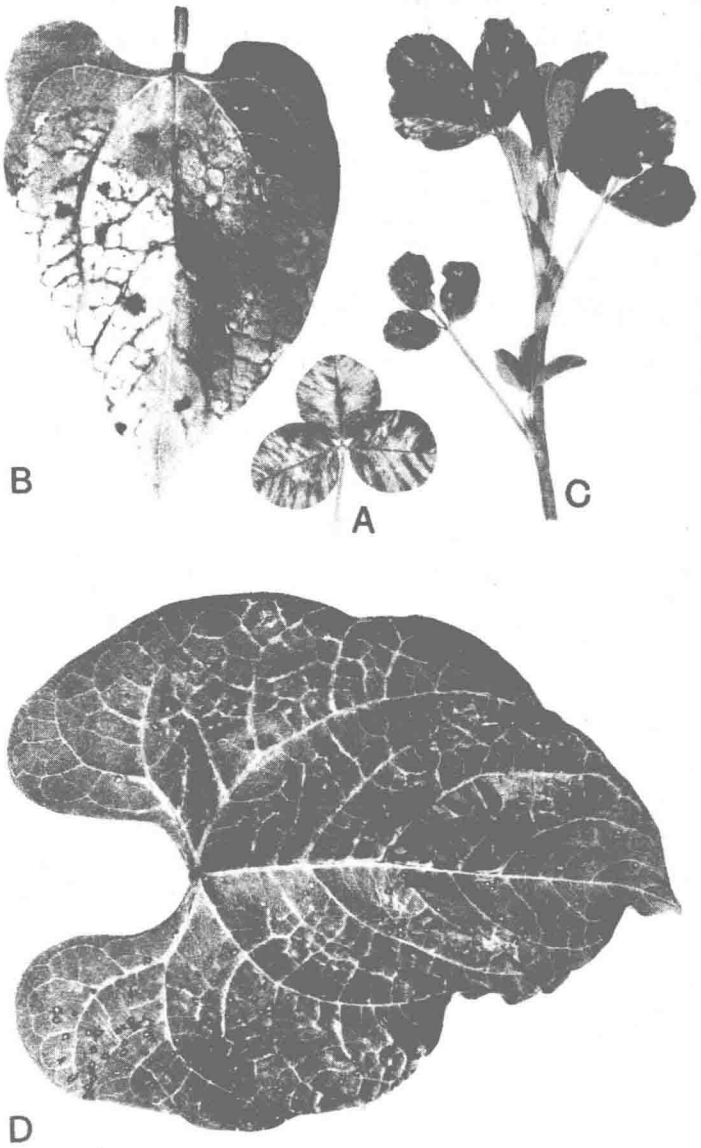


FIG. 1.

A. Pea mottle virus on white clover.
B. Local lesions caused by pea mottle virus on bean (*Phaseolus vulgaris*) var. Robust.
C. Alfalfa (lucerne) mosaic.
D. Local lesions caused by alfalfa mosaic virus on bean (*Phaseolus vulgaris*) var. Stringless Green Refugee.

(After Zaumeyer and Wade).

were used by different workers. The inactivation point, however, seems to be between 62° and 70° C. for ten-minute exposures.

Dilution End-point. Infectivity is lost at a dilution of about 1 : 2000.

Resistance to Ageing. According to Pierce the virus retains its infectivity in extracted sap for seven to nine days, and according to Zaumeyer and Wade, three to four days. Ross (1941) finds that the purified virus is fairly stable at 4° C., but is rapidly inactivated at room temperatures. It is much less stable in sap.

Other Properties of the Virus. Purified preparations of the virus contain 15 per cent. yeast nucleic acid and 0·65 per cent. sulphur. Sodium sulphite and sodium hydrosulphite inactivate the virus. It is also inactivated and hydrolysed by trypsin. The virus is apparently spherical in shape, with a specific gravity of 1·48, sedimentation constant 74×10^{-13}, molecular weight $2{\cdot}1 \times 10^{6}$ and has a diameter of 16·5 mμ. (Ross, 1941).

Transmission. The virus is sap-transmissible ; the insect vector is the aphid *Macrosiphum pisi* Kalt. Swenson (1952) has studied the aphid transmission of a strain of this virus. He found that it was transmitted most efficiently by *Aphis gossypii* and *Macrosiphum pisi*. It was also transmitted by *Aphis medicaginis*, *A. fabæ*, *Macrosiphum solanifolii* (= *euphorbiæ* Thomas) and *Myzus persicæ*. Six other aphid species failed to transmit it. The virus was shown to be of the non-persistent type.

Differential Hosts

Phaseolus vulgaris. French or string bean. When inoculated to French beans, the alfalfa mosaic virus produces small reddish-brown local lesions two days after inoculation (Fig. 1, D). Some of the spots are surrounded by an irregular ring of tiny lesions of the same colour. The larger type of lesion varies from 0·5 to 2 mm. in diameter. With age, the irregular ring of small lesions coalesces with the larger one and a clearing occurs in the centre. The lesions differ from those produced by one of the viruses from the white clover mosaic complex in that they are smaller in size and their edges are more regular. The virus does not become systemic in *P. vulgaris* (Zaumeyer and Wade, 1935).

On broad bean, *Vicia faba*, alfalfa mosaic virus produces a very pronounced vascular necrosis which kills the plant.

The varieties of *Vigna sinensis*, Black Cowpea and Virginia Black Eye, are also valuable hosts for identifying the alfalfa mosaic virus and for placing the many strains into distinct groups. The response of the cowpeas varies from sharply defined, small or large, black, irregular and immarginate local lesions to necrotic or chlorotic spots often ringlike in form (Milbrath and McWhorter, 1954).

Diseases caused by Alfalfa Mosaic Virus

The host range of this virus seems to be very wide and it attacks a

variety of plants outside the Leguminosæ. Only a few of the more important diseases can be described.

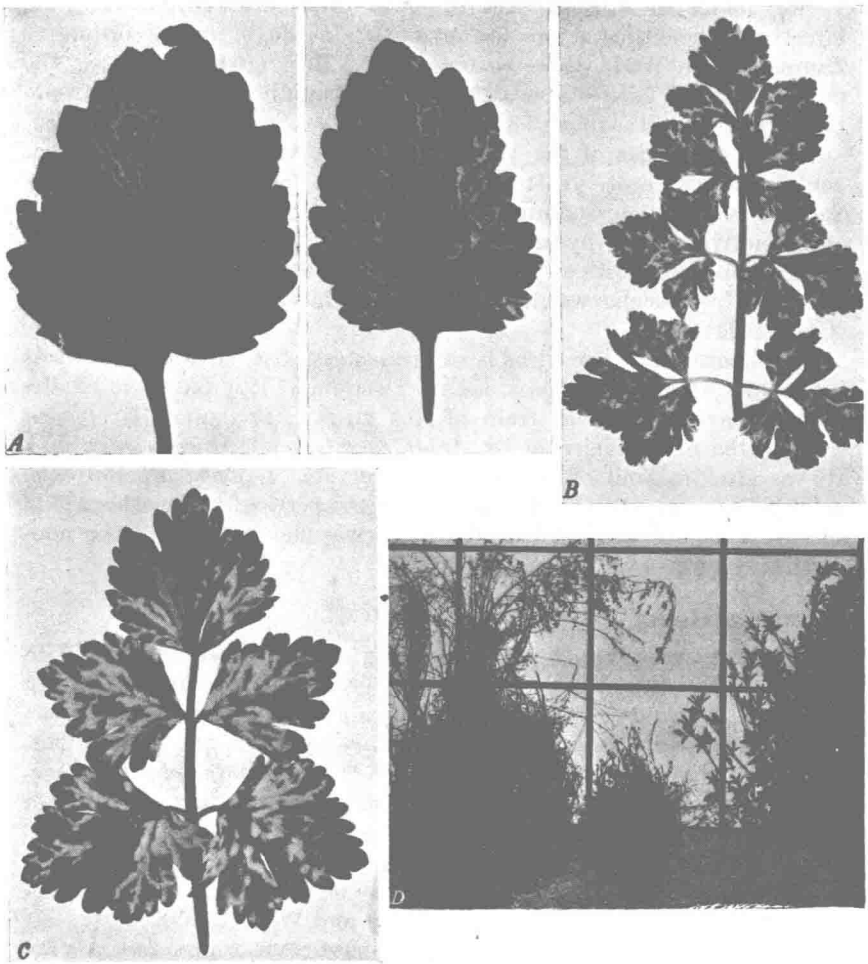


FIG. 2.

A. Aster ringspot virus on aster. (After C. W. Anderson.)
B. and C. Alfalfa mosaic virus on celery (*Apium graveolens*). (After W. C. Snyder and Saul Rich.)
D. Alfalfa Witch's Broom. (After J. D. Menzies.)

Medicago sativa L. lfalfa, Lucerne. Alfalfa Mosaic Affected plants are decidedly dwarfed and the leaves distinctly mottled and crinkled. *See* Fig. 1, C.

Nicotiana tabacum. The disease consists of primary yellow lesions

with or without necrotic centres and greyish-white necrotic rings or flecks. These are followed by systemic vein-clearing and mottling, sometimes with oak leaf pattern. On older plants symptoms are usually milder with little or no necrotic flecking.

Datura stramonium. Primary yellow lesions develop, followed by a mild systemic mottle with fine greyish-white etched rings and sometimes mild vein-banding.

Petunia spp. Dark green rings may develop on inoculated leaves and systemic vein-clearing and vein-banding on the upper leaves.

Zinnia elegans Jacq. Zinnia. Primary yellow lesions sometimes, but not always, develop on the inoculated leaves. The first sign of infection may be a downward curl or temporary twist to the leaves. Systemic mottling is indistinct in some cases and in others more definite and of the spot necrosis type.

Apium graveolens. Celery. Symptoms consist of a mild to conspicuous yellow-green mosaic, principally of the outer leaves. In some cases, however, the inner leaves also show symptoms. When the symptoms are very marked, the affected leaf presents a most striking calico-like pattern of lemon-yellow patches on a normal green background (Fig. 2, B and C). A mild blister effect is often associated with the occurrence of green islands of tissue in the yellow areas ; and in severe cases, a tendency to leaf distortion or a backward roll of the leaf may be observed. In early stages of the disease vein-clearing or a yellowing of the veins is often apparent. In later stages, yellow or cleared rings and haloes may occur, surrounding areas of green tissue (Snyder and Rich, 1942).

Vicia faba. Windsor Broad Bean. In this plant primary symptoms are black necrotic lesions ; these may become systemic and give rise to a general necrosis causing the death of the plant. Occasionally, where necrosis does not develop, a mild chlorotic mottle may be present.

Phaseolus vulgaris. Fren Bean. String Bean. Small dark necrotic lesions develop on the inoculated leaves without systemic spread. The variety Refugee Rogue and some others give no local lesions.

Soja max. Soya bean. This plant seems to react with a mild systemic mottle, without primary lesions.

Pisum sativum. Field pea, var. Laxton's Progress. In experimentally infected plants the first symptom is a drying out of the inoculated leaves. This is followed by a general wilting and stunting of the plant with mild mottling of tip leaves. In some cases only the tip leaves may wilt, in others the whole plant may be killed. The foliage becomes light green to yellow, rather suggestive of root injury instead of virus infection (Berkeley, 1947).

Lathyrus odoratus. Sweet Pea. On the inoculated leaves, solid necrotic lesions may develop ; later the inoculated leaves may drop off.

Systemic symptoms consist of curling and dwarfing of tip leaves, while a few leaves may develop chlorotic spotting or white necrotic streaks or stippling, generally towards the base of affected leaves. Plants are usually stunted and may be killed. Sometimes one lateral shoot is killed while the remainder of the plant continues to grow, though growth may be severely stunted.

Trifolium pratense. Red Clover. The general symptom picture is of mottling with a good deal of leaf distortion.

Strains of Alfalfa Mosaic Virus

Potato Calico. SYNONYM : *Marmor medicaginis* H. var. *solani* n. var.

Diseases caused by Potato Calico Virus. It has been shown by Black and Price (1940) that the virus producing potato calico is a strain of alfalfa mosaic virus. They found that plants of *Nicotiana glutinosa* and *N. tabacum* infected with potato calico virus were resistant to infection with alfalfa mosaic virus. Symptoms produced on the following plants by the two viruses were compared and found to be similar but not identical : *Nicotiana glutinosa* L., *Phaseolus vulgaris* L., *Vicia faba* L., *Vigna sinensis* Endl., *Solanum tuberosum* L., *Trifolium incarnatum* L., *T. pratense* L., *T. repens* L., and *Cucumis sativus* L.

Differential Hosts. Potato calico virus produces prominent calico symptoms with wide vein-banding on *Nicotiana glutinosa* and *N. rustica.* The type virus and the pepper strain give much less prominent symptoms without vein-banding on the same hosts. These two viruses will also infect cucumber, but potato calico virus apparently will not.

Potato Calico. Potato, var. *White Rose.* Some of the leaflets of infected plants growing in the field become irregularly spotted or blotched. These areas do not become necrotic, rather they appear devoid of chlorophyll and generally assume a bright yellow, yellowish-white, or grey colour. The spots are not always inter-veinal and may occupy as much as 95 per cent. of the leaflet area, being, as a rule, irregularly scattered. As a probable result of chlorophyll deficiency plants infected when young seldom attain normal size.

The young leaflets of healthy plants which have been artificially inoculated with unfiltered juice develop symptoms practically identical with those observed in the field, but in addition to yellowing, the lower leaflets may become necrotic at the tip, crinkled or ruffled, and in some instances, slightly stiffened. The minimum incubation period is about fifteen days (Porter, 1931).

Pepper Strain. SYNONYM : *Marmor medicaginis* var. *capsici.*

Berkeley (1947) has described a strain of alfalfa mosaic affecting pepper in Ontario. Cross-protection experiments and tests of the thermal inactivation point showed that the two viruses were related. With a few exceptions, this virus and viruses of alfalfa mosaic and potato calico produced the same symptoms on a range of host plants.

The pepper virus did not infect tomato, while the other two did ; it also produced more severe necrosis on *Nicotiana glutinosa*, *N. tabacum* and *N. rustica*.

Alfalfa Mosaic Virus N.

A strain of the virus causing severe necrosis in many host plants has been isolated from alfalfa and peas in eastern Oregon and Washington State. The host range, including solanaceous hosts, is typical of alfalfa mosaic virus, but the thermal inactivation point is 10–15° C. lower than those previously recorded for strains of that virus. It is considered to be a strain because of similar symptoms in eight families, seventeen genera, and nineteen species of plants. The designation N. is given because the virus induces severe necroses that result in the death of many susceptible plants. Particularly distinctive is the death of many varieties of *Phaseolus vulgaris* L., that following initial local lesions characteristic of the type virus, develop dark necrosis on the foliage and stems, wither and die (McWhorter, 1949).

Strains 2A, 2B, and 2C.

Zaumeyer (1938) has investigated pea streak caused by alfalfa mosaic virus and differentiates three strains by their reactions on the pea. Strains 2A and 2B produce a leaf mottling differing in intensity while strain 2C produces a leaf spotting in addition to mottling

Alfalfa Yellow Mosaic Virus. SYNONYM : *Marmor medicaginis* H. var. *flavovarians*, Zaumeyer.

The Virus. The physical properties of the virus are similar to several of the other strains of alfalfa mosaic virus. The thermal inactivation point lies between 65°–70° C. at ten-minute exposures and at 18° C. it is inactivated after ninety-six hours. The dilution end-point is about 1 : 4000.

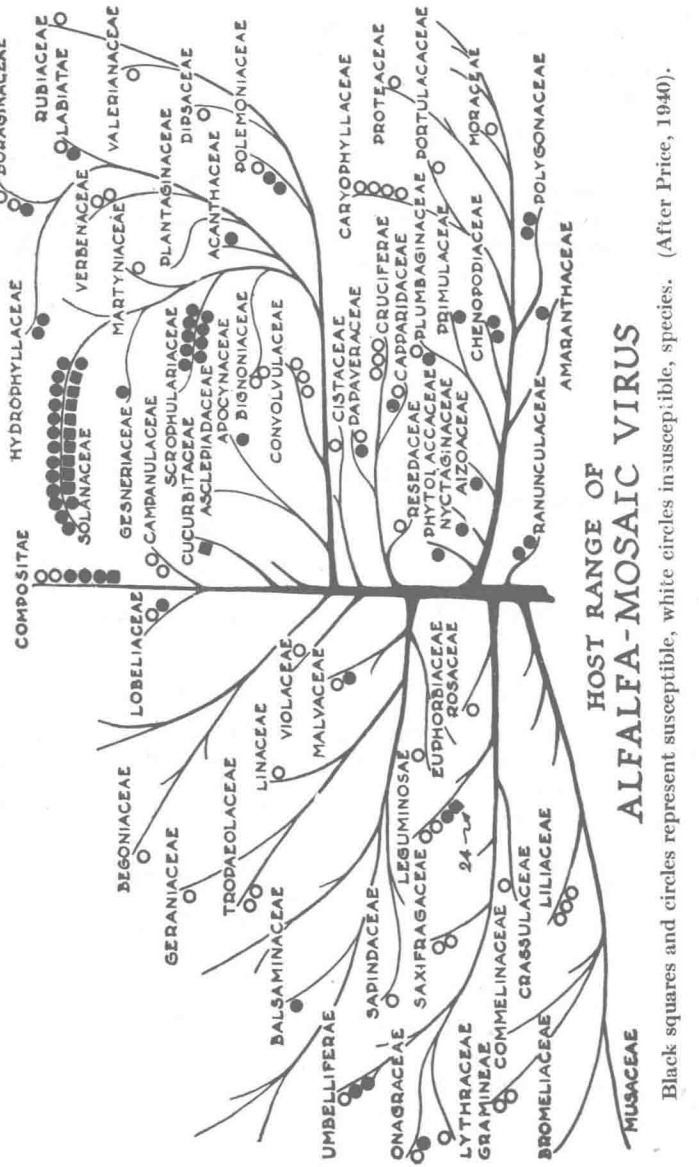
Symptomatology. A new strain of alfalfa mosaic virus producing both necrotic local lesions and systemic necrosis and mottling on beans was isolated from naturally infected alfalfa in Idaho (Zaumeyer, 1953). On naturally infected alfalfa it produces a yellow leaf mottling.

In general the host range of the alfalfa yellow mosaic virus is similar to that of the other strains. However, certain hosts, such as cucumber, cowpea, pepper, petunia and red clover are immune to this virus.

Geographical Distribution. United States of America, New Zealand (Fry, 1952b), many parts of Europe.

Host Range. The host range is very wide and includes the following : Leguminosæ, *Phaseolus vulgaris* (Willd.), Adzuki bean, *P. aureus* Roxb., string bean, *P. vulgaris*, French bean, *Medicago sativa* L., common and Turkestan alfalfa or lucerne, *Melilotus albus* Desr., white sweet clover, *Trifolium incarnatum* L., crimson clover, *T. pratense*, red clover, *T. repens* L., white clover, *Pisum sativum*, pea, *Lathyrus odoratus* L., sweet pea. Cucurbitaceæ, *Cucumis sativus*, the cucumber, but not

potato calico virus. Solanaceæ, potato, tobacco and tomato ; the last named is not susceptible to the pepper strain. Compositæ, *Zinnia*



elegans. For a more complete list of host plants see Price (1940) who found that alfalfa mosaic virus infected ninety-two species in twenty-eight families.