ROLE OF WEEDS IN THE PERPETUATION OF VIRUS DISEASES OF VEGETABLES AND ORNAMENTAL PLANTS

BY

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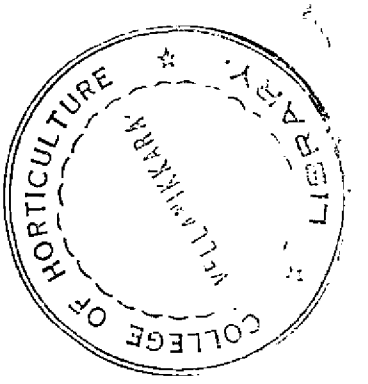

THESIS
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DECLARATION

I hereby declare that this thesis entitled " ROLE OF WEEDS IN THE PERPETUATION OF VIRUS DISEASES OF VEGETABLES AND ORNAMENTAL PLANTS" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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Vellayani,
18th February, 1981.

CERTIFICATE

Certified that this thesis, entitled " Role of weeds in perpetuation of virus diseases of vegetables and ornamental plants" is a record of research work done independently by Shri. A.V. MATHEW, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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(A.V. MATHEW)

CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Plate Number

LIST OF FIGURES

INTRODUCTION

INTRODUCTION

The deleterious effects of weeds on crop cultivation have been well documented by the findings of many scientists working in different disciplines of agriculture. Different types of weeds not only compete with crop plants for the nutrients and water but also harbour pests and pathogenic organisms and thereby act as potential sources for the incidence of pests and diseases. The role of weeds in the epiphytotic incidence of certain virus diseases affecting economic crop plants has been identified and experimentally proved by several workers (Thung, 1932; Deighton, 1938; Pruthi and Samuel, 1939; Costa, 1965 and Mariappan and Narayanasamy, 1977).

Disease symptoms resembling those found in crop plants caused by plant viruses are often noticed on a number of weed plants in different parts of Kerala. However, there are no authentic experimental evidences to prove that these are caused by virus infections and that, these weeds may act as collateral hosts of any of the viruses causing diseases of cultivated plants.

The present investigations were undertaken with a view to identify the virus/viruses infecting weeds in Kerala,

their modes of transmission, physical properties and to establish the relationship, if any, with those affecting vegetables and ornamental plants. An attempt has been made to study in detail thirteen virus diseases affecting ten species of weed plants belonging to 8 different families. The results of the studies will be useful in understanding the role of weeds in the perpetuation of the viruses infecting cultivated plants and the findings can be judiciously utilized in formulating appropriate strategy for the control of the virus diseases of the crop plants.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Considerable amount of work has been done by many plant virologists on the role of weeds as collateral hosts in the spread of viruses infecting cultivated plants. A review of the work done on the viruses infecting the weeds pertinent to the present investigation is presented in this chapter.

Ageratum conizoides L.

It was reported that Ageratum conizoides could act as a collateral host of the virus causing curl and crinkle disease of tobacco and that the disease could be controlled by the eradication of infected A.conizoides at least a month before planting tobacco (Thung,1932; 1934; 1935). Deighton (1938) reported A.conizoides as one of the collateral hosts of tobacco leaf curl in Sierra Leone. Van Der Laan (1940) reported A. conizoides among the weed hosts of Pseudo-mosaic disease of tobacco in Sumatra. The virus was transmitted from the weed to tobacco by the whitefly, Bemisia gossypiperda and both the weed and tobacco showed similar type of symptoms. Silberschmidt and Nobrega (1941) observed symptoms resembling banana mosaic on A.conizoides in Brazil. The virus was

mechenically transmissible to Nicotiana glutinosa, N.tabacum (white Burley), Datura stramonium and Petunia sp.

Gadd and Loos (1941) reported a virus disease of A.conizoides characterised by vein banding and leaf curl. The virus was transmitted from diseased to healthy plants by grafting and by the whitefly, Bemisia sp. They found that the virus could be transmitted to tobacco by the whitefly. Fernando and Udurawana (1942) reported A.conizoides as a collateral host of the mosaic of Hibiscus esculentus in Ceylon. Delatire (1947) observed A.conizoides as a collateral host of leaf curl of cotton transmitted by B.tabaci. The weed served as the collateral host of B.tabaci as well as the leaf curl virus. Thung and Hadiwidjaja (1950) reported an yellow vein banding mosaic of A.conizoides which could be transmitted from diseased to healthy plants by means of Cuscuta australis. Newton and Pieris (1953) while investigating the virus diseases of plants in Ceylon observed a conspicuous vein banding on A.conizoides which was transmitted to healthy plants by inarch grafting.

In India, Pal and Tandon (1937) reported a vein clearing disease of A.conizoides which was transmitted by grafting.

Pruthi (1937) reported a leaf curl disease of A.conizoides similar to that of tobacco. He transmitted the disease to tobacco by the whitefly, Bemisia gossypiperda. Pruthi and Samuel (1939; 1942) reported that tobacco leaf curl in North India was transmitted from the collateral host, A.conizoides by B.gossypiperda. Pruthi (1944) later confirmed that it acted as a collateral host of Tobacco leaf curl virus, transmitted by B.tabaci. Vasudeva (1957) reported that A.conizoides was found to be a collateral host of the virus causing yellow vein mosaic of bhendi.

Varma (1959) also reported that A.conizoides might act as a collateral host of Tobacco leaf curl virus. The virus was transmitted from infected Nicotiana rustica to A.conizoides by B.tabaci producing leaf curl and vein thickening. Varma (1963) reported that yellow vein mosaic of A.conizoides was transmitted by B.tabaci and that a single viruliferous whitefly could transmit the virus. The virus could infect Browallia elata and Vernonia sp. causing leaf curl and yellow vein mosaic, respectively. He could not obtain transmission of the virus to tobacco. Nair and Wilson (1970) reported a yellow vein mosaic of A.conizoides which was transmissible by

wedge grafting and by B.tabaci. They found that the virus could infect Synerdrella nodiflora causing leaf curl. Srivastava et al.(1977) reported a virus causing yellow net disease of Zinnia elegans, transmitted by B.tabaci, and they found that the same virus could infect A.conizoides.

Amaranthus spp.

Shevtchenko and Shevtchenko (1930) reported Amaranthus retroflexus as a collateral host of Sugarbeet mosaic virus. The virus was transmitted from sugarbeet to A.retroflexus and vice-versa by Aphis fabae. Pound (1947) reported that A. retroflexus might be a collateral host of Beet mosaic virus. The virus was transmitted from A.retroflexus to sugarbeet by A.fabae and Myzus persicae. Bennet (1949) also found A.retroflexus among the collateral hosts of Sugarbeet mosaic virus. The virus was transmitted to A.retroflexus from sugarbeet by means of M.persicae. Khristova (1950) reported A.retroflexus, A. albus, A.monstrosus, A. paniculatus and A.aureus as hosts of Beet mosaic virus in Bulgaria. Both Aphis fabae and Myzus persicae could transmit the virus to sugarbeet from Amaranthus spp.

Bercks and Zimmer (1956) transmitted Beet yellows virus to A.retroflexus and A.gangeticus by M.persicae, which were considered to be the carriers of the virus. Wiesner (1962) observed Amaranthus spp. among the collateral hosts of Beet yellows virus. The virus was transmitted from sugarbeet to Amaranthus spp. and vice-versa by M.persicae. Grela (1966) transmitted Beet yellows virus to A.aureus and A.speciosus by means of M.persicae and Aphis fabae. The virus was also mechanically transmissible to the weed hosts.

Doolittle and Walker (1923) reported a Cucurbit mosaic virus which infected pig weed (A.retroflexus). Schmelzer and Molnar (1975) reported A.retroflexus infected with Cucumber mosaic virus as the primary source of inoculum of the disease for cucurbits in Hungary. The virus was sap transmissible to cucurbits. Joshi and Dubey (1975) reported A.viridis among the weed hosts of Cucumber mosaic virus which acted as a potential source of inoculum for infection of cucurbits and other crops. Lockhart and Fischer (1976) reported that A.retroflexus might be a collateral host of Cucumber mosaic virus, which infected chillies in Morocco and Myzus persicae as the vector of the virus.

Zaumeyer and Kearns (1936) could transmit Bean mosaic virus to beans from A.retroflexus by Aphis medicaginis. Silberschmidt and Nobrega (1941) reported A.retroflexus among the collateral hosts of Banana mosaic virus. Hildebrand and Koch (1942) transmitted the virus causing savoy, disease of sugarbeet from Amaranthus spp. to sugarbeet by the pigweed bug, Piesma cinerea. Larson (1944) reported A.retroflexus among the local lesion hosts of potato virus X. Thomas (1949) observed A.retroflexus as the carrier of the red-node virus of beans (Phaseolus vulgaris) in Colorado.

Canova (1955) reported A.retroflexus and A.deflexus as the collateral hosts of a virus causing a sugarbeet disease called " Romagna Yellows " in Italy. M.persicae could transmit the virus to sugarbeet. Brierly and Lorentz (1957) observed A.retroflexus as the local lesion host of Hydrangea ring spot virus. Duffus (1960) reported A.retroflexus and A. tricolor among the hosts of Raddish yellows virus. The virus was transmitted to raddish and sugarbeet by Aphis helicrysi, Microsiphum dirhodum and Myzus persicae. Kovaachevski (1975) reported A.lividus and A.paniculatus as the collateral hosts of Turnip mosaic virus in Bulgaria. The virus was transmitted by sap inoculation and by aphids,

M.persicae and Brevicoryne brassicae. Locatelli et al.(1978) reported A.retroflexus as the collateral host of Tobacco rattle virus and potato virus X.

In India, Phatak (1965) reported mosaic diseases of A. viridis and A.blitum which were sap transmissible to cultivated species of amaranthus. Capoor and Rao (1969) reported a leaf mottling disease of Amorphophallus campanulatus which was transmitted to A.tricolor by M.persicae. Ramakrishnan et al.(1971) reported a virus causing mosaic disease of A.gangeticus which was transmitted to Celosia cristata and Achyranthus aspera by sap inoculation and by Aphis gossypii. The thermal inactivation point of the virus was between 60-65°C, dilution end point 1:1000 - 1:10000 and longevity in vitro 72 hours. Mariappan and Narayanasamy (1977) reported a mosaic disease of A.viridis which was transmitted by sap inoculation and by the aphids, A.gossypii, A.craccivora and M.persicae. The virus could be transmitted to six species of plants including A.gangeticus and A.caudatus by both sap inoculation and by aphids. From the physical properties, host range and serological tests the virus was identified as a strain of Amaranthus mosaic virus. The thermal inactivation point

of the virus was found to be between 60-65°C, dilution end point 1:1000 and longevity *in vitro* 3 days at 5°C and 2 days at 28 - 30 °C.

Croton spp.

Vasudeva (1957) reported *Croton sparsiflorus* as a collateral host of yellow vein mosaic virus of bhendi. Varma (1963) reported that yellow vein mosaic of *C.sparsiflorus* was transmitted by grafting and by the whitefly, *Bemisia tabaci*. He suggested that it may be a strain of Tobacco leaf curl virus. Nair and Wilson (1970) observed a yellow vein mosaic of *C.sparsiflorus* which was transmitted by wedge grafting and by *B.tabaci*. They found that the virus causing yellow vein mosaic of *C.sparsiflorus* and *Sida cordifolia* could cross infect. Bird *et al.*(1975) reported a mosaic of *Jatropha gossypifolia* which could infect *C.lobatus*. The virus was transmitted by *B.tabaci*.

Sida spp.

Kunkel (1930) recorded a mosaic disease common on *Sida rhombifolia* and other species of *Sida* in Florida which was transmitted by grafting and budding. Storey (1935) considered

that Sida spp. might be collateral hosts of tobacco leaf curl, transmitted by B.tabaci, in E. Africa. Hopkins (1936) observed a leaf curl disease of Sida spp. which could be transmitted to cotton by budding and grafting. Botero (1957) reported that S.acuta and S. salvaefolia might be collateral hosts of the virus causing "Stenosis" of cotton as they showed identical symptoms. Deighton (1938) reported S.carpinifolia and S.cordifolia as the collateral hosts of Tobacco leaf curl virus in Sierra Leone.

Shepherd (1940) found that S.carpinifolia could act as a host of Tobacco leaf curl virus. Owen (1946) reported mosaic diseases of S.acuta, S.rhombifolia, S.urens, S.glomerata and S.linifolia in Trinidad which were transmitted by grafting. Based on the symptoms he concluded that the mosaic diseases of Sida spp. in Trinidad and Brazil were caused by the same virus, ie., Abutilon infectious variegation virus (AIVV). Orlando and Silberschmidt (1946) reported infectious chlorosis of Malvaceae affecting Sida spp. in Brazil. The virus was transmitted from diseased to healthy plants of sida by a single adult whitefly, B.tabaci. They could obtain hundred per cent transmission when 10 viruliferous

whiteflies were used per plant. The virus was also transmitted from Sida spp. to Abutilon striatum var. Spurium by B. tabaci.

Delattre (1947) reported that S. carpinifolia might be the collateral host of Cotton leaf curl virus, transmitted by B. tabaci, since both cotton and S. carpinifolia showed identical symptoms. Costa (1954) recorded a wide spread mosaic, infectious chlorosis of Malvaceae, among indegenous species of Sida in Brazil. The same virus caused mosaic disease in cotton, bhendi, beans and soybeans. Costa (1955) could transmit the virus by means of the vector B. tabaci to bean causing a disease called 'Bean dwarf mosaic'.

Silberschmidt and Tommasi (1955) reported infectious chlorosis of Malvaceae on S. rhombifolia, S. acuta var. carpinifolia and Sida sp. They could transmit the virus from S. rhombifolia to the same host, Malva spp. and Althaea rosea by means of B. tabaci. Silberschmidt and Tommasi (1956) transmitted the virus of infectious chlorosis of Malvaceae to Nicandra physaloideg by means of B. tabaci. The virus was not transmitted to tobacco by either grafting or by the whitefly. Costa (1956) reported S. rhombifolia and

S.micrantha as the collateral hosts of a virus disease of cotton called 'Anthocyanosis' in Brazil. The virus was transmitted to the hosts by means of the aphid, Aphis gossypii.

Silberschmidt et al.(1957) reported the transmission of AIVV from Abutilon thompsonii to healthy S.rhombifolia plants by means of B.tabaci. Flores and Silberschmidt (1958) reported the occurrence of AIVV on S.micrantha. The virus was transmitted to the weed host and tobacco by grafting and by viruliferous B.tabaci. They could also transmit the virus from infected S.rhombifolia to Lycopersicon esculentum, Datura stramonium and Cyphomandra betaceae by grafting and by the whitefly. Bird (1958) reported infecious chlorosis of Malvaceae on S.carpinifolia which was transmitted by B.tabaci race sidae. The virus was transmitted by the vector to tobacco producing mild leaf curl. A single viruliferous insect could transmit the virus. Flores et al.(1960) observed that the virus causing the 'infectious chlorosis of Malvaceae' could infect tomato and that it was transmitted to S. rhombifolia by grafting and by B.tabaci.

Costa (1965) reported that infected S.rhomfolia and other wild Malvaceae could act as collateral hosts of mottled dwarf of bean in Brazil. The virus was transmitted from wild Malvaceae to bean by B.tabaci and identified as AIVV. Hill (1968) reported S.cordifolia as a collateral host of tobacco leaf curl virus since both tobacco and S.cordifolia showed strongly resembling symptoms. The virus was transmitted by B.tabaci. Bird and Sanchez (1971) reported that the mosaic disease of S.carpinifolia in Puerto Rico and infectious chlorosis of Malvaceae in Brazil were related to each other. Costa (1975) found that wild malvaceous plants infected with AIVV were collateral hosts of soybean crinkle mosaic virus in Brazil. The virus was easily transmitted to soybean by B.tabaci but the recovery of the virus from soybean was difficult and the transmission from soybean to soybean was generally not successful.

Bird et al.(1975) reported a yellow mosaic of S. carpinifolia in Puerto Rico, which was transmitted by B.tabaci. The virus was transmitted to tobacco by viruliferous whitefly producing mild leaf curl. Carlos Granillo et al.(1975) reported that Sida spp.might be the

collateral hosts of mosaic of cotton and golden mosaic of bean (Phaseolus vulgaris) in El Salvador. These viruses were transmitted by B.tabaci and Sida spp. were suspected to act as the reservoir of the viruses.

In India, Pruthi (1939) reported S.rhombifolia and S. humilis as the collateral hosts of tobacco leaf curl. The virus was transmitted by a single viruliferous B.tabaci to the weed hosts and tobacco. Pruthi and Samuel (1942) reported that the virus causing leaf curl of tobacco and tomato could be transmitted to S.rhombifolia by B.tabaci. Nair and Wilson (1970) reported an yellow vein mosaic of S.cordifolia which was transmitted by wedge grafting and by B.tabaci. The virus was transmitted by the whitefly to Croton sparsiflorus and Lycopersicon esculentum and yellow vein mosaic and leaf curl symptoms were produced, respectively. They transmitted yellow vein mosaic of Croton sparsiflorus to S.cordifolia by viruliferous B.tabaci and recorded the same type of symptoms.

Stachytarpheta spp.

Deighton (1938) reported Stachytarpheta sp. as a collateral host of tobacco leaf curl in Sierra Leone.

Van Der Laan (1940) reported S.dichotoma among the collateral hosts of pseudo-mosaic disease of tobacco in Sumatra. The virus was transmitted to the weed host and tobacco by B.gossypiperda.Brierly (1945) recorded mosaic, spike and rosette viruses on Stachytarpheta sp.

In India, Venkata Rao (1935) observed spike like disease of S.indica and suspected that it might act as a collateral host of sandal spike. Wilson and Sathiarajan (1965) reported a leaf distroting virus of S.indica which was transmitted by wedge grafting.

Synerdrella nodiflora Gaertin

It was reported that Synedrella nodiflora could act as a collateral host for the virus causing curl and crinkle disease of tobacco and that the disease could be controlled by the eradication of infected S.nodiflora at least a month before planting tobacco (Thung 1932; 1934; 1935). Deighton (1938) reported S.nodiflora among the collateral hosts of tobacco leaf curl in Sierra Leone. Van Der Laan (1940) observed S.nodiflora as one of the weed hosts of pseudo-mosaic disease of tobacco in Sumatra. The virus

was transmitted from infected S.nodiflora to tobacco by the whitefly B.gossypiperda and there was strong resemblance in the symptoms produced on both the host plants.

Newton and Pieris (1953) recorded a virus disease of S.nodiflora characterised by leaf cupping and chlorosis. The disease was transmitted by inarch grafting, but not by sap inoculation. Calica (1961) reported a virus disease of S.nodiflora and suspected that it might act as a carrier of the virus causing cadang-cadang of coconut in Philippines.

In India, Nair and Wilson (1970) reported a leaf curl disease of S.nodiflora which was transmitted by wedge grafting and by B.tabaci. The virus was transmitted to Ageratum conizoides by viruliferous whitefly and produced yellow vein mosaic symptoms. They confirmed that yellow vein mosaic of A.conizoides and leaf curl of S.nodiflora were caused by the same virus.

Other weed hosts

Bock et al.(1977) reported an yellow vein virus of Clitoria ternatea, a wild legume, in Kenya. The virus was

mechanically transmitted to the original host, other members of Papilionaceae and Hibiscus esculentus. Nair and Menon (1978) reported a yellow mosaic of Micrococca mercurialis which was transmitted by wedge grafting and by the whitefly, B.tabaci.

Mechanical transmission of whitefly-borne disease agents

Costa and Bennett (1950) reported for the first time the mechanical transmission of a whitefly transmitted virus, causing mosaic disease of Euphorbia prunifolia. The virus was mechanically transmitted to E.prunifolia and Datura stramonium, but the percentage of transmission was very low. The juice expressed from diseased E.prunifolia plants were rubbed over the leaves of seedlings that had been sprinkled with carborundum. Similarly Costa and Carvalho (1960a) have also reported mechanical transmission of the virus. Bird et al.(1975a) also reported similar observations from Puerto Rico. They confirmed that the mosaic disease of E.prunifolia reported from Brazil and Puerto Rico was caused by the same virus.

Sheffield (1957;1958) reported two virus diseases of sweet potato, virus A and virus B, from E.Africa. Of these,

virus A was transmitted by Myzus persicae and virus B by Bemisia tabaci. The virus A was not mechanically transmissible to any of the hosts tested. The virus B was also not mechanically transmissible to its original host, Ipomoea batatas, but transmissible to Petunia sp. and other test species of Ipomoea. When the original host was used as the source of inoculum the percentage of transmission was very low. The virus was transmitted to the test species of Ipomoea by B. tabaci and when this was used as the source of inoculum the percentage of mechanical transmission was considerably increased.

Costa and Carvalho (1960b) obtained mechanical transmission of the mosaic virus of Abutilon striatum var. thompsonii when Malva parviflora and M. rotundifolia seedlings were used as test plants. Mechanical transmission directly from A. striatum was not successful, but after transference to Sida micrantha, S. rhombifolia or M. parviflora by grafting and when these plants were used as source of inoculum they could get successful transmission to M. parviflora and M. rotundifolia. Similar observations were also reported by Flores and Silberschmidt (1967). They could not obtain

mechanical transmission of the virus when the natural hosts, A. thompsonii and A. spurium, were used as the source and test plants.

Cohen and Nitzany (1960) reported a vein clearing and chlorosis of cucumber from Israel which was transmitted mechanically and by B. tabaci. The virus was easily transmitted from all its known hosts by mechanical means.

Herold (1967) reported a mosaic disease of Anthurium andreanum transmitted by B. tabaci. The virus was transmitted mechanically from A. andreanum to Nicotiana clevlandii and N. tabacum (White Burley), but not to the original host. The virus was easily transmitted by sap inoculation from both the species of tobacco to N. glutinosa, N. tabacum (Samsun), Browallia sp. and Physalis peruviana.

Meiners et al. (1973) reported a virus disease of Calopogonium mucunoides transmitted by B. tabaci. Beans (Phaseolus vulgaris) infected with the virus from C. mucunoides by B. tabaci was used as the source of inoculum for mechanical transmission. The virus was sap transmitted from infected to healthy beans, but not to the original host.

Meiners et al.(1975) reported mechanical transmission of mosaic virus of Euphorbia prunifolia and golden mosaic virus of C.mucunoides from infected beans to healthy beans. The bean plants were infected by exposure to whiteflies which were allowed to feed for 24 hours on diseased E.prunifolia or C.mucunoides. Inoculum for mechanical transmission was prepared in phosphate buffer of pH 6.8 from infected beans.

Bird et al.(1975b) reported mechanical transmission of golden yellow mosaic virus of beans which was transmitted by B.tabaci. Mechanical inoculation was done by preparing the inoculum in cold 0.1M phosphate buffer of pH 7.5. Galvez and Castano (1975) could obtain mechanical transmission of golden mosaic virus of beans when the inoculum was prepared in phosphate buffer at 0.1M, pH 7.5, with 1 per cent 2-mercaptoethanol.

Costa et al.(1975)reported a golden mosaic virus of tomato transmitted by B.tabaci. The virus was also transmitted by mechanical means, but the percentage of transmission was very low. The virus was transmitted to Nicotiana glutinosa, Physalis sp. and Datura stramonium

by B. tabaci. The percentage of mechanical transmission increased when the inocula were obtained from and infected into these plants.

Lastra and Uzcathegui (1975) reported mechanical transmission of tomato yellow mosaic virus which was commonly transmitted by B. tabaci.

Bock and Guthrie (1978) reported the mechanical transmission of African cassava mosaic virus from cassava to cassava by using the inoculum prepared in phosphate buffer of pH 7.0 or in deionized water.

In India, Subramanian and Narayanasamy (1978) reported the mechanical transmission of yellow mosaic virus of Dolichos lablab. The sap was extracted in 0.1M phosphate buffer by using chilled mortar and pestle. The percentage of transmission ranged from 52-76 and 92-100 in the pH range of 6.6 - 7.2 and 7.4 - 8.0 respectively.

MATERIALS AND METHODS

MATERIALS AND METHODS

I. Culture of the viruses

Periodical visits were made to different regions in Kerala and the weed plants, showing obvious symptoms of virus diseases were collected and established in pots. Cultures of the viruses were maintained by grafting to their natural hosts and kept in separate compartments of an insect-proof house. They were used as source of viruses for further studies.

The following virus diseases affecting weeds were studied.

1. Yellow vein mosaic of *Ageratum conizoides* L.
2. Leaf curl of *Ageratum conizoides* L.
3. Mosaic of *Amaranthus viridis* L.
4. Mosaic of *Clitoria ternatea* L.
5. Yellow vein mosaic of *Croton sparsiflorus* Morong.
6. Yellow mosaic of *Hemidesmus indicus* R.Br.
7. Yellow mosaic of *Micrococca mercurialis* Benth.
8. Yellow mosaic of *Sebastiania chamaelea* Muell.
9. Yellow vein mosaic of *Sida cordifolia* L.
10. Leaf curl of *Stachytarpheta indica* Vahl.

11. Mosaic of Stachytarpheta indica Vahl.
12. Yellow mosaic mottle of Stachytarpheta indica Vahl. var. jamaicensis.
13. Leaf curl of Synedrella nodiflora Gaertin.

II. Seed materials

Seeds of vegetables and ornamental plants were obtained from the Instructional Farm, College of Agriculture, Vellayani. Tobacco seeds were supplied by the Central Tobacco Research Institute, Rajahmundry and the seeds of weed plants were collected locally from healthy plants. All those seeds were sown in pots containing the standard potting mixture (sand, soil and cowdung in the ratio of 1:1:2).

III. Symptomatology

Symptomatology was studied by observing the morphological changes in plants under field conditions and also by noting the reaction of the plants inoculated with the virus under insect-proof conditions.

IV. Transmission

The transmission studies were conducted under insect-proof conditions as described below:-

1. Sap transmission

Sap transmissionswere conducted by using concentrated sap, standard sap, sap extracted in deionized water, in phosphate buffer at room temperature and in phosphate buffer in the cold. In all sap inoculation studies 600-mesh carborundum powder was used as the abrasive.

Young leaves of infected plants showing typical symptoms were collected and triturated with mortar and pestle. Then it was filtered through a fine muslin cloth and the filtrate was used for inoculation.

The standard sap was prepared by adding 1 ml of sterile distilled water to every g of infected tissue used for extraction of sap.

Inoculum in deionized water was prepared by adding 1 ml of deionized water to every g of infected tissue used for extraction of sap.

Inoculum in phosphate buffer of pH 7.0 and 7.4 was prepared by adding 2 ml of 0.1M phosphate buffer of the desired pH to every g of infected leaf tissue.

Extraction of sap in phosphate buffer in the cold was done by adopting the method described by Subramanian and Narayanasamy (1978) with slight modifications. An enamel tray was filled to 3/4 of its capacity with tap water. The mortar and pestle were kept in the tray which was then placed in a freezer till the water was frozen. Phosphate buffer (0.1M) of pH 7.0 and 7.4 was prepared and cooled in a refrigerator to near freezing point. Young leaves showing clear symptoms were excised, rinsed in iced water, shaken free of water and macerated in the mortar kept in the ice tray with phosphate buffer at the rate of 3 ml per g of leaf material. The extracted sap was then filtered through a fine muslin cloth into a petridish kept in an ice tray. The sap was immediately rubbed with a swab of absorbant cotton over the surface of the three topmost fully opened leaves of 15 day old test plants which were dusted with a small quantity of carborundum powder. The excess sap was washed away using distilled water after

inoculation. The same inoculation technique was employed in all sap transmission studies. Yellow vein mosaic viruses of Croton sparsiflorus, Sida cordifolia, leaf curl of Stachytarpheta indica and yellow mosaic mottle of Stachytarpheta indica var. jamaicensis were transmitted to tomato by grafting and by whiteflies. Attempts were then made to transmit the viruses mechanically from tomato to tomato and back to their original hosts.

2. Graft transmission

Graft transmission of viruses from diseased to healthy plants was done by wedge grafting.

3. Insect transmission

Insect transmission studies were carried out using whiteflies, Bemisia tabaci Genn. and two species of aphids, viz., Aphis craccivora Koch. and Aphis gossypii Glov.

i). Whitefly transmission

Healthy colony of whiteflies was reared on tobacco plants in insect-proof cages and they were used for the transmission trials.

Plastic transmission cages designed by Nene (1972) were used for all transmission studies with whiteflies. The top portion of the seedling was introduced into the transmission cage in such a way that the stem passed through the rectangular slit on the mouth of the cage. Desired number of whiteflies collected in small test tubes were then released into the transmission cage, the sides of which were covered by a black cloth except the wire netting which was facing a light source and the cap of the cage was immediately screwed on. The remaining portion of the rectangular slit of the cage was closed with modelling clay. The cages were made immobile by fixing them in between bamboo pegs and fastening them with rubber bands. After the desired feeding period the modelling clay was removed and the seedling was gently tapped with a glass rod to disturb the whiteflies and induce them to move to the side of the cage facing a light source. Both acquisition and inoculation feedings were done in these cages and 24 hours time was given for each.

Ten seedlings (15 day old) were used as test plants in each case. Twenty viruliferous whiteflies were released on

each test plant for inoculation feeding. After the inoculation feeding, the insects were killed by spraying the plants thoroughly with 0.1 per cent ekalux. The inoculated seedlings were labelled and kept in the insect-proof house. Observations on the appearance of symptoms were taken daily. Spraying with 0.1 per cent ekalux was repeated every week. The experiment was repeated in each case to confirm the results.

ii). Minimum number of whiteflies required for transmission of the viruses

After 24 hours acquisition feeding a fixed number (1, 2, 3, 5, 10, 15 and 20) of whiteflies was allowed to feed on the test plants for 24 hours. The procedure described above was followed for inoculation feeding in this experiment. The experiment was repeated thrice in each case.

iii). Aphid transmission

Aphis craccivora and A.gossypii were collected from the field and reared on healthy cowpea and brinjal plants respectively in insect-proof cages. The progenies multiplied on their respective host plants in separate insect-proof cages were used for the studies.

The aphids were collected by giving a gentle tap to the plants to disturb them from their feeding position. The moving aphids were transferred to petri plates with the help of a camel hair brush. The insects were then transferred to diseased plants for acquisition feeding and the plants were covered with glass chimneys and placed under insect-proof conditions. After 24 hours of acquisition feeding the glass chimneys were removed and the plants were given a gentle tap to disturb the feeding aphids. The moving viruliferous aphids were then collected and released on young healthy test plants covered with glass chimneys. Thirty adult aphids were used for inoculation in each case. After an inoculation feeding period of 24 hours the aphids were killed by spraying 0.1 per cent ekalux. The inoculated plants were labelled and kept in the insect-proof house. Observations on the appearance of symptoms were taken daily and the plants were sprayed with 0.1 per cent ekalux at weekly intervals. The experiment was repeated to confirm the results.

4. Seed transmission

Seeds collected from diseased plants were sown in pots and kept inside an insect-proof house. Hundred seeds were

used in each case. Observations on the appearance of symptoms were taken upto 40 days after germination. Seed transmission studies could not be carried out for yellow mosaic virus of Hemidesmus indicus since flowers and seeds were not formed in any of the plant during the course of the present investigation.

V. Physical properties of the viruses

Physical properties were studied in the case of three viruses, viz., mosaic diseases of Amaranthus viridis, Stachytarpheta indica and yellow mosaic disease of Micrococca mercurialis which could be transmitted successfully by sap inoculation. Tobacco plant (White Burley) was used as test plant for studying the physical properties of mosaic virus of Stachytarpheta indica since maximum percentage of infection was obtained on it. In the other two cases their original hosts were used as test plants.

1) Thermal inactivation point

The sap was extracted from infected tissues by triturating with mortar and pestle. Five ml of the sap was pipetted into thin walled glass test tubes. Care was taken not to smear the sap on the sides of the tubes. The test tubes were

then kept in a thermostatically controlled water bath for 10 minutes at the required temperature. The level of water in the water bath was always kept just above the level of sap in the test tube. After the treatment the test tubes were suddenly cooled by dipping in cold water. The sap was subjected to different temperatures from 40° to 90°C at intervals of 5°C. The treated sap was used for inoculating vigorously growing 15 day old test plants. The inoculation of the first set of plants was done with sap treated at the highest temperature and then the other sets of plants were inoculated with sap treated at low temperatures. Ten plants were inoculated in each treatment and the experiment was repeated to confirm the results. Observations on the number of plants infected were recorded.

2) Dilution end point

The sap was prepared as in the previous case and was diluted with sterile distilled water in the ratio of 1:10, 1:100, 1:500, 1:750, 1:1000, 1:1500, 1:2000, 1:2500 and 1:5000 in the case of mosaic diseases of Amaranthus viridis and Stachytarpheta indica. In the case of yellow mosaic of Micrococca mercurialis the sap was diluted with phosphate

buffer in the ratio of 1:10, 1:25, 1:50, 1:75 and 1:100. The diluted sap was inoculated separately on test plants starting from the highest dilution. Ten plants were inoculated in each set of treatment and the experiment was repeated to confirm the results. The inoculated plants were labelled and kept under insect-proof conditions and observed for the development of symptoms.

3) Longevity in vitro

The sap was prepared as in the above experiment and kept in test tubes at room temperature (27-32°C) and also in a refrigerator (5-10°C). One tube each, containing the sap from each treatment was taken after specific periods, viz., 4, 8, 16, 24, 32, 48, 72, 96, 120 and 144 hours and inoculated on the test plants. Ten plants were inoculated in each set of treatment and the experiment was repeated to confirm the results. The inoculated plants were labelled and kept under insect-proof conditions and observed for the development of symptoms.

VI. Host range

The following fifty different plant species belonging to 12 families were tested to determine the host range of the viruses.

I. Amaranthaceae

1. Amaranthus caudatus L.
2. Amaranthus gangeticus L.
3. Amaranthus viridis L.
4. Celosia cristata L.
5. Gomphrena globosa L.

II. Asclepiadaceae

6. Hemidesmus indicus R.Br.

III. Balsaminaceae

7. Impatiens balsamina L.

IV. Compositae

8. Ageratum conizoides L.
9. Dahlia pinnata Cav.
10. Synedrella nodiflora Gaertin.
11. Zinnia elegans Jacq.

V. Cucurbitaceae

12. Benincasa hispida Cogn.
13. Citrullus vulgaris Schrad.
14. Cucurbita maxima L.
15. Cururbita pepo L. var. condensa
16. Cucumis sativus L.

17. *Luffa acutangula* Roxb.

18. *Trichosanthes anguina* L.

VI. *Euphorbiaceae*

19. *Croton sparsiflorus* Morong.

20. *Manihot esculenta* Crantz.

21. *Micrococca mercurialis* Benth.

22. *Sebastiania chamaelea* Muell.

VII. *Leguminosae*

23. *Canavalia ensiformis* D.C.

24. *Cyamopsis tetragonoloba* (L.) Taub.

25. *Dolichos biflorus* L.

26. *Glycine max* (L.) Merr.

27. *Phaseolus aureus* (L.) Roxb.

28. *Phaseolus mungo* (L.) Roxb.

29. *Vigna sinensis* (L.) Savi.

VIII. *Malvaceae*

30. *Abelmoschus esculentus* (L.) Moench

31. *Hibicus rosasinensis* L.

32. *Sida carpinifolia* L.

33. *Sida cordifolia* L.

IX. *Pedaliaceae*

34. *Sesamum indicum* L.

X. Saxifragaceae

35. Hydrangea hortensis D.C.

XI. Solanaceae

36. Capsicum annuum L.

37. Datura metel D.C.

38. Datura stramonium L.

39. Lycopersicon esculentum Mill.

40. Nicotiana tabacum L. var. White Burley

41. Nicotiana tabacum L. var. Samsun

42. Nicotiana glutinosa L.

43. Petuina hybrida Vilm.

44. Physalis minima L.

45. Solanum melongena L.

46. Solanum nigrum L.

47. Solanum torvum L.

XII. Verbenaceae

48. Lantana camara L.

49. Stachytarpheta indica Vahl.

50. Stachytarpheta indica Vahl var. jamaicensis

The viruses which showed positive results in host range studies were back inoculated to their original hosts to ascertain that they again produced the original symptoms.

RESULTS

RESULTS

I. Symptomatology

1. Yellow vein mosaic of Ageratum conizoides

The symptoms appeared as vein clearing on the newly formed leaves followed by yellowing of the veins. In most of the diseased plants the leaves exhibited a typical yellow vein mosaic with slight thickening of the veins on the abaxial surface of the leaves. In some plants the yellowing of the veins became intense and it spread to the interveinal areas showing yellow mottling (Plate I). In severe cases all the leaves became almost completely yellow in colour. Affected plants were considerably stunted but flowering and seed setting were not much affected.

2. Leaf curl of Ageratum conizoides

The initial symptoms started as mild vein clearing of the young leaves and at a later stage curling and cupping were seen. The leaves were thick, brittle and leathery and the veins became thick which where more discernible on the abaxial surface of the leaves. In severe cases of infection the leaves became very small in size which were crowded as a bunch at the top due to shortening of internodes. The

Healthy Diseased

Plate No.1 Yellow vein mosaic of Ageratum conizoides

Healthy Diseased

Plate No.2 Leaf curl of Ageratum conizoides

affected plants were severely stunted and flowering was almost completely inhibited (Plate 2).

3. Mosaic of Amaranthus viridis

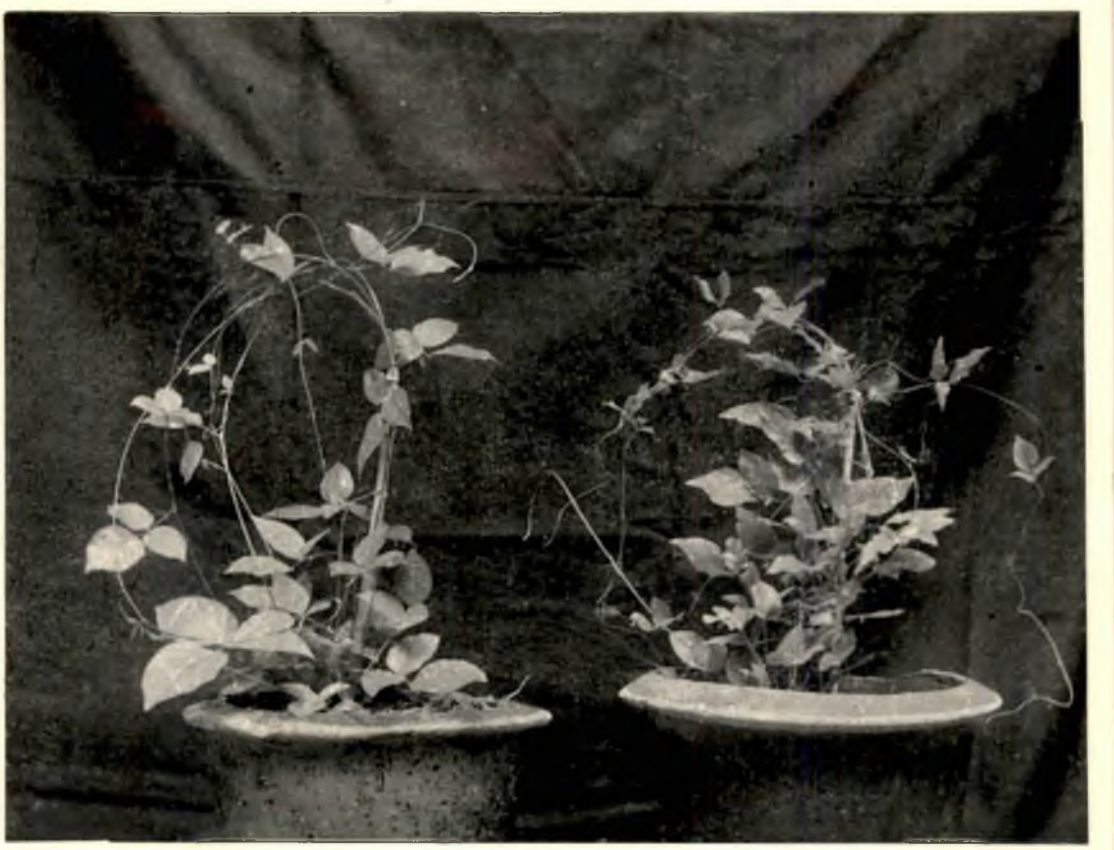
The symptoms appeared as mild vein clearing of the young leaves. This was followed by mild chlorosis of the leaves and later, characteristic mosaic symptoms developed. Downward rolling of the leaf margins and reduction in the size of the leaves were also seen. The affected plants became severely stunted and the inflorescence was short and reduced in size (Plate 3).

4. Mosaic of Clitoria ternatea

The symptoms appeared as alternate pale and dark green irregular areas on the newly formed leaves to give a typical mosaic pattern. Blistering, downward rolling of margins and crinkling of the leaves were the other important symptoms. The trifoliate leaves were considerably reduced in size, the width being reduced to about ¼ of the normal lamina. The length of the vine was considerably reduced (Plate 4). Flowering was not affected but the seeds were malformed and shrivelled. Sometimes pods without even a single normal seed were also found.

Healthy Diseased

Plate No.3 Mosaic of *Amaranthus viridis*



Healthy Diseased

Plate No.4 Mosaic of *Clitoria ternatea*

5. Yellow vein mosaic of Croton sparsiflorus

The initial symptoms appeared as vein clearing of the young leaves which later developed into characteristic yellow vein mosaic symptoms. This was followed by curling, cupping and reduction in size of lamina and thickening of veins on the abaxial surface of the leaves. The affected plants were severely stunted but flowering and fruiting were not affected much (Plate 5). Plants with only one branch or part of a branch showing the disease symptoms were also observed under field conditions. Sometimes the tender shoots were pale yellow in colour.

6. Yellow mosaic of Hemidesmus indicus

The initial symptoms appeared as circular or irregular chlorotic spots on the young leaves. The chlorotic spots spread in between the veins and veinlets. As the disease progressed the colour of these spots turned deep yellow and they coalesced to form bigger patches on the lamina. The leaves were considerably reduced in size and showed varying degrees of distortion of the lamina (Plate 6). The tender vines became pale yellow in colour and the length of the vines was reduced considerably.

Healthy Diseased

Plate No.5 Yellow vein mosaic of *Croton sparciflorus*

Healthy Diseased

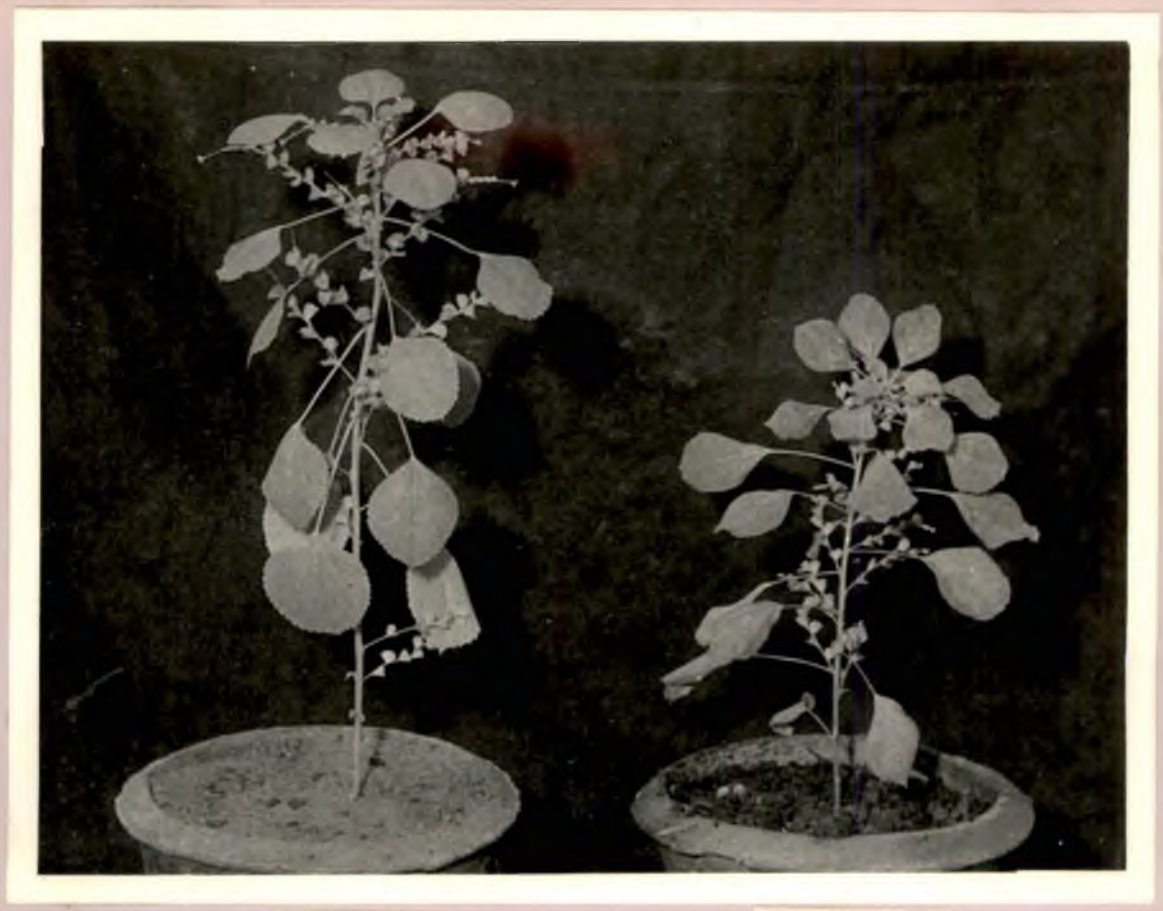
Plate No.6 Yellow mosaic of *Hemidesmus indicus*

7. Yellow mosaic of Micrococca mercurialis

The symptoms appeared as small circular, oblong or irregular yellow spots on the leaf lamina near the base. The veins and veinlets turned yellow in colour. In the initial stages the spots were limited by the veins and later spread as a broad band of chlorotic tissue. In advanced stages these spots became bright yellow, coalesced and gradually the whole leaf turned yellow. The leaves became small and occasionally cup shaped by the slight inward rolling of the margins(Plate 7). Shortening of the internodes, premature defoliation and shedding of flowers also occurred. The affected plants were severely stunted. Masking of symptoms was observed under reduced light intensity.

8. Yellow mosaic of Sebastiania chamaelea

The symptoms appeared as small circular or irregular yellow spots near the base or margin of the young leaves. Pale green and deep yellow areas alternated on the lamina showing the characteristic symptom of yellow mosaic. The veins and veinlets turned yellow and in advanced cases the colour of all the leaves turned almost complete yellow.



Healthy Diseased

Plate No.7 Yellow mosaic of Micrococca mercurialis

Healthy Diseased

Plate No.8 Yellow mosaic of Sebastiania chamaelea

Rolling of the margin of the leaves also occurred. In some cases localized cupping of the leaves was observed which appeared as galls when viewed from the abaxial side of the leaves. The size of the leaves was considerably reduced and the plants were stunted (Plate 8). Flowering and fruiting were also reduced.

9. Yellow vein mosaic of Sida cordifolia

The symptoms appeared as circular or irregular chlorotic spots on the young leaves of infected plants. The leaves later showed typical yellow vein mosaic pattern often followed by a general chlorosis of the leaves. Thickening of veins and development of enation were observed. Curling and cupping were also found associated with the yellow vein mosaic symptom (Plate 9). Plants with only one branch or part of a branch showing symptoms were also frequently observed in the field. The plants were stunted in growth, but flowers and fruits were not much affected. The yellow vein mosaic symptoms were masked under conditions of reduced light intensity.

10. Leaf curl of Stachytarpheta indica

The symptoms first appeared as mild curling of the young leaves. This was followed by severe curling and cupping

Healthy Diseased

Plate No.9 Yellow vein mosaic of *Sida cordifolia*

Healthy Diseased

Plate No.10 Leaf curl of *Stachytarpheta indica*

of the leaves. The leaves became thick, leathery and brittle. In advanced stages of infection the leaves became very small in size. The affected plants were severely stunted and showed bending of the spikes. The length and size of the spikes were also reduced (Plate 10).

11. Mosaic of Stachytarpheta indica

Irregular chlorotic patches with light and dark green shades were first observed on the young leaves. Later the chlorotic patches faded and characteristic mosaic symptoms appeared. This was followed by upward rolling of the leaf margins and the formation of raised blisters on the adaxial surface of the leaves. In severe cases of infection the leaves were considerably malformed and reduced in size and filiform in shape. The plants were severely stunted. The spikes became very thin and the flowers were sparsely distributed on them (Plate 11). Premature drying and shedding of the flowers were also observed.

12. Yellow mosaic mottle of Stachytarpheta indica var. jamaicensis

The symptoms appeared as circular or irregular chlorotic spots intermingled with dark green areas on the young leaves.

Healthy Diseased

Plate No.11 Mosaic of Stachytarpheta indica

Healthy Diseased

Plate No.12 Yellow mosaic mottle of Stachytarpheta indica var. jamaicensis

The veins and veinlets turned yellow in colour. These chlorotic spots later coalesced to form large yellow patches covering almost the entire lamina. This was followed by downward rolling of the leaf margins, mottling and distortion of the leaf blade. The plants were severely stunted and showed bending of the spikes. The length and size of the spikes were also reduced (Plate 12).

13. Leaf curl of Synedrella nodiflora

The initial symptom of the disease started as mild vein clearing of the young leaves. As the infection progressed the leaves were reduced in size with general stunting of the plant. The leaves showed curling and in some cases the leaf margins were chlorotic. The young leaves were pale green in colour. The older leaves were dark green, thick, leathery and brittle (Plate 13). The veins were thickened on the abaxial surface of the leaves. In the affected plants the production of flowers and fruits was not much affected.

II. Transmission

The results of different methods of transmission are presented below:-

Healthy Diseased

Plate No. 13 Leaf curl of *Synedrella nodiflora*

Healthy Diseased

Plate No. 14 Symptoms of yellow mosaic developed on *Micrococca mercurialis* by sap inoculation

1. Sap transmission

Among the 13 viruses studied only 3 viruses were sap transmissible, viz., mosaic of Amaranthus viridis, mosaic of Stachytarpheta indica and yellow mosaic of Micrococca mercurialis.

i). Mosaic virus of Amaranthus viridis

Symptoms of the virus infection appeared on test plants 10 - 14 days after inoculation with concentrated sap. The percentage of transmission was 90. In the plants inoculated with standard sap, symptoms appeared after 12-15 days of inoculation and the percentage of transmission was 70. When inoculated with the sap extracted in deionized water symptoms developed 12 - 15 days after inoculation. The percentage of transmission was 65. Symptoms of the disease appeared 10 - 12 days after inoculation with the sap extracted in phosphate buffer of pH 7.4 and the percentage of transmission was 90 (Table 1).

ii). Mosaic virus of Stachytarpheta indica

Symptoms of the virus infection developed on test plants 8 - 10 and 9 - 12 days after inoculation with concentrated sap

and standard sap respectively. The percentages of transmission were 60 and 40 respectively. When inoculated with the sap extracted in deionized water the symptoms appeared 10 - 12 days after inoculation and the percentage of transmission was 50. In the plants inoculated with the sap extracted in phosphate buffer of pH 7.4 the symptoms appeared 8-10 days after inoculation. The percentage of transmission was 90 (Table 1).

iii). Yellow mosaic virus of Micrococca mercurialis

Inoculations with concentrated sap, standard sap and sap extracted in deionized water were not successful. The virus was sap transmissible only when the sap was extracted in phosphate buffer (Plate 14). In the plants inoculated with the sap extracted in phosphate buffer of pH 7.0 and 7.4 at room temperature the symptoms developed 10 - 12 days after inoculation. The percentages of transmission were 40 and 60 respectively. When the plants were inoculated with the sap extracted in phosphate buffer of pH 7.0 and 7.4 in the cold the symptoms developed 9 - 11 days after inoculation. The percentages of transmission were 80 and 90 respectively (Table 1).

Table 1

Sap transmission of the viruses

Inoculum	Mosaic of *Amaranthus viridis*		Mosaic of *Stachytarpheta indica*		Yellow mosaic of *Micrococca mercurialis*	
	Incubation period in days	Per cent transmission	Incubation period in days	Per cent transmission	Incubation period in days	Per cent transmission
Concentrated sap	10-14	90	8-10	60	Nil	Nil
Standard sap	12-15	70	9-12	40	Nil	Nil
Sap extracted in deionized water	12-15	65	10-12	50	Nil	Nil
Sap extracted in phosphate buffer of pH 7.0 at 27-32°C.	*	*	*	*	10-12	40
Sap extracted in phosphate buffer of pH 7.4 at 27-32°C.	10-12	90	8-10	90	10-12	60
Sap extracted in phosphate buffer of pH 7.0 in the cold	*	*	*	*	9-11	80
Sap extracted in phosphate buffer of pH 7.4 in the cold	*	*	*	*	9-11	90

* Not attempted

2. Graft transmission

All the 13 viruses were transmitted by grafting. Symptoms of yellow vein mosaic virus and leaf curl virus infections appeared in Ageratum conizoides, 12 - 14 and 10 - 12 days respectively after grafting. The percentage of graft transmission was 90 in both cases. In the case of mosaic of Amaranthus viridis, mosaic of Clitoria ternatea, yellow vein mosaic of Croton sparsiflorus, yellow mosaic of Hemidesmus indicus and Micrococca mercurialis the symptoms appeared 12 - 14, 20 - 22, 15 - 17, 19 - 21 and 13 - 15 days respectively after grafting. The percentages of transmission were 60, 50, 100, 80 and 100 respectively. In yellow mosaic of Sebastiania chamaelea and yellow vein mosaic of Sida cordifolia the symptoms appeared 11 - 13 and 13 - 15 days respectively after grafting. The percentages of transmission were 90 and 100 respectively. Symptoms of leaf curl of Stachytarpheta indica, mosaic of Stachytarpheta indica and yellow mosaic mottle of Stachytarpheta indica var. jamaicensis appeared 20 - 22, 12 - 14 and 17 - 19 days respectively after grafting and the percentage of transmission was 100 in all the cases. In Synedrella nodiflora symptoms of leaf curl appeared 18-20 days

after grafting and 100 per cent graft transmission was obtained (Table 2).

3. Insect transmission

Out of the 13 viruses studied 8 were transmitted by whiteflies, Bemisia tabaci Genn. and 3 by aphids, Aphis craccivora Koch. and Aphis gossypii Glov. In the case of 2 viruses, viz., yellow mosaic of Hemidesmus indicus and Sebastiania chamaelea insect transmission trials were not successful.

i). Whitefly transmitted viruses

The following viruses were transmitted by whiteflies.

1. Yellow vein mosaic of Ageratum conizoides
2. Leaf curl of Ageratum conizoides
3. Yellow vein mosaic of Croton sparsiflorus
4. Yellow mosaic of Micrococca mercurialis
5. Yellow vein mosaic of Sida cordifolia
6. Leaf curl of Stachytarpheta indica
7. Yellow mosaic mottle of Stachytarpheta indica var. jamaicensis
8. Leaf curl of Synedrella nodiflora

Table 2

Graft transmission of the viruses

Name of the virus diseases	Incubation period (in days)	Percentage of transmission
Yellow vein mosaic of *Ageratum conizoides*	12-14	90
Leaf curl of *Ageratum conizoides*	10-12	90
Mosaic of *Amaranthus viridis*	12-14	60
Mosaic of *Clitoria ternatea*	20-22	50
Yellow vein mosaic of *Croton sparsiflorus*	15-17	100
Yellow mosaic of *Hemidesmus indicus*	19-21	80
Yellow mosaic of *Micrococca mercurialis*	13-15	100
Yellow mosaic of *Sebastiania chamaelea*	11-13	90
Yellow vein mosaic of *Sida cordifolia*	13-15	100
Leaf curl of *Stachytarpheta indica*	20-22	100
Mosaic of *Stachytarpheta indica*	12-14	100
Yellow mosaic mottle of *Stachytarpheta indica* var. *jamaicensis*	17-19	100
Leaf curl of *Synedrella nodiflora*	18-20	70

Symptoms of yellow vein mosaic virus and leaf curl virus disease of A.conizoides developed 11 - 14 and 13 - 15 days after inoculation with viruliferous whiteflies. In yellow vein mosaic of Croton sparsiflorus, yellow mosaic of Micrococca mercurialis and yellow vein mosaic of Sida cordifolia the symptoms appeared 14 - 16, 15 - 17 and 15 - 18 days respectively after inoculation with whiteflies. In leaf curl of Stachytarpheta indica, yellow mosaic mottle of Stachytarpheta indica var.jamaicensis and leaf curl of Synedrella nodiflora the symptoms appeared 21-23, 20-22 and 16-18 days respectively after inoculation with whiteflies. In all the above trials 100 per cent transmission were obtained when the plants were inoculated with 20 viruliferous whiteflies (Table 3).

11). Minimum number of whiteflies required for transmission of the viruses

Out of the 8 whitefly transmitted viruses, 6 were transmitted by a single viruliferous whitefly, Bemisia tabaci. They are yellow vein mosaic of Ageratum conizoides (Table 4; Fig.1); leaf curl of Ageratum conizoides (Table 5: Fig.2); yellow vein mosaic of Croton sparsiflorus (Table 6; Fig.3);

Table 3

Whitefly transmission of the viruses

Name of the disease	Incubation period (in days)	Percentage of transmission
Yellow vein mosaic of *Ageratum conizoides*	11-14	100
Leaf curl of *Ageratum conizoides*	13-15	100
Yellow vein mosaic of *Corton sparsiflorus*	14-16	100
Yellow mosaic of *Micrococca mercurialis*	15-17	100
Yellow vein mosaic of *Sida cordifolia*	15-18	100
Leaf curl of *Stachytarpheta indica*	21-23	100
Yellow mosaic mottle of *Stachytarpheta indica* var. *jamaicensis*	20-22	100
Leaf curl of *Synedrella nodiflora*	16-18	100

leaf curl of Stachytarpheta indica(Table 9; Fig.6);yellow mosaic mottle of Staohytarpheta indica var. jamaicensis (Table 10; Fig.7) and leaf curl of Synedrella nodiflora (Table 11; Fig.8). The minimum number of whiteflies required for successful transmission of yellow mosaic of Micrococca mercurialis (Table 7; Fig.4) and yellow vein mosaic of Sida cordifolia (Table 8; Fig.5) was found to be two.

In leaf curl of A.conizoides, yellow vein mosaic of C.sparsiflorus, leaf curl of S. indica and yellow mosaic mottle of S. indica var.jamaicensis 10 viruliferous whiteflies were required to obtain 100 per cent transmission. Fifteen whiteflies were required for 100 per cent transmission of yellow vein mosaic of A.conizoides. In yellow mosaic of M.mercurialis, yellow vein mosaic of Sida cordifolia and leaf curl of Synedrella nodiflora 20 viruliferous whiteflies were necessary for 100 per cent transmission.

iii). Aphid transmitted viruses

Mosaic viruses of Amaranthus viridis, Clitoria ternatea and Stachytarpheta indica were found to be transmitted by both the species of aphids tried, viz., Aphis craccivora and Aphis gossypii.

Table 4

Number of viruliferous whiteflies and per cent transmission of yellow vein mosaic of *Ageratum conizoides*

Number of whiteflies per plant	Number of plants infected / Number of plants inoculated				Per cent transmission
	I	II	III	Total	
0	0/8	0/12	0/10	0/30	0.00
1	4/12	4/12	3/10	11/34	32.35
2	3/10	6/15	4/10	13/35	37.14
3	6/12	5/13	6/10	7/35	48.57
5	8/14	6/13	7/10	21/37	56.76
10	10/10	12/15	8/10	30/35	85.71
15	10/10	15/15	10/10	35/35	100.00
20	15/15	13/13	10/10	38/38	100.00

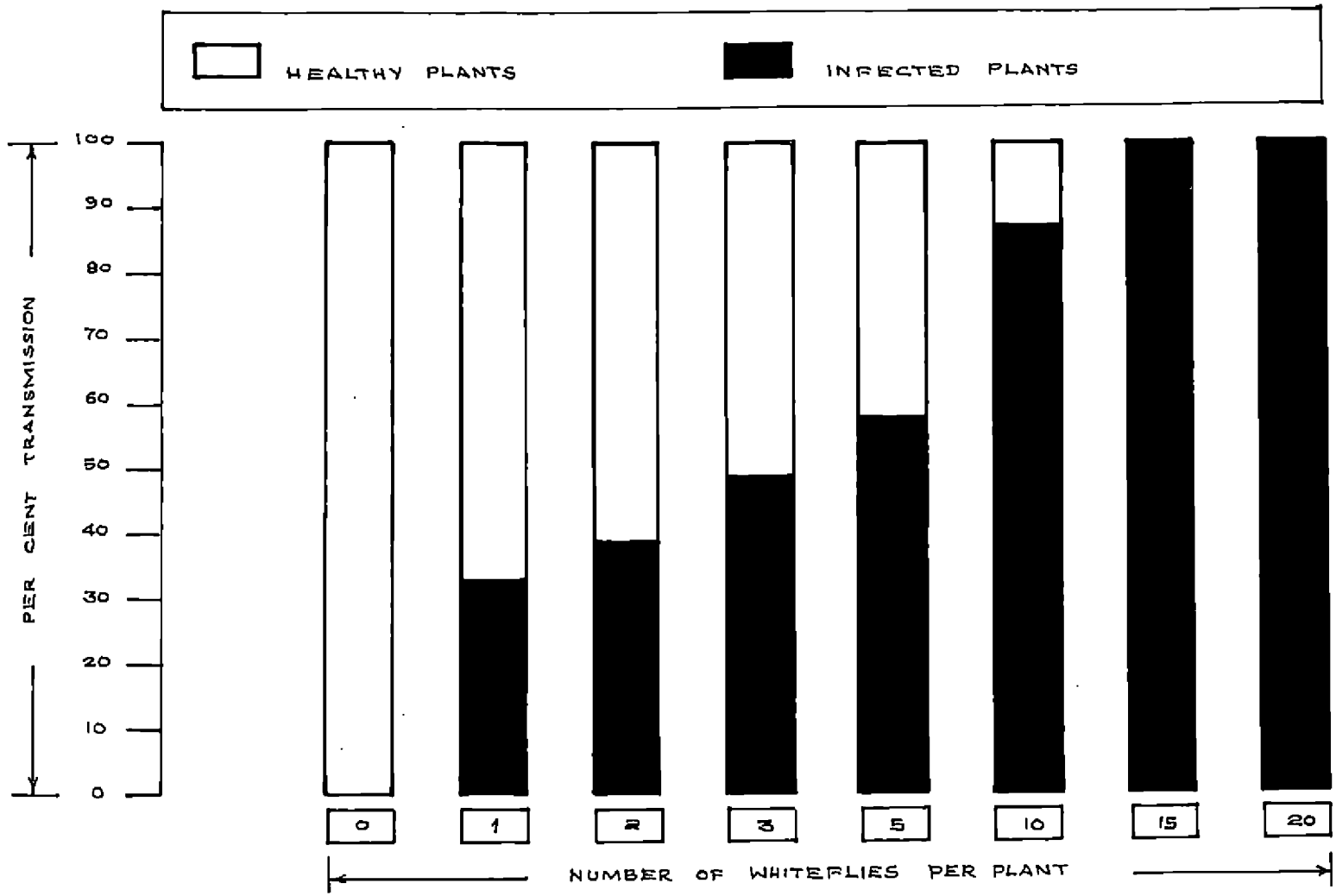


FIG: 1. TRANSMISSION OF YELLOW VEIN MOSAIC VIRUS OF *Ageratum conizoides* BY *Bemisia tabaci*

Table 5

Number of viruliferous whiteflies and the per cent transmission of leaf curl of *Ageratum conizoides*

Number of whiteflies per plant	Number of plants infected / Number of plants inoculated				Per cent transmission
	I	II	III	Total	
0	0/10	0/15	0/10	0/35	0.00
1	2/10	4/15	2/10	8/35	22.86
2	4/12	4/13	3/10	11/35	31.43
3	5/13	5/12	4/10	14/35	40.00
5	10/15	7/12	7/10	24/35	64.86
10	14/14	13/13	10/10	37/37	100.00
15	13/13	12/12	10/10	35/35	100.00
20	16/16	14/14	10/10	40/40	100.00

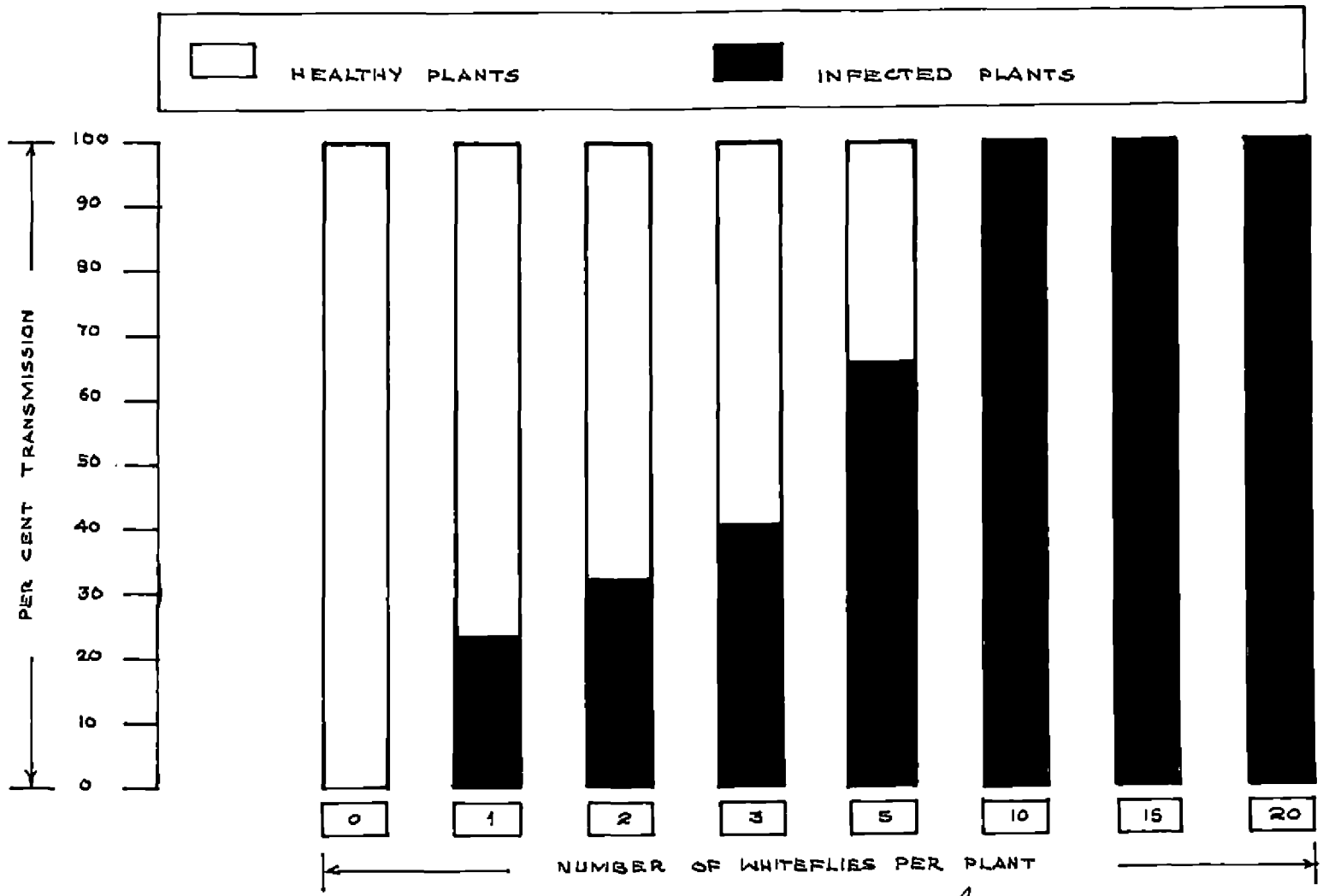


FIG: 2 TRANSMISSION OF LEAF CURL VIRUS OF *Ageratum conizoides* BY *Bemisia tabaci*

Table 6

Number of viruliferous whiteflies and per cent transmission of yellow vein mosaic of Croton sparsiflorus

Number of whiteflies per plant	Number of plants infected / Number of plants inoculated				Per cent transmission
	I	II	III	Total	
0	0/10	0/12	0/10	0/32	0.00
1	2/10	3/12	2/10	7/32	21.88
2	3/13	3/10	2/10	8/33	24.24
3	5/12	6/13	4/10	15/35	42.86
5	9/13	8/12	8/10	26/35	74.29
10	13/13	12/12	10/10	35/35	100.00
15	12/12	14/14	10/10	36/36	100.00
20	14/14	16/16	10/10	40/40	100.00

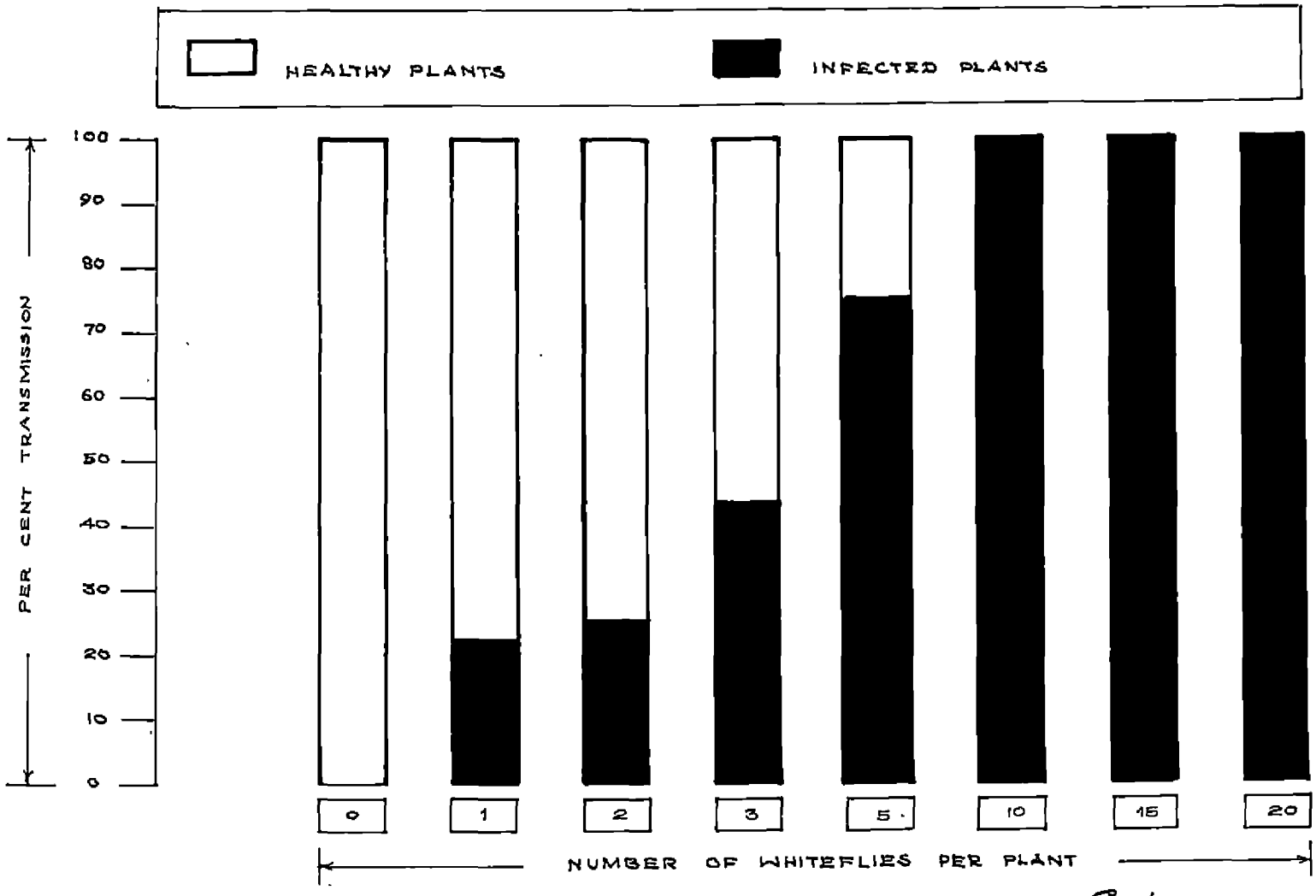


FIG: 3 TRANSMISSION OF YELLOW VEIN MOSAIC VIRUS OF *Croton sparsiflorus* BY *Bemisia tabaci*

Table 7

Number of viruliferous whiteflies and the per cent transmission of yellow mosaic of Micrococca mercurialis

Number of whiteflies per plant	Number of plants infected / Number of plants inoculated				Per cent transmission
	I	II	III	Total	
0	0/10	0/12	0/10	0/32	0.00
1	0/15	0/15	0/10	0/40	0.00
2	2/15	1/12	2/10	5/37	13.51
3	3/14	4/15	4/10	11/39	28.21
5	5/15	6/12	5/10	16/37	43.24
10	8/13	9/15	6/10	23/38	60.53
15	13/15	9/12	8/10	30/37	81.08
20	15/15	15/15	10/10	40/40	100.00

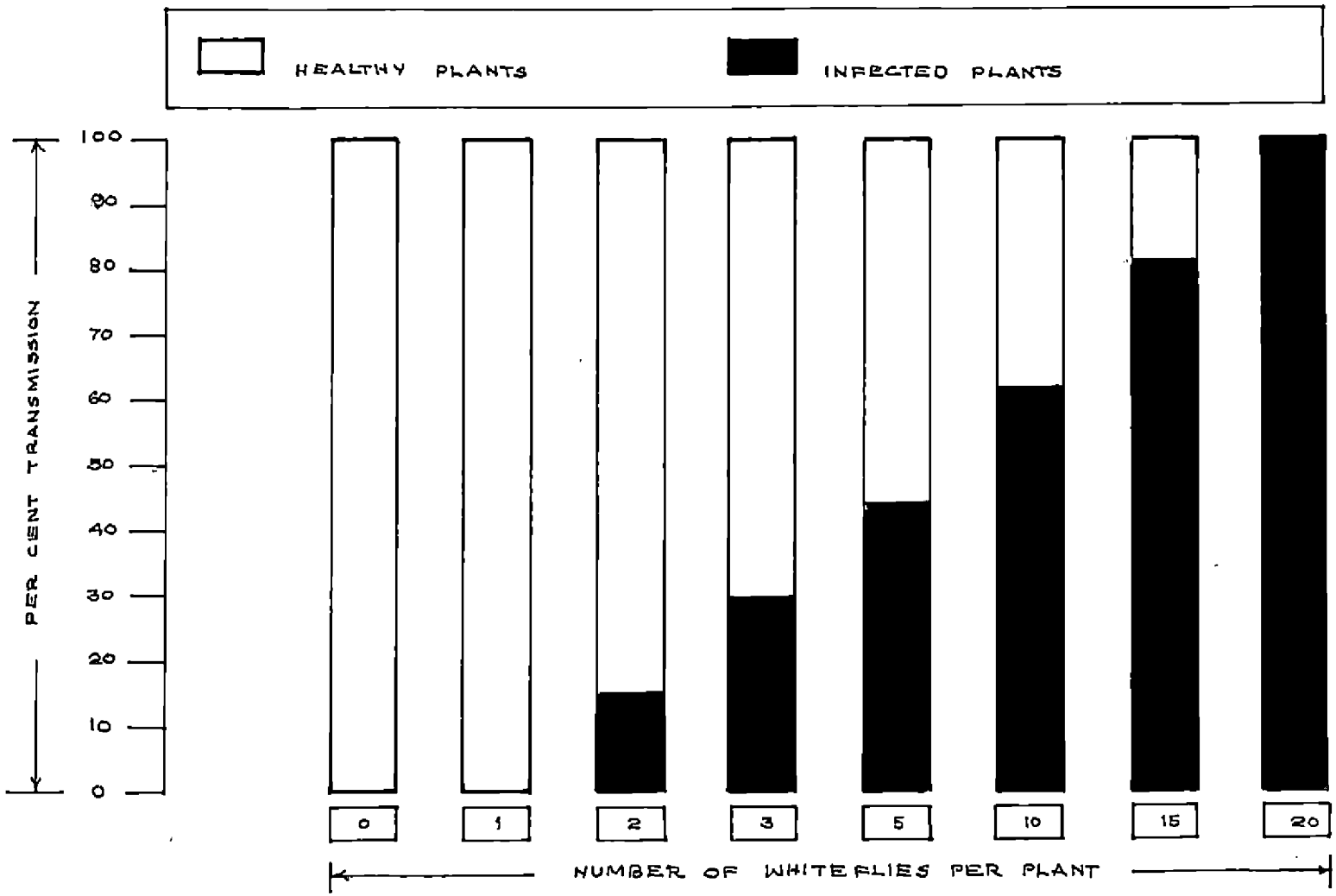


FIG: 4 TRANSMISSION OF YELLOW MOSAIC VIRUS OF *Micrococca mercurialis* BY *Bemisia tabaci*

Table 8

Number of viruliferous whiteflies and per cent transmission of yellow vein mosaic of *Sida cordifolia*

Number of whiteflies per plant	Number of plants infected / Number of plants inoculated				Per cent transmission
	I	II	III	Total	
0	0/12	0/13	0/10	0/35	0.00
1	0/14	0/16	0/10	0/40	0.00
2	2/15	3/15	2/10	7/40	17.50
3	3/14	5/16	4/10	12/40	30.00
5	8/15	5/13	6/10	19/38	50.00
10	10/15	9/14	8/10	27/39	69.23
15	11/14	12/16	9/10	30/40	75.00
20	15/15	14/14	10/10	39/39	100.00

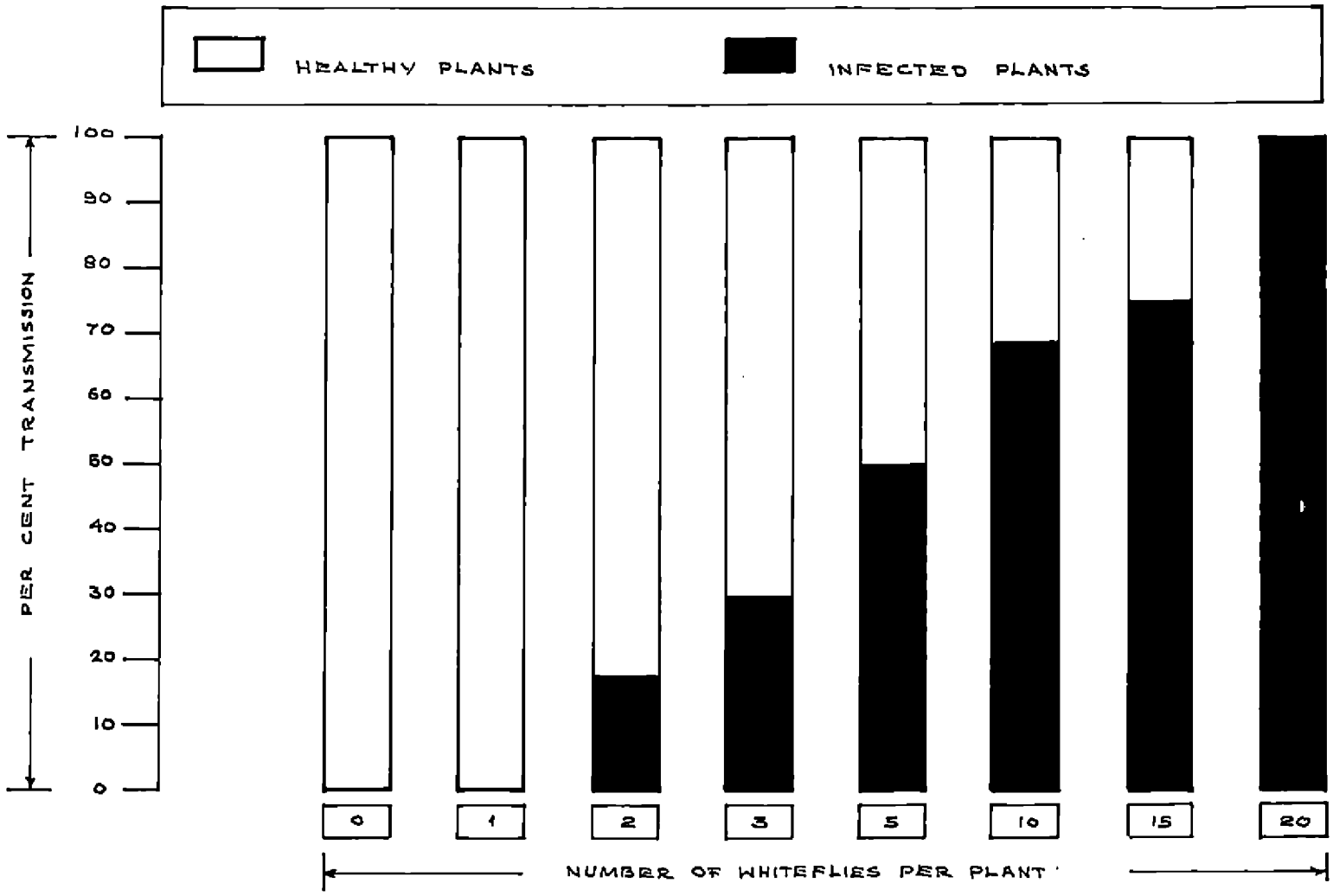


FIG: 5 TRANSMISSION OF YELLOW VEIN MOSAIC VIRUS OF *Sida cordifolia* BY *Bemisia tabaci*

Table 9

Number of viruliferous whiteflies and the percent transmission of leaf curl of Stachytarpheta indica

Number of whiteflies per plant	Number of plants infected / Number of plants inoculated				Per cent transmission
	I	II	III	Total	
0	0/12	0/13	0/10	0/35	0.00
1	3/14	3/12	2/10	8/36	22.22
2	4/13	5/15	4/10	13/38	34.21
3	7/15	9/15	6/10	22/40	55.00
5	9/14	11/16	8/10	28/40	70.00
10	15/15	15/15	10/10	40/40	100.00
15	13/13	12/12	10/10	35/35	100.00
20	16/16	12/12	10/10	38/38	100.00

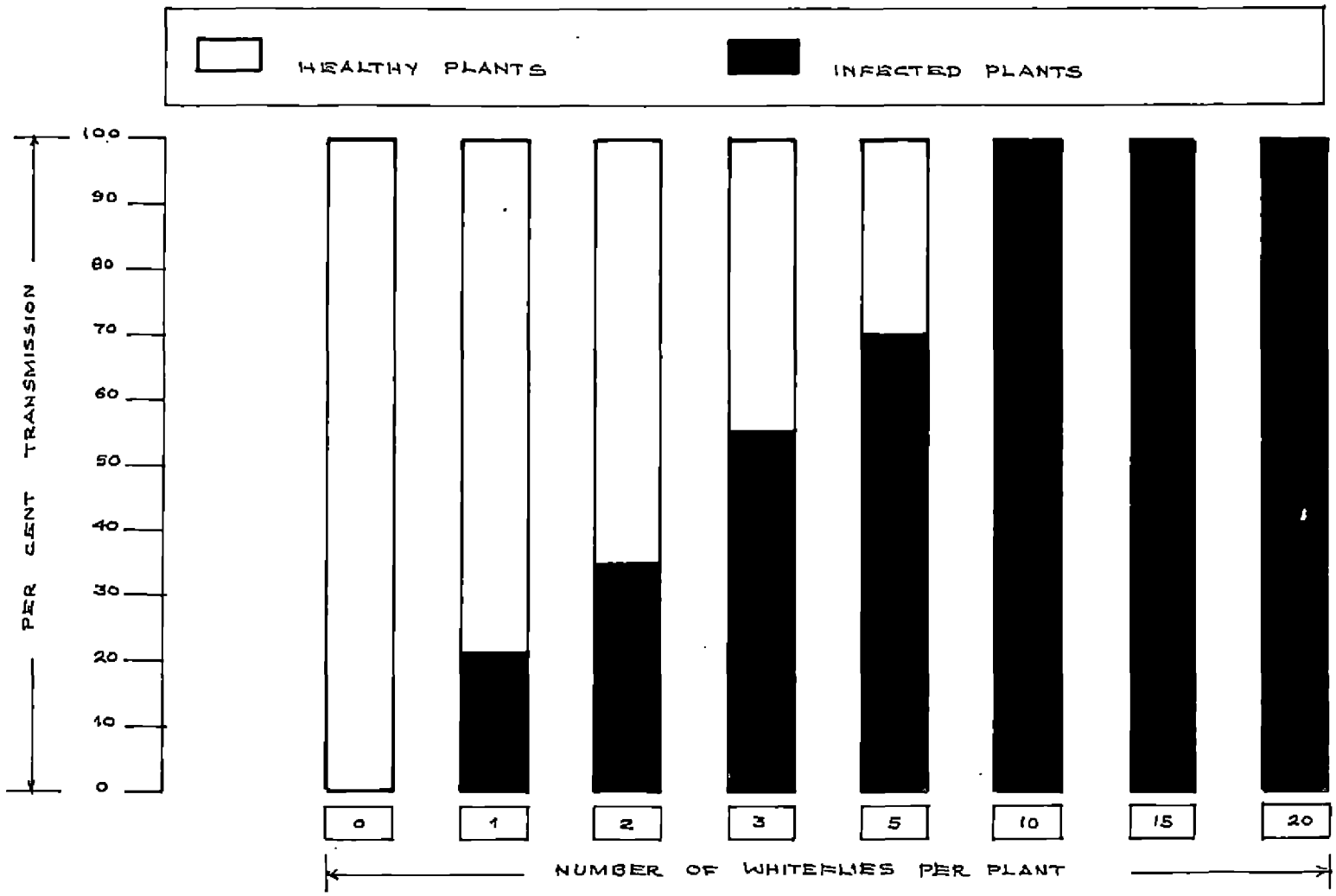


FIG: 6 TRANSMISSION OF LEAF CURL VIRUS OF *Stachytarpheta indica* BY *Bemisia tabaci*

Table 10

Number of viruliferous whiteflies and the per cent transmission of yellow mosaic mottle of *Stachytarpheta indica* var. *jamaicensis*

Number of whiteflies per plant	Number of plants infected / Number of plants inoculated				Per cent transmission
	I	II	III	Total	
0	0/13	0/12	0/10	0/25	0.00
1	4/15	5/15	3/10	12/40	30.00
2	5/12	6/16	4/10	15/38	39.49
3	7/14	8/13	6/10	21/37	56.76
5	10/15	9/15	8/10	28/40	70.00
10	14/14	16/16	10/10	40/40	100.00
15	13/13	12/12	10/10	35/35	100.00
20	16/16	13/13	10/10	39/39	100.00

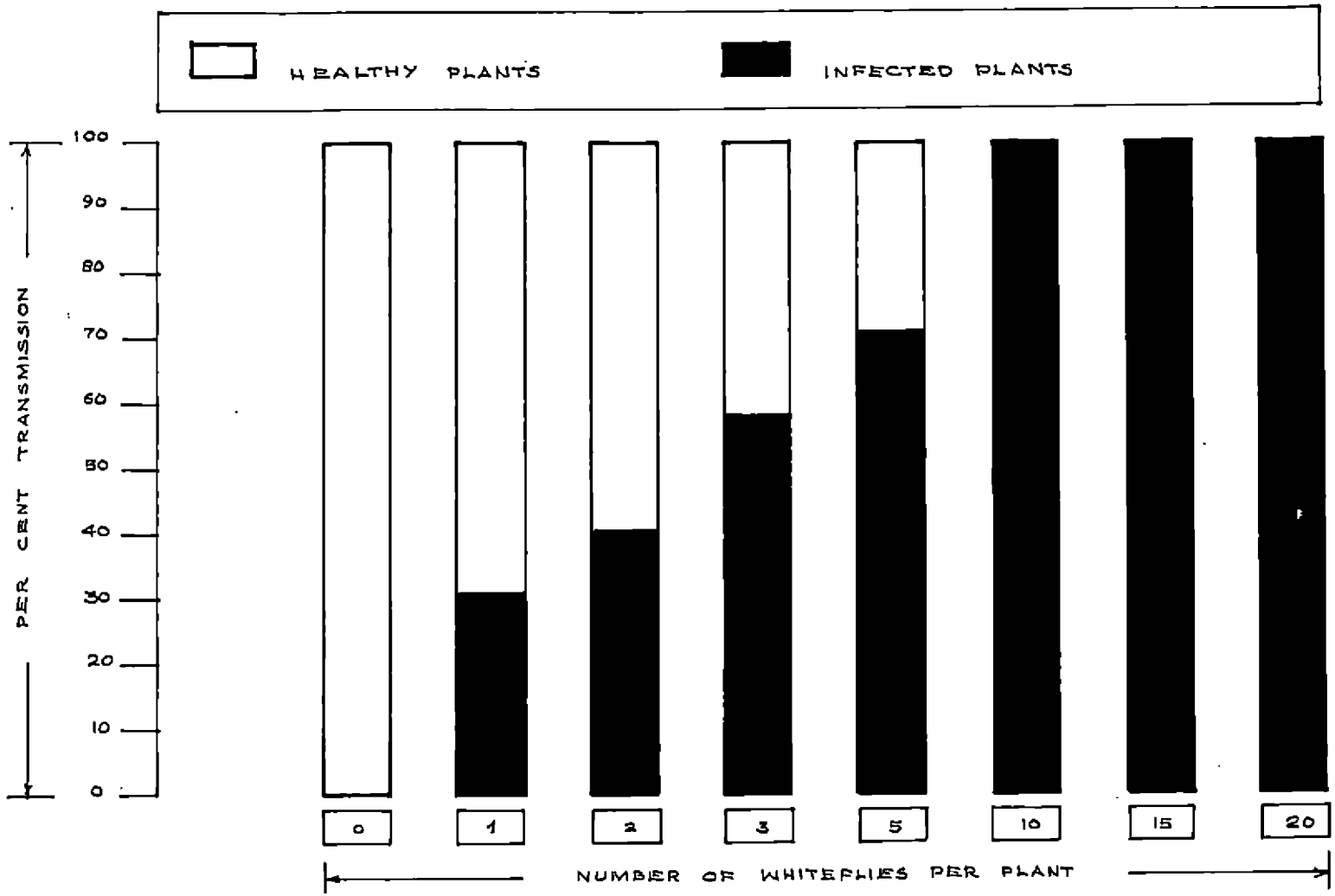


FIG: 7 TRANSMISSION OF YELLOW MOSAIC MOTTLE VIRUS OF *Stachytarpheta indica* var: *jamaicensis* BY *Bemisia tabaci*

Table 11

Number of viruliferous whiteflies and the per cent transmission of leaf curl of Synedrella nodiflora

Number of whiteflies per plant	Number of plants infected / Number of plants inoculated				Per cent transmission
	I	II	III	Total	
0	0/15	0/15	0/10	0/40	0.00
1	3/14	2/15	2/10	8/39	20.51
2	4/15	3/15	4/10	11/40	27.50
3	6/16	5/12	4/10	15/38	39.47
5	7/15	8/15	6/10	21/40	52.50
10	8/14	9/15	8/10	25/39	64.10
15	10/15	12/15	8/10	30/40	75.00
20	15/15	15/15	10/10	40/40	100.00

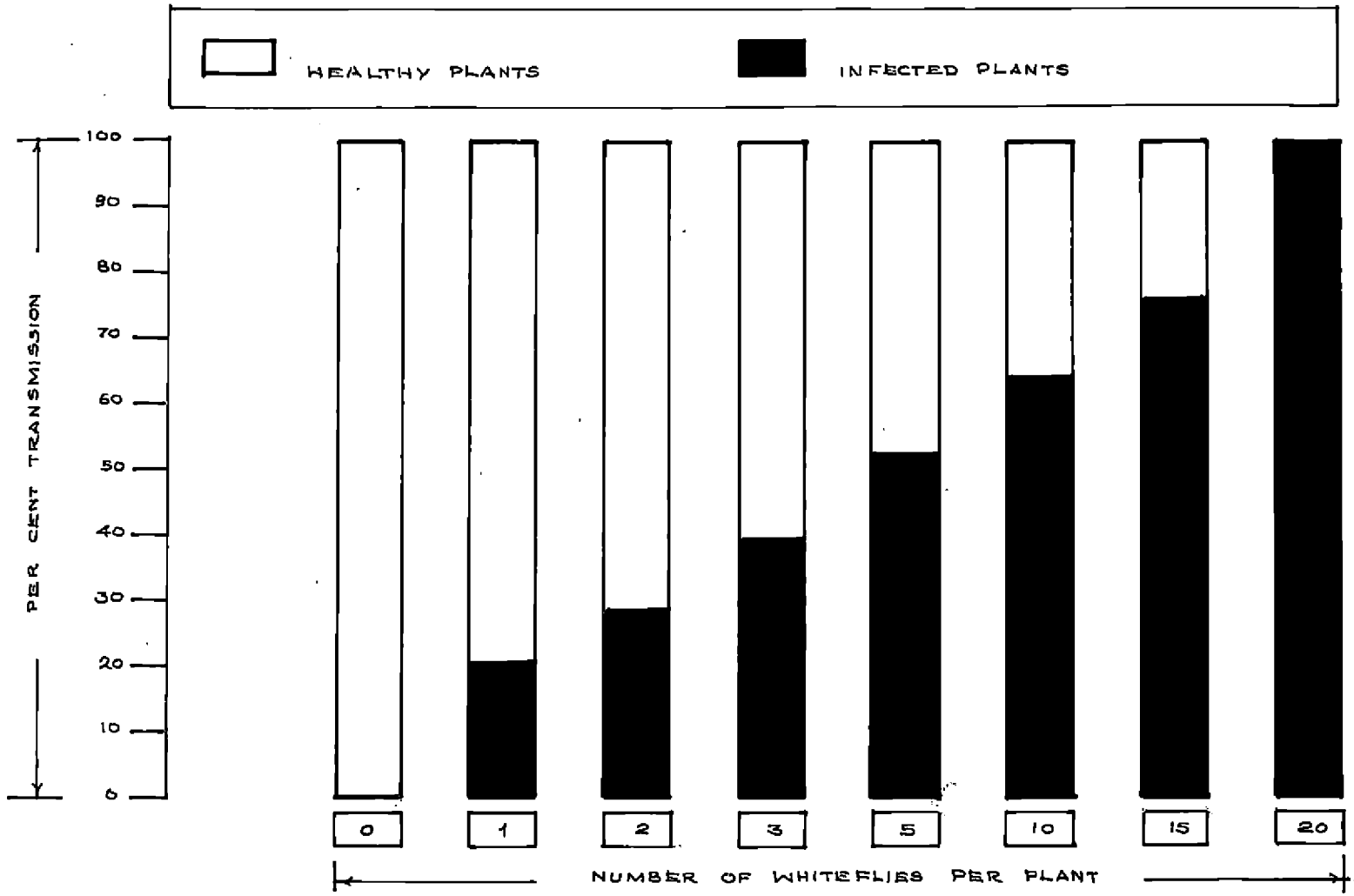


FIG: 8 TRANSMISSION OF LEAF CURL VIRUS OF *Synedrella nodiflora* BY *Bemisia tabaci*

The mosaic virus of A.viridis was transmitted by Aphis craccivora and A.gossypii and the percentages of transmission were 80 and 90 respectively. The symptoms developed 14-16 and 11-13 days respectively after inoculation with the viruliferous aphids (Table 15).

In C.ternatea the symptoms of mosaic appeared 20-23 days after inoculation with viruliferous A.craccivora and A. gossypii. The percentages of transmission were 100 and 70 respectively.

The mosaic virus of S.indica was also transmitted by A.craccivora and A.gossypii and the percentages of transmission were 60 and 40 respectively. The symptoms developed 12 - 14 and 13 - 15 days respectively after inoculation with the aphids (Table 16).

4. Seed transmission

None of the 12 viruses tested was found to be transmitted through seeds. The plants did not show any symptom of the disease upto 40 days of growth, indicating that the viruses are not transmitted through seeds.

III. Physical properties of the viruses

1. Mosaic virus of *Amaranthus viridis*

i). Dilution end point

The dilution end point of the virus was found to be between 1:1500 and 1:2000.

In control (concentrated sap) 90 per cent of the test plants became infected. The percentage of transmission decreased when diluted sap was inoculated on the test plants. When the dilution was 1:500 the percentage of transmission was 30 and further reduced to 15 and 8 when the dilutions were 1:1000 and 1:1500 respectively. There was no infection at dilutions 1:2000 and above (Table 12).

ii). Thermal inactivation point

The thermal inactivation point of the virus was found to be between 55 and 60°C.

The percentage of transmission was 80 when concentrated sap at room temperature (control) was used for inoculating the test plants. The percentages of transmission were reduced when the sap treated at higher temperatures was used for

Table 12

Physical properties of the mosaic virus of *Amaranthus viridis*

Dilution end point		Thermal inactivation point		Longevity *in vitro*		
Dilution	Per cent transmission	Temp. °C.	Per cent transmission	Age of the sap in hours	Per cent transmission	
					At room temp. (27-32°C)	At 5-10°C
Control	90	Control	80	Control	80	..
1: 10	60	40	60	4	70	70
1: 100	40	45	40	8	50	60
1: 500	30	50	30	16	40	50
1: 750	20	55	20	24	30	40
1:1000	15	60	0	32	20	40
1:1500	8	65	0	48	10	20
1:2000	0	70	0	72	0	10
1:2500	0	75	0	96	0	0
1:5000	0	80	0	120	0	0
		85	0	144	0	0
		90	0	168	0	0

inoculation. When the temperature was increased to 40, 45 50 and 55°C the corresponding percentages of transmission were 60, 40, 30 and 20 respectively. There was no transmission when the sap used for inoculation was treated at 60°C and above and the test plants remained completely healthy (Table 12).

iii). Longevity in vitro

The longevity in vitro of the virus at room temperature was found to be between 48 and 72 hours and that at 5-10°C, between 72 and 96 hours.

Eighty per cent of the test plants became infected in the control whereas the per cent transmission was 70 when the sap was inoculated after 4 hours of storage both at room temperature as well as at 5-10°C. After 8 hours of storage at room temperature and at 5-10°C the percentages of transmission were 50 and 60 respectively. When the duration of storage was increased to 16, 24, 32, 48 and 72 hours the corresponding percentages of transmission at the two sets of temperatures were 40 and 50, 30 and 40, 20 and 40, 10 and 20 and zero and 10 respectively. There was no transmission when

the sap was stored for 72 hours or more at room temperature and for 96 hours or more at 5-10°C (Table 12).

2. Mosaic virus of Stachyterpheta indica

i). Dilution end point

The dilution end point of the virus was found to be between 1:750 and 1:1000.

When concentrated sap (control) was used for inoculation 100 per cent transmission was obtained. The percentage of transmission decreased when diluted sap was used for inoculation. The percentages of transmission were 80, 50, 30 and 20 at 1:10, 1:100, 1:500 and 1:750 dilutions respectively. At 1:1000 dilution and above there was no infection and the test plants remained completely healthy (Table 13).

ii). Thermal inactivation point

The thermal inactivation point of the virus was found to be between 70 and 75°C.

The percentage of transmission was 100 in the control. When the temperature was increased to 40, 45, 50, 55, 60, 65 and 70°C the corresponding percentages of transmission were

Table 13

Physical properties of the mosaic virus of Stachytarpheta indica

Dilution end point		Thermal inactivation point		Longevity in vitro		
Dilution	Per cent transmission	Temperature °C	Per cent transmission	Age of the sap in hours	Per cent transmission	
					At room temp. (27-32°C)	At 5-10°C
Control	100	Control	100	Control	100	..
1: 10	80	40	80	4	100	100
1:100	50	45	70	8	80	100
1:500	30	50	50	16	60	80
1:750	20	55	40	24	40	60
1:1000	0	60	20	32	40	50
1:1500	0	65	10	48	20	40
1:2000	0	70	8	72	0	20
1:2500	0	75	0	96	0	10
1:5000	0	80	0	120	0	0
		85	0	144	0	0
		90	0	168	0	0

80, 70, 50, 40, 20, 10 and 8 respectively. There was no transmission when the sap treated at 75°C and above was used for inoculation and the test plants remained completely healthy (Table 13).

iii). Longevity in vitro

The longevity in vitro of the virus at room temperature was found to be between 48 and 72 hours and that at 5-10°C between 96 and 120 hours.

When the sap at room temperature (control) was immediately used for inoculation 100 per cent transmission was obtained. The percentage of transmission was 100 even after the sap was stored for 4 hours, both at room temperature as well as at 5-10°C. When the duration of storage was increased to 8, 16, 32, 48, 72 and 96 hours the corresponding percentages of transmission at the two sets of temperatures were 80 and 100, 60 and 80, 40 and 60, 40 and 50, 20 and 40, zero and 20 and zero and 10 respectively. The virus lost its infectivity when the sap was stored for 72 hours or more at room temperature and for 120 hours or more at 5-10°C (Table 13).

3. Yellow mosaic virus of Micrococca mercurialis

i). Dilution end point

It has been found that the dilution end point of the virus was between 1:10 and 1:25.

When the sap extracted in phosphate buffer of pH 7.4 (control) was used for inoculation of the test plants, 60 per cent transmission was obtained. At 1:10 dilution, 20 per cent of the inoculated test plants were found to be infected. There was no infection at 1:25 dilution and above (Table 14).

ii). Thermal inactivation point

The thermal inactivation point of the virus was found to be between 50 and 55°C.

When the sap at room temperature (control) was used for inoculating the test plants 60 per cent transmission was obtained. When the temperature was increased to 40, 45 and 50°C the corresponding percentages of transmission were 40, 30 and 10 respectively. There was no infection when the sap treated at 55°C and above was used for inoculation (Table 14).

Table 14

Physical properties of the yellow mosaic virus of *Micrococca marcurialis*

Dilution end point		Thermal inactivation point		Longevity *in vitro*		
Dilution	Per cent transmission	Temperature °C	Per cent transmission	Age of the sap in hours	Per cent transmission	
					At room temp. (27-32°C)	At 5-10°C
Control	60	Control	60	Control	60	..
1:10	20	40	40	4	30	30
1: 25	0	45	30	8	20	30
1:50	0	50	10	16	0	20
1:75	0	55	0	24	0	10
1:100	0	60	0	32	0	0
		65	0	32	0	0
		70	0	48	0	0
		75	0	72	0	0
		80	0	96	0	0
		85	0	120	0	0
		90	0	144	0	0
				168	0	0

Table 15

Aphid transmission of the mosaic virus of *Amaranthus viridis*

Species of plants susceptible to the mosaic virus isolate	*Aphis craccivora*		*Aphis gossypii*	
	Incubation period in days	Per cent transmission.	Incubation period in days	Per cent transmission
Amaranthus caudatus	14-16	80	11-13	80
Amaranthus gangeticus	13-16	70	12-14	80
Amaranthus viridis	14-16	80	11-13	90
Celosia cristata	15-17	50	13-15	60
Gomphrena globosa	14-17	50	12-15	50

Table 16

Aphid transmission of the mosaic virus of *Stachytarpheta indica*

Species of plants susceptible to the mosaic virus isolate	*Aphis craccivora*		*Aphis gossypii*	
	Incubation period in days	Per cent transmission	Incubation period in days	Per cent transmission
Benincasa hispida	11-13	50	Nil	Nil
Cucumis sativus	11-13	60	13-15	50
Cucurbita maxima	Nil	Nil	Nil	Nil
Nicotiana tabacum var. white Burley	12-14	80	12-14	60
Nicotiana tabacum var. Samsun	12-14	70	13-15	60
Stachytarpheta indica	12-14	60	13-15	40
Stachytarpheta indica var. *jamaicensis*	12-14	60	13-15	40
Trichosanthus anguina	11-13	50	12-14	50

iii). Longevity in vitro

It has been foundsthat the longevity in vitro of the virus at room temperature was between 8 and 16 hours and that at 5-10°C between 24 and 32 hours.

When the sap at room temperature (control) was immediately used for inoculation 60 per cent of the test plants became infected. The percentage of transmission was 30 when the sap was stored for 4 hours both at room temperature and at 5-10°C. When the sap was stored for 8, 16 and 24 hours the corresponding percentages of transmission at the two sets of temperatures were 20 and 30, zero and 20 and zero and 10 respectively. There was no infection when the sap was stored for 16 hours or more at room temperature and for 32 hours or more at 5-10°C (Table 14).

IV. Host range

Out of the 13 virus diseases affecting weeds studied, 5 were not able to infect any plants other than their natural hosts. They are yellow vein mosaic of Ageratum conizoides, leaf curl of A.conizoides, mosaic of Clitoria ternatea, yellow mosaic of Micrococca mercurialis and leaf

curl of Synedrella nodiflora. In the case of yellow mosaic viruses of Hemidesmus indicus and Sebastiania chamaelea, transmission to the original hosts was obtained only by grafting and therefore, host range studies were not carried out.

Six viruses, viz., mosaic of Amaranthus viridis, yellow vein mosaic of Croton sparsiflorus and Sida cordifolia, leaf curl of Stachytarpheta indica, yellow mosaic mottle of S.indica var. jamaicensis and mosaic of Stachytarpheta indica, on artificial inoculation infected other plants including some economically important crop plants. These six viruses, which gave positive results in host range studies, when back inoculated to their original hosts produced the original symptoms, except yellow vein mosaic of C.sparsiflorus.

1. Mosaic virus of Amaranthus viridis.

The host range of the virus was studied by inoculating the concentrated sap extracted from diseased plants on healthy test plants. The virus was transmitted to four host plants, A.caudatus, A.gangeticus, Celosia cristata and Gomphrena globosa, all belonging to the family Amaranthaceae.

i). Amaranthus caudatus

The virus produced symptoms of vein clearing, mosaic mottling, reduction in leaf size and stunted growth after 10-14 days of inoculation. The percentage of transmission was 80.

ii). Amaranthus gangeticus

On Amaranthus gangeticus also the virus produced similar symptoms as on A.caudatus after 10-14 days of inoculation and 75 per cent of the test plants became infected.

iii). Celosia cristata

On Celosia cristata symptoms of mosaic mottling, vein clearing, chlorosis, reduction in leaf size and stunted growth resulted 10-14 days after inoculation. Sixty per cent of the test plants were infected.

iv). Gromphrena globosa

The virus produced chlorosis, mosaic mottling and stunting of the plants 10-14 days after inoculation and the percentage of transmission was 45.

The above findings on the host range of the mosaic virus of A.viridis was confirmed by aphid transmission of the virus to all the 4 hosts. It has been found that A.gossypii was more efficient than A.craccivora in transmitting the virus. The incubation period of the virus in the plants was less and per cent transmission was more when the virus was transmitted by A.gossypii (Table 15).

2. Yellow vein mosaic virus of Croton sparsiflorus

The host range of the virus was studied by inoculating the test plants by viruliferous whiteflies, Bemisia tabaci. The virus was transmitted only to a single species of test plant, viz., Lycopersicon esculentum, belonging to the family Solenaceae.

On L.esculentum the virus produced mild vein clearing and leaf curl symptoms 16-18 days after inoculation. Diffused chlorotic spots were observed on the leaves, which becam thick, short and leathery in appearance. The leaf-lets were irregularly curled (Plate 15). The plants were stunted, flowering and fruiting were also badly affected. Eighty per cent of the inoculated plants were infected. The virus was not transmitted from tomato to tomato and back to the

Healthy Diseased

Plate No. 15 Symptoms of leaf curl developed on tomato (Lycopersicon esculentum) by inoculating the yellow vein mosaic virus of Croton sparsiflorus

Healthy Diseased

Plate No.16 Symptoms of leaf curl developed on tomato (Lycopersicon esculentum) by inoculating the yellow vein mosaic virus of Sida cordifolia

original host. Attempts to transmit the virus from tomato to tobacco by both grafting and by whiteflies were not successful. The virus was also not transmitted from tomato to tomato and back to C.sparsiflorus by mechanical means.

3. Yellow vein mosaic virus of Sida cordifolia

The host range of the virus was studied by inoculating the test plants by viruliferous Bemisia tabaci. The host range was confined to a single species of test plant, viz., Lycopersicon esculentum.

The virus infected L.esculentum with the production of leaf curl symptoms. The symptoms started as mild vein clearing of the younger leaves after 20-23 days of inoculation. Later irregular curling of the leaf-lets, thickening of veins on the abaxial surface of the leaves and reduction in leaf size were resulted. The internodes were shortened and the plants were stunted (Plate 16). Flowering and fruiting were severely affected and 100 per cent of the test plants became infected. The virus was transmitted from tomato to tomato and back to the original host by B.tabaci. Attempts to transmit the virus from tomato to tobacco by both grafting and by B.tabaci were not successful. The virus

was also not transmitted from tomato to tomato and back to the original host by mechanical means.

4. Leaf curl virus of Stachytarpheta indica

The host range of the virus was studied by inoculating the test plants by viruliferous Bemisia tabaci. The virus infected two species of the test plants, viz., Lycopersicon esculentum, belonging to the family Solanaceae and Stachytarpheta indica var. jamaicensis of the family Verbenaceae.

i). Lycopersicon esculentum

The symptoms first appeared as mild mosaic and curling of the young leaf-lets after 20-22 days of inoculation. The leaves of infected plants became thick, leathery and hard (Plate 17). The plants were stunted, but flowering and fruiting were not affected much. The infected plants showed only mild leaf curl symptoms and 60 per cent of the test plants became infected. The virus was not transmitted from tomato to tomato but transmitted back to S. indica by B. tabaci. Attempts made to transmit the virus from tomato to tobacco by both grafting and by B. tabaci were not successful. The

virus was not transmitted from tomato to tomato and back to the original host by mechanical means.

ii). Stachytarpheta indica var. jamaicensis.

On S. indica var. jamaicensis the virus produced symptoms of leaf curl and mottling 18-20 days after inoculation. The plants were stunted and 80 per cent of the test plants became infected. The virus was easily transmitted back to the original host by B. tabaci. The virus was not transmitted to tobacco from S. indica var. jamaicensis by both grafting and by B. tabaci.

5. Yellow mosaic mottle virus of Stachytarpheta indica var. jamaicensis

The host range of the virus was studied by inoculating the test plants by viruliferous B. tabaci. The host range was confined to 3 species of test plants, viz., Lycopersicon esculentum of the family Solanaceae, Celosia cristata of the family Amaranthaceae and Stachytarpheta indica of the family Verbenaceae.

Healthy Diseased

Plate No.17 Symptoms of leaf curl developed on tomato (Lycopersicon esculentum) by inoculating the leaf curl virus of Stachytarpheta indica

Healthy Diseased

Plate No.18 Symptoms of leaf curl developed on tomato (Lycopersicon esculentum) by inoculating the yellow mosaic mottle virus of Stachytarpheta indica var.jamaicensis.

i). Lycopersicon esculentum

The initial symptoms appeared as chlorotic spots on the younger leaves after 18-20 days of inoculation. Later these chlorotic spots became diffused and the leaves exhibited curling of the leaf margins and thickened veins. The infected plants showed severe leaf curl symptoms. The internodes were shortened and the plants were severely stunted (Plate 18). Flowering and fruiting were completely arrested and 60 per cent of the test plants became infected. The virus was not transmitted from tomato to tomato but transmitted back to the original host by B.tabaci. Attempts to transmit the virus from tomato to tobacco by both grafting and by B.tabaci were not successful. The virus was also not transmitted from tomato to tomato and back to the original host by mechanical means.

ii). Celosia cristata

The symptoms first appeared as mild curling and crinkling of the leaves with chlorotic streaks 12-14 days after inoculation. The margins of the leaves were rolled downwards followed by the leaf tips. The leaves became thick

and brittle. The affected plants were stunted and the leaves were reduced in size (Plate 19). Flowering and fruiting were completely inhibited. The virus was not transmitted from C.cristata to C.cristata but transmitted back to the original host by B.tabaci. Attempts to transmit the virus from C.cristata to tobacco by both grafting and by B.tabaci were not successful.

iii). Stachytarpheta indica

On S.indica, the yellow mosaic mottle virus produced leaf curl symptoms with light yellow chlorotic areas. The symptoms appeared 20 days after inoculation and the percentage of transmission was 100. The infected plants were severely stunted and the spikes were reduced in size and length. The virus was easily transmitted from S.indica to S.indica and back to the original host. The virus was not transmitted to tobacco from S.indica by either grafting or by viruliferous whiteflies.

6. Mosaic virus of Stachytarpheta indica

The host range of the virus was studied by inoculating concentrated sap on healthy test plants. The virus was

transmitted to 7 different test plants, viz., Benincasa hispida, Cucumis sativus, Cucurbita maxima, Trichosanthes anguina (Cucurbitaceae), Nicotiana tabacum var. White Burley, Nicotiana tabacum var. Samsun (Solanaceae) and Stachytarpheta indica var. jamaicensis (Verbenaceae).

i). Benincasa hispida

The virus infection produced chlorosis, mosaic mottling leaf distortion and raised blisters on the leaves. The leaves were reduced in size and the plants were stunted in growth. The symptoms developed within 7-10 days after inoculation and the percentage of transmission was 30.

ii). Cucumis sativus

The symptoms were first noticed on the developing young leaves as small greenish yellow areas which were lighter than the healthy areas. Later characteristic yellow mottle symptoms developed. The leaves were reduced in size, crinkled and distorted. In advanced stages of infection there was downward rolling of the margins of the lamina. The symptoms appeared 8-10 days after inoculation. The percentage of transmission was 60.

Healthy Diseased

Plate No.19 Symptoms of leaf curl developed on Celosia cristata by inoculating the yellow mosaic mottle virus of Stachytarpheta indica var.jamaicensis

Healthy Diseased

Plate No.20 Symptoms of Stachytarpheta mosaic virus on snake gourd (Trichosanthes anguina)

iii). Cucurbita maxima

Yellowish green chlorotic patches developed on the lamina 8-10 days after inoculation. The darker green portions of the leaves produced raised blisters. The size of the leaves was reduced considerably, internodes were shortened and the plants stunted. Sixty per cent of the test plants became infected.

iv). Trichosanthes anguina

The symptoms first appeared as mild mottling of the young leaves 8-10 days after inoculation. Small yellowish green areas appeared on the young leaves which later developed into characteristic mosaic symptoms consisting of irregular dark green chlorotic patches. The leaves were markedly reduced in size, variously crinkled and deformed (Plate 20). The internodes were shortened and the plants were stunted. The percentage of transmission was 80.

v). Nicotiana tabacum var. White Burley

The symptoms first appeared as mild curling of the younger leaves followed by faint mottling of leaves. The leaves showed mosaic symptoms which developed into large chlorotic

patches. The leaves were reduced in size and severely distorted. The plants were considerably stunted (Plate 21). The symptoms appeared 6-8 days after inoculation and 100 per cent transmission was obtained.

vi). Nicotiana tabacum var.Samsun

The symptoms appeared 7-9 days after inoculation (Plate 22). The symptoms were more or less similar to that appeared on White Burley tobacco, but the affected plants were not so much stunted. The percentage of transmission was 100.

vii). Stachytarpheta indica var.jamaicensis

The symptoms first appeared as upward rolling of the leaves 10-12 days after inoculation. The leaves were pale green, chlorotic, reduced in size and severely distorted. The affected plants were considerably stunted. The length of the spike was reduced and the flowers were sparse. The percentage of transmission was 50.

The above findings on the host range of mosaic virus of S.indica was confirmed by aphid transmission of the virus to all the hosts except Cucurbita maxima. In Beninceasa hispide

Healthy Diseased

Plate No.21 Symptoms of Stachytarpheta mosaic virus on Tobacco (Nicotiana tabacum var. White Burley)

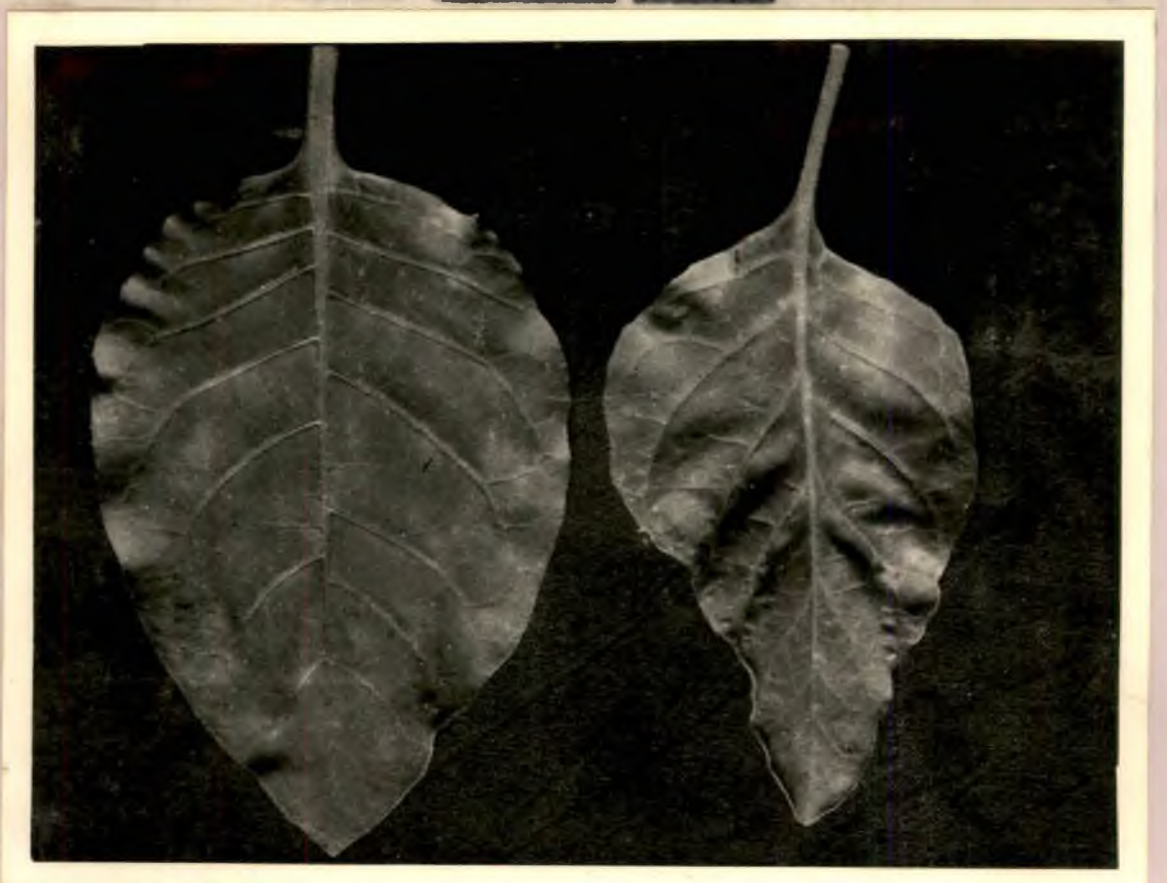


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Plate No.22 Symptoms of Stachytarpheta mosaic virus on Tobacco (Nicotiana tabacum var. Samsun)

only A.craccivora could transmit the virus. It has been found that in general, A.craccivora was more efficient than A.gossypii in transmitting the virus. The incubation period of the virus in the plants was less and the per cent transmission was more when A.craccivora was used as the vector (Table 16).

DISCUSSION

DISCUSSION

The role of weeds in the epiphytotic incidence of many virus diseases affecting crop plants has been well established. Disease symptoms caused by viruses are often noticed on a number of weeds in different parts of Kerala. But only a few weeds are identified as collateral hosts of viruses affecting crop plants. Hence, it was felt necessary to study the viruses infecting the common weeds, and to determine whether these weeds act as collateral hosts of viruses affecting crop plants and to establish the role of weeds in the perpetuation of viruses infecting crop plants.

In the present study the viral nature of 13 diseases affecting weeds was established by transmission studies. The study revealed the presence of 6 virus isolates from weeds, capable of infecting crop plants. Out of the 13 viruses infecting weeds studied, 8 were found to be transmitted by whitefly, Bemisia tabaci and 3 by aphids, viz., Aphis craccivora and Aphis gossypii. In 2 cases successful transmission of the viruses was obtained only through grafting.

The viruses infecting weeds are broadly grouped into 3 based on the modes of their transmission, viz., whitefly-

transmitted viruses, aphid transmitted viruses and viruses transmitted by grafting only and the results are discussed.

I. Whitefly-transmitted viruses

It was found that 8 viruses infecting weeds, viz., yellow vein mosaic of Ageratum conizoides, leaf curl of A.conizoides, leaf curl of Synedrella nodiflora, yellow vein mosaic of Croton sparsiflorus, yellow mosaic of Micrococca mercurialis, yellow vein mosaic of Sida cordifolia, leaf curl of Stachytarpheta indica and yellow mosaic mottle of S.indica var.jamaicensis were transmitted by Bemisia tabaci (Table 3). All the 8 viruses were transmitted by wedge grafting also (Table 2). Attempts made for the sap transmission of the viruses were not successful except in the case of yellow mosaic of M.mercurialis and none of the viruses was transmitted through seeds.

Symptomatological studies of the yellow vein mosaic of A.conizoides revealed that the symptoms were similar to those reported by Varma (1963) and Nair and Wilson (1970). They also could not get the transmission of the virus by sap inoculation and through seeds. The leaf curl virus

of A.conizoides resembled to that reported by Pruthi (1937) in the symptom manifestation and transmission.

The leaf curl virus of Synedrella nodiflora was similar to that reported by Nair and Wilson (1970) in its symptoms and transmission. Newton and Pieris (1953) also reported a virus disease of S.nodiflora characterised by leaf cupping and chlorosis, which was transmitted by inarching, but not by sap inoculation.

The observations on yellow vein mosaic virus diseases of Croton sparsiflorus and Sida cordifolia showed that very often one or two branches only of infected plants exhibited the symptoms while other branches remained green and apparently healthy. Subsequently, all the branches of the plants get infected. Similar observations were reported by Keur (1934) in variegation of Abutilon. He found that the virus was not present in the green branches of variegated Abutilon as evidenced by the non-transmissibility of the virus from such branches to healthy Abutilon by grafting. The appearances of green branches on C.sparsiflorus and S.cordifolia may be due to the local arrest in the movement or lack of movement of the virus from infected branches

since all the branches develop the symptoms at a later stage.

Yellow mosaic virus of Micrococca mercurialis was similar to that reported by Nair and Menon (1978) in the production of symptoms. Studies on the symptoms and transmission of the leaf curl virus of Stachytarpheta indica and yellow mosaic mottle virus of S.indica var.jamaicensis showed that they are new reports from India. Van Der Laan (1940) reported a virus disease of S.dichotoma which was transmitted by Bemisia gossypiperda. Wilson and Sathiarajan (1965) reported a graft-transmissible leaf distorting virus of S.indica. There are no earlier reports of any whitefly-transmitted viruses infecting S.indica and its variety and hence these form new records of the virus diseases of this host plant.

It was found that a single viruliferous whitefly could transmit yellow vein mosaic of Ageratum conizoides (Table 4), leaf curl of A.conizoides (Table 5), leaf curl of Synedrella nodiflora (Table 11), yellow vein mosaic of Croton sparsiflorus (Table 6), leaf curl of Stachytarpheta indica (Table 9) and yellow mosaic mottle of S.indica var. jamaicensis (Table 10). For yellow mosaic of Micrococca mercurialis and yellow vein mosaic of Sida cordifolia two

viruliferous whiteflies were necessary for successful transmission (Table 7 and 8). However, the percentage of transmission was considerably increased when the number of whiteflies per plant was increased for inoculation (Fig.1 to 8). Similar result was reported by Varma (1963) for yellow vein mosaic of A.conizoides. Increase in per cent transmission was reported by several workers in the case of other whitefly-transmitted viruses also, viz., leaf curl of Zinnia elegans (Mathur, 1933), Abutilon infectious variegation (Orlando and Silberschmidt, 1946; Costa, 1955), bhendi yellow vein mosaic (Varma, 1952), tomato yellow leaf curl (Cohen and Nitzany, 1966) and yellow mosaic of mung bean (Nene, 1972).

It was observed that the incubation period of the whitefly-transmitted viruses in their respective plants was not dependent upon the number of viruliferous whiteflies used for inoculation. Similarly the severity of the disease was also not influenced by the number of whiteflies used for inoculation. Similar results were reported by Kirkpatrick (1931) for Cotton leaf curl virus, Mathur (1933) for Zinnia leaf curl virus and Nair (1971) for Urd bean yellow mosaic virus.

Out of the 8 whitefly-transmitted viruses only one virus, viz., yellow mosaic of Micrococca mercurialis was transmitted by sap inoculation. The virus under present study was similar to that described by Nair and Menon (1978) in symptoms and transmission. But they could not transmit the virus by sap inoculation, whereas mechanical transmission was successful when the sap was extracted in phosphate buffer and inoculated. There was a considerable effect on the transmissibility and incubation period of the virus when the sap extracted in phosphate buffer in the cold was used for inoculation (Table 1). The success of the method in transmitting the virus by sap inoculation may be due to the fact that the virus was not denatured or oxidised on exposure when sap was extracted at low temperature in phosphate buffer of pH 7.0 and 7.4. Similar results of mechanical transmission of whitefly-transmitted viruses were reported by Bird et al.(1975b) for golden yellow mosaic virus of beans, Galvez and Castano (1975) for golden mosaic virus of beans, Bock and Guthrie (1978) for African cassava mosaic virus and Subramanian and Narayanasamy (1978) for yellow mosaic virus of Dolichos lablab.

Studies on the physical properties of the yellow mosaic virus of Micrococca mercurialis showed that it has a dilution end point of 1:10 - 1:25 indicating that at dilutions above 1:25, the concentration of inoculum present in the preparation was not sufficient to cause infection. The virus had a thermal inactivation point of 50-55°C. The percentages of transmission decreased when the samples of sap treated at higher temperatures were used for inoculation (Table 14). This may be due to the partial/ complete inactivation of the virus by heat treatment. The longevity in vitro of the virus was found to be 8-16 hours at room temperature and 24-32 hours at refrigerated conditions (Table 14).

Among the physical properties of the virus under study, only thermal inactivation point was similar to that of Abutilon Infectious Variegation Virus but differed widely from it in dilution end point and longevity in vitro which were reported to be 1:625 and 24 hours at room temperature respectively (Costa and Carvalho, 1960a). The physical properties were not comparable to those of other sap transmissible whitefly-borne viruses such as Euphorbia

mosaic (Costa and Carvalho, 1960b) and Bean golden mosaic Galvez and Castano 1975). Further studies are, therefore, warranted for the characterisation of the virus.

The results revealed that the concentration of the virus in the host was very low and was quickly inactivated on dilution since there was no infectivity at a dilution of 1:25 and above. The studies also indicated that the virus is not stable and not able to withstand exposure on extraction as evidenced by the loss of infectivity of the sap stored *in vitro* for 24 hours.

Host range studies of the whitefly-transmitted viruses showed that yellow vein mosaic of *Ageratum conizoides*, leaf curl of *A.conizoides*, leaf curl of *Synedrella nodiflora* and yellow mosaic of *Micrococca mercurialis* were not able to infect any of the test plants other than their respective natural hosts. Thung (1932; 1934) reported *A.conizoides* and *S.nodiflora* as the collateral hosts of curl and crinkle disease of tobacco. Pruthi (1937) reported a leaf curl disease of *A.conizoides* which was transmitted to tobacco by *Bemisia gossypiperda*. Van Der Laan (1940) observed that *A.conizoides* and *S.nodiflora* acted as the collateral hosts

of pseudo-mosaic disease of tobacco which was also transmitted by B.gossypiperda. Deighton (1938), Pruthi and Samuel (1939), Pruthi (1944) and Varma (1959) reported A.conizoides as a collateral host of Tobacco leaf curl virus. But Varma (1963) reported that yellow vein mosaic of A. conizoides was distinct from Tobacco leaf curl virus since he could not transmit the virus to tobacco. The result of the present study is also in agreement with the above findings (Varma, 1963). The results revealed that yellow vein mosaic of A.conizoides, leaf curl viruses of A.conizoides and S.nodiflora failed to infect tobacco and they may be different from Tobacco leaf curl virus.

Vasudeva (1957) reported that A.conizoides and Croton sparsiflorus acted as collateral hosts of yellow vein mosaic of bhendi. But in the present study the viruses failed to infect bhendi, despite repeated efforts. Nair and Wilson (1970) reported that yellow vein mosaic of A.conizoides and leaf curl of S.nodiflora could cross infect each other. But the results show that these viruses did not cross infect and indicated that they are distinct unrelated viruses.

Four whitefly-transmitted viruses, viz., yellow vein mosaic viruses of Croton sparsiflorus and Sida cordifolia, leaf curl of Stachytarpheta indica and yellow mosaic mottle of S.indica var.jamaicensis produced leaf curl symptoms in tomato. Leaf curl of S.indica infected S.indica var. jamaicensis also on which it produced leaf curl like symptoms. In addition to tomato, S.indica and Celosia cristata were also infected by the virus causing yellow mosaic mottle of S.indica var.jamaicensis.

Yellow vein mosaic of C.sparsiflorus produced mild leaf curl symptoms and that of S.cordifolia produced severe leaf curl symptoms on tomato. Varma (1963) reported that yellow vein mosaic of C.sparsiflorus might be a strain of Tobacco leaf curl virus which requires further confirmation. However, the results of the present investigation showed that the virus was not transmissible to tobacco by whitefly or by grafting. The virus also could not be transmitted back from infected tomato to C.sparsiflorus or to healthy tomato. Nair and Wilson (1970) found that yellow vein mosaic viruses of C.sparsiflorus and Sida cordifolia could

cross infect each other. But in the present study the viruses failed to cross infect each other. They could also transmit the yellow vein mosaic virus of Sida cordifolia to tomato on which it produced symptoms of severe leaf curl, but failed to infect tobacco. The result of the present study is also in agreement with their finding. Deighton (1938), Shepherd (1940) and Hill (1968) reported S.cordifolia as the collateral host of Tobacco leaf curl virus. The above discussion on the virus diseases of Croton sparsiflorus and S.cordifolia clearly showed that there can be regional variations in the incidence and geographical distribution of the viruses affecting weeds which necessitates detailed investigations in different regions/localities for their characterisation.

Leaf curl of Stachytarpheta indica produced mild leaf curl symptoms and yellow mosaic mottle of S.indica var. jamaicensis produced severe leaf curl symptoms on tomato, but both failed to infect tobacco. Deighton (1938) reported Stachytarpheta sp.as the collateral host of Tobacco leaf curl virus. Van Der Lean (1940) reported S.dichotoma among the collateral hosts of pseudo-mosaic disease of tobacco. In the present study the viruses failed to infect any of the tobacco varieties tested.

The leaf curl virus of Stachytarpheta indica and yellow mosaic mottle of S.indica var.jamaicensis were not transmitted from infected tomato to healthy tomato by B.tabaci; but transmitted back to their original hosts. Similar results have been reported for many other whitefly-transmitted viruses. Costa (1965) transmitted Abutilon mosaic virus from Sida sp. to beans by B.tabaci causing a disease called 'mottled dwarf'. The virus was not transmitted from bean to bean, but easily transmitted back to Sida sp. Costa (1975) could transmit the Abutilon mosaic virus to soybean causing 'soybean crinkle mosaic'. The virus was not transmitted from soybean to soybean, but transmitted back to the original host.

All the four viruses, which produced leaf curl symptoms on tomato could not infect tobacco. Similar result was roported by Silberschmidt and Tommasi (1956) in the case of the virus causing infectious chlorosis of Malvaceae, which was transmitted to Nicandra physaloides a solanaceous plant, but not to tobacco.

Attempts to transmit the viruses, which produced leaf curl symptoms on tomato, from tomato to tomato and back to

their original hosts by mechanical means were not successful. Costa and Carvalho (1960a) reported the mechanical transmission of the whitefly-transmitted mosaic virus of Abuliton from Sida micrantha and Malva parviflora to M.parviflora and M.rotundifolia. They first transmitted the virus to S.micrantha and M.parviflora by grafting and from these plants successful mechanical transmission was made. Similar results were reported in the case of other whitefly-transmitted viruses like golden mosaic virus of Calopogonium mucunoides and mosaic virus of Euphorbia prunilifolia (Meiners et al.1973; 1975).

The studies revealed that none of the viruses was related to Tobacco leaf curl virus eventhough they produced leaf curl symptoms in tomato. Further studies are, therefore, required to identify the viruses and to establish their relationship to the already known viruses of crop plants.

II. Aphid transmitted viruses

1. Mosaic of Amaranthus viridis

Symptomatological studies of the mosaic virus of A.viridis showed that the symptoms were similar to those

reported by Mariappan and Narayanasamy (1977). The virus was transmitted by sap inoculation, by grafting and by aphids, viz., Aphis craccivora and A.gossypii.

Inoculation with concentrated sap decreased the incubation period of the virus in the plant and increased the per cent transmission. It may be due to the high concentration of the virus in the concentrated sap. There was not much effect when the plants were inoculated with the sap extracted in deionized water and sap extracted in phosphate buffer compared to standard sap and concentrated sap respectively (Table 1).

Phatak (1965) reported a mosaic disease of A.viridis which was transmitted by grafting and by sap inoculation. Mariappan and Narayanasamy (1977) reported a mosaic disease of A.viridis which was transmitted by grafting, sap inoculation and by the aphids, viz., Aphis gossypii, A.craccivora and Myzus persicae. A.gossypii was more efficient than A.craccivora in transmitting the virus; the percentage of transmission being 90 and 80 respectively. Mariappan and Narayanasamy (1977) also found that

A.gossypii was more efficient than A.craccivora and M. persicae as vectors of the virus. The incubation period of the virus in the plants was reduced to 11-13 days when transmitted by A.gossypii as against 14-16 days for A. craccivora (Table 15).

The virus had a dilution end point of 1:1500 - 1:2000, thermal inactivation point of 55-60°C and longevity in vitro of 48-72 hours at room temperature and 72-96 hours at refrigerated conditions (Table 12). The physical properties of the virus were similar to those of the mosaic virus of A.viridis reported by Mariappan and Narayanasamy (1977) except the thermal inactivation point which differed slightly.

Host range studies of the virus showed that it was transmitted only to the members of Amaranthaceae. The virus produced systemic infections of A.caudatus, A.gangeticus, Celosia cristata and Gomphrena globosa and produced mosaic symptoms. Ramakrishnan et al.(1971) reported a mosaic virus of A.gangeticus which was transmitted to many members of Amaranthaceae and Solanaceae. In the case of the mosaic virus of A.viridis reported by Mariappan

and Narayanasamy (1977) the host range was distributed in Amaranthaceae, Aizoaceae and Solanaceae. The virus under study failed to infect any plants of the family Solanaceae tried.

From the results of the studies on symptoms, mode of transmission and physical properties it is found that the virus under study had similariaties to that reported by Nariappan and Narayanasamy (1977). However, the host range of the virus under investigation is confined to plants belonging to Amaranthaceae and hence, it is identified as a strain/vairant of Amaranthus mosaic virus.

ii). Mosaic of Stachytarpheta indica

The mosaic virus of S.indica was transmitted by sap inoculation (Table 1), by grafting (Table 2) and by Aphis craccivora and A.gossypii (Table 16).

Inoculation of plant with concentrated sap reduced the incubation period and increased the per cent transmission as compared to that inoculated with standard sap. There was no difference in the incubation period of the virus in plants inoculated with the sap extracted in deionized

water when compared to standard sap, but the per cent transmission increased from 40 to 50. There was an appreciable increase in the per cent transmission of the virus when the plants were inoculated with the sap extracted in phosphate buffer. The percentage of transmission increased from 60 to 90 when compared to concentrated sap but the incubation period was the same (Table 1). Similar observations were also reported by earlier workers (Thornberry, 1935; Costa, 1944). They reported several fold increase of infectivity of Cucumber mosaic virus (CMV) with the use of phosphate buffer.

The virus was transmitted by two species of aphids tested, viz., Aphis craccivora and A.gossypii. It has been found that A.craccivora was more efficient than A.gossypii in transmitting the virus as evidenced by the higher percentage of transmission and reduction in the incubation period of the virus in the plant (Table 16). There are no earlier reports of any sap transmitted or aphid transmitted virus infecting S.indica and hence, this is recorded as a new virus diseases of the weed.

The physical properties of the mosaic virus of S.indica resembled CMV and its strains in the properties.

Chamberlain (1939) described the physical properties of a strain of CMV as having a dilution end point of 1:1000, thermal inactivation point 62-66°C and longevity *in vitro* 96 hours at room temperature. Debey *et al.*(1974) described the physical properties of *Cucumis virus* I as having a dilution end point of 1:1000 - 1:5000, thermal inactivation point 65-70°C and longevity *in vitro* in phosphate buffer 16-18 hours at room temperature and 192 hours at 8°C. Joseph and Menon (1978) reported a mosaic disease of snake gourd caused by a strain of *Cucumis virus* I and the virus had a dilution end point 1:5000-1:10000, thermal inactivation point 70-75°C and longevity *in vitro* 72-96 hours at room temperature and 144-168 hours at refrigerated condition. The above details show that there can be variations in the physical properties of strains of CMV.

Host range studies of the virus showed that it was transmitted to species of plants belonging to *Cucurbitaceae*, *Solanaceae* and *Verbenaceae*. The virus produced mosaic symptoms on 7 host plants, viz., *Benincasa hispida*, *Cucumis sativus*, *Cucurbita maxima*, *Trichosanthes anguina*, *Nicotiana tabacum* var. White Burley, *N. tabacum* var. Samsun and *Stachytarpheta indica* var. *jamaicensis*.

It has been found that the mosaic virus of S.indica had similarities with some strains of Cucumis virus I in its host range. Ainsworth (1934) reported a yellow mosaic of cucumber which infected cucurbits, tomato and Datura stramonium. But the virus under the present study did not infect tomato and D.stramonium. Joseph and Menon (1978) reported a mosaic disease of snake gourd caused by a strain of Cucumis virus I which infected plants belonging to the families of Cucurbitaceae, Solanaceae and Compositae including Nicotiana glutinosa, Capsicum annuum and Petunia hybrida. The virus under the present study failed to infect N.glutinosa, C.annuum, P.hybrida and the members of Compositae.

Various authors have studied the physical properties and host range of CMV and its strains which differed slightly and in some even widely but never agreed in toto with the properties of each other. These variations can be attributed mainly to the prevalence of different strains of the virus infecting different hosts and also to the host-virus interaction which might have contributed to the changes in the characteristics and properties of the virus and its strains.

So based on the results of the studies on the physical properties and host range, the mosaic virus of S.indica is grouped as a strain of Cucumis virus I.

(iii). Mosaic of Clitoria ternatea

The mosaic virus of C.ternatea was transmitted by grafting and by both the species of aphids tried, viz., Aphis craccivora and A.gossypii but not by sap inoculation or through seeds. A.craccivora was found to be more efficient than A.gossypii in transmitting the virus and the percentages of transmission were 100 and 70 respectively. The incubation period of the virus in the plants remained the same ie., 20-23 days with both the species of aphids.

The virus did not infect any of the plants tested except its original host. Bock et al.(1977) reported a yellow vein virus of Clitoria ternatea which was sap transmitted to Hibiscus esculentus and some other members of the family Papilionaceae. The virus under study is identified as quite different from that reported by Bock et al.(1977) and so this forms the first record of the incidence of

mosaic disease of C.ternatea. However, further studies are required for the identification of the virus.

III. Viruses transmitted by grafting only

i). Yellow mosaic of Hemidesmus indicus

The yellow mosaic virus of H.indicus was transmitted only by wedge grafting (Table 2) but not by sap inoculation or by any of the insects tried. Only the viral nature of the disease has been established and this is a new record of the virus disease of this plant. However, further studies are warranted to determine the vector(s) and host range and also its role in the perpetuation of the virus affecting crop plants.

ii). Yellow mosaic of Sebastiania chamaelea

This virus was also transmitted by wedge grafting only (Table 2) but not by sap inoculation or by any of the insects tried or through seeds. In this case also, only the viral nature of the disease was established. There is no report of any virus disease affecting S.chamaelea from India and hence, this is a new record. Further studies are required in detail about the virus to determine the vector(s) and host range.

As reported by earlier workers, the results of the present investigations also have clearly indicated that the weeds form an important source of inoculum for the spread of viruses to cultivated plants. The studies showed that yellow vein mosaic viruses of Corton sparsiflorus and Sida cordifolia, leaf curl of Stachytarpheta indica and yellow mosaic mottle of S.indica var.jamaicensis can infect tomato and cause leaf curl symptoms which indicates the role of weed hosts in the perpetuation of the virus when tomato is not cultivated. The mosaic virus of S.indica has a little more wider host range and it infected plants of Cucurbitaceae and Solanaceae. It is worth remembering that weeds like S.indica are perennial in nature and they form a permanent reservoir for the viruses. So the necessity for the eradication of weeds also becomes all the more important for the successful control of virus diseases as evidenced by the result of the study. During the course of investigation, a few new virus diseases of the weeds have been recorded, whose role in the perpetuation and as a source of virus inoculum for infecting crop plants deserve further elaborate studies. Though whitefly-transmitted viruses are not generally transmissible by mechanical means, the yellow

mosaic virus of Micrococca mercurialis was transmitted by inoculation with sap extracted in phosphate buffer of pH 7.0 and 7.4. Another factor which has been revealed by the studies is the importance and predominance of whitefly-transmitted viruses in a tropical area like Kerala.

SUMMARY

SUMMARY

Virus diseases affecting ten different species of weed plants and their possible relationship with the virus diseases of certain cultivated plants were subjected to detailed studies. It has been found that these ten weeds were affected by 13 virus diseases. All these viruses were transmitted by wedge grafting.

Among the 13 viruses studied, 3 viruses, viz., mosaic of Amaranthus viridis, yellow mosaic of Micrococca mercurialis and mosaic of Stachytarpheta indica were transmitted by sap inoculation and by insect vectors also. The following 8 viruses were transmitted by the whitefly, Bemisia tabaci Genn.

1. Yellow vein mosaic of Ageratum conizoides
2. Leaf curl of Ageratum conizoides
3. Yellow vein mosaic of Croton sparsiflorus
4. Yellow mosaic of Micrococca mercurialis
5. Yellow vein mosaic of Sida cordifolia
6. Leaf curl of Stachytarpheta indica
7. Yellow mosaic mottle of Stachytarpheta indica var. Jamaicensis
8. Leaf curl of Synedrella nodiflora

Three viruses, viz., mosaic of Amaranthus viridis, mosaic of Clitoria ternatea and mosaic of Stachytarpheta indica were transmitted by Aphis craccivora Koch. and Aphis gossypii Glov. In the case of two viruses, viz., yellow mosaic of Hemidesmus indicus and Sebastiania chamaelea insect transmission trials were not successful.

Out of the 8 whitefly transmitted viruses 6 viruses, viz., yellow vein mosaic of A.conizoides, leaf curl of A.conizoides, yellow vein mosaic of Croton sparsiflorus leaf curl of S.indica, yellow mosaic mottle of S. indica var. jamaicensis and leaf curl of S.nodiflora, were successfully transmitted by a single viruliferous whitefly. For yellow mosaic of Micrococca mercurialis and yellow vein mosaic of S.cordifolia, two viruliferous whiteflies were necessary for successful transmission. Yellow mosaic of M.mercurialis was transmitted by sap inoculation also when the plants were inoculated with the sap extracted in phosphate buffer of pH 7.0 and 7.4.

It was found that ten viruliferous whiteflies could give 100 per cent transmission for four viruses, viz., leaf curl of A.conizoides, yellow vein mosaic of C.sparsiflorus, leaf curl of S.indica and yellow mosaic mottle of S.indica

var.jamaicensis. Fifteen whiteflies were required for 100 per cent transmission of yellow vein mosaic of A.conizoides. In yellow mosaic of M.mercurialis, yellow vein mosaic of S.cordifolia and leaf curl of S.nodiflora 20 viruliferous whiteflies were necessary.

None of the thirteen viruses was transmitted through the seeds of infected plants.

The physical properties of the 3 sap transmissible viruses were studied. The dilution end point of the mosaic virus of A.viridis was between 1:1500 and 1:2000, thermal inactivation point between 55 and 60°C and longevity in vitro at room temperature between 48 and 72 hours and at refrigerated condition (5°-10°C) between 72 and 96 hours.

The dilution end point of the mosaic virus of S.indica was between 1:750 and 1:1000, thermal inactivation point between 70 and 75°C and longevity in vitro at room temperature between 48 and 72 hours and at refrigerated condition between 96 and 120 hours.

Yellow mosaic virus of M.mercurialis had a dilution end point between 1:10 and 1:25, thermal inactivation point between 50 and 55°C and longevity in vitro at

room temperature between 8 and 16 hours and at refrigerated condition between 24 and 32 hours.

In the host range studies, it was found that 5 viruses were not able to infect any plants other than their natural hosts. They are yellow vein mosaic of A.conizoides, leaf curl of A.conizoides, mosaic of Clitoria ternatea, yellow mosaic of M.mercurialis and leaf curl of S.nodiflora. In the case of yellow mosaic viruses of Hemidesmus indicus and Sebastiania chamaelea host range studies were not conducted since grafting was the only successful method of their transmission. Six viruses, viz., mosaic of A.viridis yellow vein mosaic of C.sparsiflorus and Sida cordifolia, leaf curl of Stachytarpheta indica, yellow mosaic mottle of S.indica var.jamaicensis and mosaic of S.indica, on artificial inoculation infected other plants including some economically important crop plants.

Mosaic virus of A.viridis infected A.caudatus, A. gangeticus, Celosia cristata and Gomphrena globosa, all belonging to the family Amaranthaceae.

The host range of yellow vein mosaic of Croton sparsiflorus and Sida cordifolia was confined only to a single test plant, tomato, in which the viruses produced symptoms of leaf curl.

Leaf curl of Stachytarpheta indica could infect tomato and S.indica var.jamaicensis (Verbenaceae) in which the virus produced leaf curl symptoms.

Host range studies with the yellow mosaic mottle of S.indica var.jamaicensis showed that tomato, Celosia cristata and S.indica were susceptible to infection by the virus and it produced severe leaf curl symptoms in them.

Mosaic virus of S.indica was transmitted to 7 different test plants, viz., Benincasa hispida, Cucumis sativus, Cucurbita maxima, Trichosanthes anguina (Cucurbitaceae) Nicotiana tabacum var. White Burley, N.tabacum var.Samsun (Solanaceae) and S.indica var.jamaicensis (Verbenaceae). In all the 7 hosts the virus produced mosaic symptoms.

The symptoms, transmission, physical properties and host range of the mosaic viruses of A.viridis and S.indica indicated that they may be strains of Amaranthus mosaic virus and Cucumis virus I respectively.

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* Originals not seen

ROLE OF WEEDS IN THE PERPETUATION OF VIRUS DISEASES OF VEGETABLES AND ORNAMENTAL PLANTS

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ABSTRACT OF A THESIS
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ABSTRACT

Virus diseases affecting ten different weed plants and their possible role in the perpetuation of virus diseases of certain cultivated plants were investigated. These ten weeds were affected by 13 virus diseases.

All the 13 viruses were transmitted by wedge grafting. Among the 13 viruses studied, 3 viruses, viz., mosaic of Amaranthus viridis, yellow mosaic of Micrococca mercurialis and mosaic of Stachytarpheta indica were transmitted by sap inoculation and by insect vectors. Eight viruses, viz., yellow vein mosaic of Ageratum conizoides, leaf curl of A.conizoides, yellow vein mosaic of Croton sparsiflorus and Sida cordifolia, yellow mosaic of Micrococca mercurialis, leaf curl of Stachytarpheta indica and Synedrella nodiflora and yellow mosaic mottle of Stachytarpheta indica var.jamaicensis were transmitted by the whitefly, Bemisia tabaci Genn.

Three viruses, viz., mosaic viruses of Amaranthus viridis, Clitoria ternatea and Stachytarpheta indica were transmitted by Aphis craccivora Koch. and A.gossypii Glov. In the case of yellow mosaic viruses of Hemidesmus indicus and Sebastiania chamaelea insect transmission trials were not successful.

Out of the 8 whitefly-transmitted viruses 6 were successfully transmitted by a single viruliferous whitefly. Two whiteflies were necessary for the successful transmission of 2 viruses. For 100 per cent transmission ten viruliferous whiteflies were required for four viruses; 15 whiteflies were required for one virus and 20 whiteflies for 3 viruses.

(Mosaic of A.viridis had a dilution end point of 1:1500 - 1:2000, thermal inactivation point of 55-60°C and longevity in vitro at room temperature 48-72 hours and at refrigerated condition 72-96 hours.)

The dilution end point of the mosaic virus of S.indica was 1:750 - 1:1000, thermal inactivation point 70-75°C and longevity in vitro at room temperature 48-72 hours and at refrigerated condition 96-120 hours.

Yellow mosaic virus of M.mercurialis had a dilution end point of 1:10 - 1:25, thermal inactivation point 50-55°C and longevity in vitro at room temperature 8-16 hours and at refrigerated condition 24-32 hours.

In the host range studies it was found that six viruses could infect some plants other than their natural hosts, including some economically important plants.

Mosaic virus of A.viridis infected A.caudatus, A. gangeticus, Celosia cristata and Gomphrena globosa causing mosaic symptoms in all these hosts.

Yellow vein mosaic of Croton sparsiflorus and Sida cordifolia, leaf curl of Stachytarpheta indica and yellow mosaic mottle of S.indica var.jamaicensis infected tomato, producing leaf curl symptoms. Besides tomato, leaf curl of S.indica infected S.indica var.jamaicensis also producing leaf curl symptoms. Yellow mosaic mottle of S.indica var. jamaicensis produced severe leaf curl symptoms in S.indica and Celosia cristata also.

Mosaic virus of S.indica infected 7 different test plants, viz., Benincasa hispida, Cucumis sativus, Cucurbita maxima, Trichosanthes anguina, Nicotiana tabacum var.White Burley, N.tabacum var.Samsun and S.indica var.jamaicensis producing mosaic symptoms.

Based on the symptoms, modes of transmission, physical properties and host range of the mosaic viruses of A.viridis and S.indica, they are identified as strains of Amaranthus mosaic virus and Cucumis virus I respectively.