STUDIES ON LEAF CURL DISEASE OF SESAMUM

BY

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DECLARATION

I hereby declare that this thesis entitled " STUDIES ON LEAF CURL DISEASE OF SESAMUM " 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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CERTIFICATE

Certified that this thesis, entitled " Studies on Leaf Curl Disease of Sesamum " is a record of research work done independently by Kum. M. Jayasree, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

INTRODUCTION

Sesamum (Segamum indicum L.) is one of the very important edible oil seed crops in India. Next to China, India is the largest producer of this oil seed. This crop is affected by many diseases including those caused by viruses and mycoplasma like organisms. Among the virus diseases leaf curl is an important and destructive disease especially when sesamum is cultivated in uplands. In many parts of Kerala sesamum is cultivated in the upland conditions also. Leaf curl disease of sesamum is characterized by severe abaxial curling of the leaves, leathery appearance of leaves and thickening of veins on the lower surface of the leaves. Severely affected plants remain stunted and bear only very few pods. If the infection occurs during seedling stage, the loss in crop yield will be very heavy. Only very limited information is available on the symptomatology, host range, transmission, vector-virus relationship and loss in yield regarding this disease.

The following details were worked out in the present investigation.

1. Symptomatology
2. Methods of transmission
3. Vector-virus relationships

4. Host range of the virus

5. Pattern of spread of the disease in the field

6. Estimation of loss caused by the disease.

Review of literature

REVIEW OF LITERATURE

The sesamum crop, in Kerala, is affected by a number of diseases, especially when it is cultivated in the upland conditions. Leaf curl is one of the important diseases of sesamum, but the research work done on this disease is very limited. The review of literature presented here pertains to leaf curl disease of sesamum as well as that of chilli, tomato, tobacco etc. in which the causal viruses are transmitted by the whitefly Bemisia tabaci Genn.

Symptomatology

Muniyappa (1980) described leaf curl diseases of plants in general. The most characteristic symptom of the leaf curl is the abaxial curling of the leaf blade. The interveinal areas of the leaf are sometimes distorted, and laminae are partially suppressed, especially near the petiole, resulting in the formation of narrow strap like leaves. Curling of the leaves accompanied by puckering and blistering of interveinal areas and thickening and swelling of the veins are observed in infected plants. In advanced stages axillary buds are stimulated to produce clusters of leaves that are reduced in size. Mishra et al.(1963) reported that the whole plant assumes a bushy appearance with stunted growth in leaf curl diseases. Leaves become leathery and brittle. Rolling of leaves downward and upward in the form of an inverted cup and thickening of

veins are also observed in some cases.

The leaf curl disease of sesamum was first observed in India during 1954 (Anon., 1954). Sahambi (1958) described that the disease is characterised by severe downward curling and leathery appearance of leaves and thickening of veins on the lower surface of the leaves. Severely affected plants remain stunted and bear only very few pods.

Vasudeva and Sam Raj (1948) reported that in leaf curl disease of tomato the affected plants are stunted and the leaves and internodes are greatly reduced in size and crowded together. The leaflets are deformed and their margins are curled inwards or outwards. Infected plants become pale and tend to produce stunted lateral branches, which results in bushy growth of the plant. The virus causes partial or complete sterility. In case of early infection no fruit formation takes place and only deformed fruits are formed when infected later.

Mishra et al.(1963) described the symptoms of chilli leaf curl. The chief symptoms produced are abaxial and adaxial curling of the leaves, puckering and distortion of the interveinal areas and thickening and swelling of the veins. In advanced stages of the disease, axillary buds are stimulated to produce clusters of leaves which are reduced in size. The whole plant assumes a bushy appearance with stunted growth.

Fewer flowers and fruits are developed on the diseased plants.

In the case of cotton leaf curl disease the first sign of thickening of veins is seen in the epicalyx of the buds. The new leaves produced are small, exceedingly crinkled and curled at the edges, either upward or downward. The primary stems of the plant often grow taller than normal, the internodes will be elongated and irregularly curved and sometimes the whole plant becomes stunted in growth (Nair et al. 1964).

Nariani (1968) described the symptoms of enation leaf curl of tomato. There is curling, twisting and rolling of leaves and dark green vein enation on the underside of the leaflets.

The tobacco leaf curl disease is characterised by the downward curling of young leaves, thickening of veins on the undersurface of the leaves and stunting of the plant sometimes with vein clearing symptom as well (Pruthi, 1944).

Sap transmission

There are reports regarding the sap transmission of some whitefly transmitted viruses, but sap transmission of leaf curl viruses has not been reported so far. The first report on the mechanical transmission of a whitefly transmitted virus was that by Costa and Bennet (1950). They have succeeded in

mechanically transmitting the Euphorbia mosaic virus to Euphorbia prunifolia as well as to Datura stramonium eventhough the percentages of transmission were very low. The expressed juice from diseased E.prunifolia plants was rubbed over the leaves of seedlings that had been sprinkled with carborundum powder. Similarly Costa and Carvalho (1960 a) have also reported mechanical transmission of Euphorbia mosaic virus. Bird et al.(1975 a) also reported similar observation 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 East Africa. Of these the former was transmitted by Myzus persicae and the latter by B.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 was transmissible to Petunia sp. and other test species of Ipomoea. The percentages of transmission were very low when the original host was used as the source of inoculum. When the virus was transmitted to the test species of Ipomoea by B.tabaci and when that was used as the source of inoculum the percentage of mechanical transmission was considerably increased.

Costa and Carvalho (1960 b) succeeded in the mechanical transmission of the mosaic virus of Abutilon striatum var. thompsonii to the seedlings of Malva parviflora and M.rotundifolia. Mechanical transmission directly from A.striatum was not successful, but after transference to Sida micrantha and S.rhombifolia or M.parviflora by grafting and when these plants were used as sources of inoculum they could get successful transmission of the virus to M.parviflora and M.rotundifolia. Flores and Silberschmidt (1967) also reported similar observations. Here also 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 Nitazany (1960) from Israel reported a virus disease of cucumber causing vein clearing and chlorosis. They found that the virus was transmitted mechanically and by B.tabaci and that it was easily transmitted from all its known hosts by mechanical means. Herold (1967) conducted studies on a mosaic disease of Anthuricum androanum transmitted by B. tabaci and observed that the virus could be transmitted mechanically from A.androanum to Nicotiana clevlandii and N.tabaccum (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.

A virus disease of Calapogonium mucunoides transmitted by B.tabaci was reported by Meiners et al.(1973). In this case Beans (Phaseolus vulgaris) infected with the virus from C.mucunoides by B.tabaci was used as the source of inoculum for mechanical transmission and it was found that the virus could be sap transmissible from infected to healthy beans, but not to the original hosts.

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 (B.tabaci) which were allowed to feed for 24 h on diseased E.prunifolia and C.mucunoides. Inoculum for mechanical transmission was prepared in phosphate buffer of pH 6.8 from infected beans.

Golden yellow mosaic disease of beans is also caused by a whitefly transmitted virus which can be mechanically transmitted by using cold 0.1 M phosphate buffer of pH 7.5(Bird et al.1975 b). Galvez and Castano (1975) could get the mechanical transmission of the same virus by preparing the inoculum in 0.1 M phosphate buffer of pH 7.5 with 1% 2-mercaptoethanol.

Costa et al.(1975) reported a golden mosaic virus of tomato 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 inoculated into these plants. In the case of tomato yellow mosaic virus, which is also transmitted by B.tabaci successful mechanical transmission was reported by Lastra and Uzcathegui (1975).

Mechanical transmission of African cassava mosaic virus from cassava to cassava was reported by Bock and Guthrie (1978). Successful transmission was achieved when the inoculum was prepared in phosphate buffer of pH 7.7 or borate buffer of pH 8.7 or in deionized water.

In India, Subramanian and Narayanaswamy (1978) reported 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 to 76 and 92 to 100 in pH range of 6.6 to 7.2 and 7.4 to 8.0 respectively.

Mathew (1981) reported the mechanical transmission of yellow mosaic virus of Micrococca mercurialis when the sap was extracted in phosphate buffer of pH 7.0 to 7.4.

Graft transmission

Almost all the grafting methods can be successfully applied for graft transmission of leaf curl viruses.

The leaf curl of sesamum when first reported, it was also stated that the causal virus was transmitted by grafting (Anon., 1954).

Reddy and Yaraguntaiah (1979) reported that in the case of tomato leaf curl virus, 100 per cent transmission was obtained by approach grafting. By patch and tongue grafting 95.8 per cent transmission was obtained and by wedge and leaf grafting the percentages of transmissions were 70 and 5 respectively.

Seed transmission

Benigno (1977) reported that leaf curl virus of squash is transmissible through seeds. There are no other reports of seed transmission of leaf curl viruses.

Transmission by vectors

Almost all the leaf curl viruses are transmitted by the whitefly, Bemisia tabaci Genn. They include sesamum leaf curl virus (Anon., 1954, Sahambi, 1958), chilli leaf curl virus (Park and Fernando, 1938; Mishra et al. 1963), tomato leaf curl virus (Vasudeva and Sam Raj, 1948; Yassin and Abusalih, 1972) leaf curl virus of tobacco (Storey, 1931) etc.

Vector-virus relationships

The details regarding the vector-virus relationships of sesamum leaf curl virus have not been worked out so far. But

different aspects of vector-virus relationships of many other leaf curl viruses have been reported from India and elsewhere.

Krikpatrick (1931) worked on the vector-virus relationship of cotton leaf curl virus and reported that the virus is picked up by the adult whitefly (B.tabaci) in just over 3 h but maximum infectivity is attained only after a minimum stay of 4.5 h on the source plant. The virus is transmitted to healthy plants in 30 min. When once the whitefly becomes viruliferous, it remains capable of transmitting the virus for at least 7 days and probably throughout its life. It has been reported that for tobacco leaf curl virus only 15 min was required for acquisition as well as for inoculation (Pruthi and Samuel,1939; Pruthi, 1944).

Cohen and Nitzany (1966) while studying the vector-virus relationship of Tomato yellow leaf curl virus observed that the minimum acquisition and inoculation feeding periods were 15 min and 30 min respectively. The incubation period in the vector was at least 21 h. The virus persisted in the vector for periods of upto 20 days but not throughout the life span of the insect. It was found that for 100 per cent transmission a minimum number of 15 whiteflies per plant was needed.

The vector-virus relationship of Tomato leaf curl virus (TLCV) was worked out by Butler and Rataul (1977). They found

that the incubation period of TLCV in tomato plants varied from 8 days in August to 90 days in winter months. The minimum acquisition and inoculation feeding periods in these two seasons were 31 min and 32 min respectively. The male and female whiteflies retained infectivity for 5 and 53 days, respectively.

In the case of leaf curl of weeds, viz., Acanthospermum hispidum DC., Blainvillea rhomboidea Cass. and Flaveria australasia H.K. the minimum acquisition and inoculation feeding periods were found to be 1 h (Mariappan and Narayanaswamy, 1977).

Reddy and Yaraguntaiah (1981) also worked on the vector-virus relationship of Tomato leaf curl virus. They reported that in the case of TLCV the duration of both the minimum acquisition and inoculation feeding periods was 30 min. The incubation period of the virus in the vector was found to be 6 h. A single viruliferous whitefly could transmit the virus successfully and a minimum number of 10 whiteflies per plant was required to get 100 per cent transmission. It was also observed that the whiteflies once acquired the virus, could transmit the disease throughout their life period. There was no transovarial transmission and they concluded that the vector-virus relationship of tomato leaf curl virus is closest to circulative type of virus.

Mathew (1981) worked on the leaf curl virus diseases of Ageratum conizoides, Stachytarpheta indica and Synedrella nodiflora. He reported that only a single whitefly (B.tabaci) was required for the transmission of each of the three viruses and a minimum number of 10 viruliferous whiteflies were required for 100 per cent transmission in the case of first two viruses and for the third it was 20.

Host range

Many of the leaf curl viruses infecting crop plants were found to cause diseases in crop plants as well as weeds. For example, tobacco leaf curl virus could infect Ageratum conizoides (Thung, 1932), Sida carpinifolia (Sheperd, 1937) Crotalaria juncea, Euphorbia hirta, Launia asplenifolia, Lycopersicon esculentum, Scoparia dulcis, Solanum nigrum, Vernonia cinerea (Pruthi and Samuel, 1939, 1942); Withania sommifera (Phatak and Raychaudhuri, 1967); Achanthospermum hispidum, Blainvillea rhomboidea and Flaveria australasica (Mariappan and Narayanaswamy, 1977).

In the case of Tomato leaf curl virus many plants were reported as the collateral hosts viz., Ageratum conizoides (Thung, 1932), Sida rhombifolia (Pruthi and Samuel, 1942), Nicotiana tabacum, Solanum tuberosum, Datura stramonium, Nicotiana sylvestris, Nicotiana glutinosa (Vasudeva and Sam Raj, 1948; Yassin and Nour, 1965).

Thung (1934) while working with the leaf curl and crinkle diseases of tobacco found that the sources of infection of these diseases were confined to the weeds Ageratum conizoides, Synedrella nodiflora and Vernonia cinerea. In the case of cotton leaf curl virus Sida spinosa (Tarr, 1947) and Sida carpinifolia (Ducker et al., 1948) were reported as the collateral hosts. Seth and Dhanraj (1972) reported that a new strain of Tobacco leaf curl virus which causes enations in chilli can also attack Nicotiana tabacum (Harrison's special), Nicotiana glutinosa, Datura stramonium, Petunia hybrida and Lycopersicon esculentum.

Pattern of spread

Pattern of spread of diseases has been studied in detail in the case of diseases affecting human beings and animals. In plant diseases the pattern of spread has not been worked out in many cases.

Gompertz (1825) proposed an asymmetric sigmoid curve in the case of the spread of human diseases. Winsor (1932) has discussed its application to the growth of any organism when the relative growth rate decreases with time.

Beniwal et al.(1979) had tried the nature and rate of spread of Urd bean leaf crinkle disease under field conditions. In this particular case the actual vector has not been identified and no regular pattern of spread has been obtained.

Estimation of yield loss

Sahambi (1958) while describing the leaf curl disease of sesamum reported that if the virus infection occurs during the early stages of growth of the plants there will be considerable reduction in yield.

In the case of tomato leaf curl disease Sastry and Singh (1973) estimated the extent of yield loss caused at different stages of infection and they found that the yield loss amounted to 92.3% when plants were infected within 20 days of planting. Plants infected after 35 and 50 days showed losses of 74.1 and 28.9% respectively.

Materials and methods

MATERIALS AND METHODS

I. Seed materials

Seeds of sesamum (*Sesamum indicum* L.) required for the studies were obtained from the Department of Plant Breeding, College of Agriculture, Vellayani. Tobacco seeds were obtained from the Central Tobacco Research Institute, Rajahmundry. The seeds were sown in pots containing potting mixture (river sand, garden soil and cowdung in the ratio 1:1:2).

II. Culture of the virus

The culture of the virus causing the Sesamum Leaf Curl disease was obtained from naturally infected sesamum plants in the research plots of the Department of Plant Breeding, College of Agriculture, Vellayani. The culture was maintained by occasional transmission by the whitefly, *Bemisia tabaci* Genn. to healthy plants in an insect proof glass house.

III. Symptomatology

Symptomatology was studied by closely observing the development of symptoms in naturally infected sesamum plants under field conditions and also by noting reactions of plants artificially inoculated with the virus under insect proof conditions.

IV. Transmission of the virus

Various transmission studies were conducted under insect proof glass house conditions as described below:-

1. Sap transmission:- Sap transmission studies were conducted using concentrated sap, standard sap, sap extracted in phosphate buffer, citrate buffer and borate buffer. Extraction of sap in all the buffers was done both at room temperature as well as in the cold. In all sap transmission 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. It was then filtered through fine muslin cloth and the filtrate was used as the concentrated sap. Standard sap was prepared by adding one ml of sterile distilled water to every g of infected tissue used for extraction of sap.

The phosphate buffer (0.7M, 0.1M and 0.2M) of pH 8, 7.8, 7.6, 7.4 and 6.8 was prepared and used as extraction medium. The sap was extracted after adding one ml each of the buffer solution to every g of infected leaf tissue.

Extraction of sap in phosphate buffer in the cold was done by adopting the method described by Subramonian and Narayanaswamy (1978). An aluminium 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 of pH 8, 7.8, 7.6, 7.4 and 6.8 was prepared at three concentrations each, viz., 0.07M, 0.1M

and 0.2 M and cooled in a refrigerator to near freezing point.

Young leaves of sesamum showing clear symptoms of leaf curl disease were excised, rinsed in iced water and macerated in the mortar kept in the ice tray with phosphate buffer at the rate of one ml per g of leaf material. The expressed sap was then filtered through a fine muslin cloth into a petri dish kept in an ice tray. The sap was immediately rubbed with a swab of absorbant cotton over the surface of the top most 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.

Citrate buffer of pH 5.8, 6.0 and 6.2 was prepared at two concentrations each, viz., 0.1M and 0.05M. Inoculum in citrate buffer was prepared by adding one ml of the buffer to every g of infected leaf tissue.

Borate buffer was prepared at 0.3 M concentration only, at pH 7.6, 7.8 and 8.0. Here also preparation of inoculum was done in the same way as in the case of citrate buffer.

The expressed sap was filtered through a muslin cloth into a petri dish. Inoculations were carried out by gently

rubbing the upper surface of the fully opened leaves of 15 day old test plants as described in the case of phosphate buffer. Ten plants each, were inoculated for every experiment and they were kept under insect proof glass house conditions. In each case three plants were kept as control by rubbing with buffer alone. All the experiments were done twice.

2. Graft transmission: - Two methods of grafting viz., wedge grafting and side grafting were employed.

1. Wedge grafting:- The top shoots of sesamum plants showing typical symptoms were selected for the preparation of scion. The base of the shoots having 2-3 small leaves were prepared into wedges which were inserted into the clefts made on the top of the stock plants aged 20-25 days, tied rigidly with strips of polythene and kept in the glass house after covering with polythene bags to retain humidity. Such plants were kept under observation for 30 days for development of symptoms.

2. Side grafting: The scions were prepared as described under wedge grafting and inserted into a cleft cut at an angle on the side of the stem whose thickness was little more than the thickness of the scion.

3. Seed transmission:- Seeds were collected twice from plants showing clear symptoms of the disease. The number of seeds

collected for the first and second time were 120 and 190 respectively. The seeds were sown in pots and kept under insect proof conditions for observation upto a period of 50 days.

4. Insect transmission

The whitefly, Bemisia tabaci Genn. Was used for insect transmission studies.

Pure colony of B.tabaci was reared on healthy tobacco plants in suitable cages. Plastic transmission cages designed by Nene (1972) were used for transmission studies.

The top portion of either the main stem or fresh branches showing typical symptoms was introduced into the transmission cage through the rectangular slit at the opening of the cage. Whiteflies were collected with an aspirator and released into the transmission cage. The transmission cage was covered with a black cloth except at the region of the wire netting which was kept facing the light source while releasing the whiteflies. The cap of the transmission cage was immediately screwed on and the remaining portion of the rectangular slit of the cage was kept closed by cotton wool. The cages were kept in position with the help of two bamboo slivers and a rubber band. After the desired feeding period, the cotton was removed and gently tapped with a glass rod to disturb

the whiteflies. This stimulated the whiteflies to move away from the leaves to the side of the cage facing the light source.

In all transmission experiments ten seedlings were used as test plants. The number of whiteflies released on each test plant for inoculation feeding was fixed. After inoculation feeding the insects were killed by spraying the plants with 0.1% quinalphos. The inoculated plants were labelled and kept in an insect proof glass house. Observations were taken daily on the appearance of symptoms. Spraying with quinalphos (0.1%) was done at weekly intervals to prevent whitefly infestation. The experiments were done twice.

V. Vector-virus relationships

1. Minimum acquisition feeding period:- The whiteflies were given acquisition feeding for periods ranging from 5 min to 6 h viz., 5 min, 10 min, 15 min, 30 min, 1 h, 2 h, 4h and 6 h. One hour pre-acquisition starvation was given in all the cases. After the acquisition feeding period whiteflies were released on healthy sesamum seedlings at the rate of twenty per plant and an inoculation feeding period of 48 h was given. Ten seedlings were used for each experiment. The experiment was done twice and observations were recorded on the number of plants infected.

2. Incubation period in the vector:- Non-viruliferous whiteflies were allowed to feed on leaf curl affected sesamum plants for 24 h and transferred separately to different sets of healthy test plants. They were given specified inoculation feeding periods of 1, 2, 4, 6, 8, 10, 12 and 16 h. After the specified inoculation feeding periods the test plants were sprayed with 0.1% quinalphos and observed for the development of symptoms. Here also 5 test plants were used in each case.

3. Minimum inoculation feeding period:- Non-viruliferous whiteflies were collected and given pre-acquisition starvation for a period of one h and acquisition feeding period of 30 h. Here also the number of whiteflies released per healthy plant for inoculation feeding was 20. Periods ranging from 5 min to 6 h viz., 5 min, 10 min, 15 min, 30 min, 1 h, 2 h, 4 h and 6 h were given for inoculation feeding. The experiment was done twice and observations on the number of plants infected were recorded.

4. Retention of infectivity by the vector:- This experiment was conducted to determine for how long the vector could retain the viruliferous nature without further access to a virus source. The whiteflies were given an acquisition feeding period of 24 h. After the acquisition feeding seven whiteflies among them were released singly on each of the

seven test plants. After an inoculation feeding period of 24 h, they were transferred to fresh healthy test plants. They were serially transferred to fresh healthy plants like this after every 24 h till their death. The inoculated plants were frequently sprayed with 0.1% quinalphos and kept under insect proof conditions for observations.

5. Minimum number of whiteflies required for virus transmission

After 24 h acquisition feeding on leaf curl affected sesamum plants, a fixed number of adult whiteflies, viz., 1, 3, 5, 10, 15 and 20 per test plants were allowed inoculation feeding of 24 h. Five test plants were inoculated in each case. The experiment was done twice.

VI. Host range

The following different plant species belonging to 12 families were tested to study the host range of the virus using viruliferous whiteflies.

1. Amaranthaceae

Amaranthus caudatus L.

A. viridis L.

Spinancea oleraceae L.

2. Acanthaceae

Justicia diffusa Willd.

3. Capparidaceae

Cleome viscosa L.

4. Compositae

Ageratum conizoides L.

Acanthospermum hispidum DC.

Emilia sonchifolia D.C.

Eupatorium odoratum

Synedrella nodiflora Gaertin.

Tridax procumbens L.

Vernonea cinerea Less.

Zinnia elegans Jacq.

Zinnia linnearis L.

5. Cucurbitaceae

Cucurbita maxima Duch.

Cucumis melo L.

Cucumis sativus L.

Cucurbita pepo L.

Momordica charentia L.

6. Euphorbiaceae

Acalypha indica L.

Croton sparsiflorus Morong.

Euphorbia geniculata L.

E.hirta L.

Jatropha curcas L.

Micrococca mercurialis Benth.

Phyllanthus niruri

7. Malvaceae

Abelmoschus esculentus (L) Moench.

Gossypium hirsutum L.

Sida acuta Burm F.

S.cordifolia L.

S.rhombifolia L.

8. Papilionaceae

Alysicarpus vaginalis Dc.

Clitoria ternatea L.

Crotalaria junoea L.

C.striata L.

Cyanopsis tetragonoloba (L.) Taub.

Dolichos lablab L.

Glycine max (L) Meu.

Phaseolus aureus (L.) Roxb.

9. Rubiaceae

Knoxia sp.

Oldenlandia aspera Dc.

10. Scrophulariaceae

Scoparia dulcis L.

11. Solanaceae

Capsicum annuum L.

Datura stramonium L.

Lycopersicon esculentum Mill.

Nicotiana tabacum L.

Solanum melongena L.

12. Verbenaceae

Lantana camara L.

Stachytarpheta indica Vahl.

Back transmission to sesamum was done in the case of those hosts which produced any symptoms to confirm the identity of the virus.

VI. Pattern of spread

A rectangular pattern was adopted for this experiment. Plot size was 2.75 M x 2.25 M with a plant spacing of 30 cm x 15 cm. Altogether there were seven rows and within each row there were

18 plants and hence the total number of plants was 126. There were two replications.

Layout of the plot and sowing were done during the month of January 1983. Thinning of the crop was done on the 12th day after sowing. On 20th day a leaf curl affected sesamum plant was planted as source of inoculum in the 4th row at the centre, then the plot was closely observed during every week for the spread of the disease and the information was plotted on the layout plan.

The pattern of spread of the disease was explained by the Gompertz Curve proposed by Gompertz (1825) which is

$$Y' = Y_0' \quad A^{B^x}$$

where Y' = the expected spread of disease

Y_0' = is the point at which the spread approaches a maximum, called the asymptote

A^B = the rate of spread of disease

x = weeks

The contents of the equation were estimated by the method of selected points (Yaminae, 1964) to the data averaged over two replications.

VIII. Estimation of yield loss

A pot culture experiment was conducted to estimate the loss in yield of sesamum caused by sesamum leaf curl disease.

This experiment was done in CRD. There were 6 treatments viz., uninoculated (control), inoculations done on 7, 14, 21, 28 and 35 day old plants. There was only one plant per pot. Four varieties of sesamum were used, viz., Kayamkulam-1, Kayamkulam-2, KRR-1 and Pt.58-35. There were three replications and the total number of pots were 72.

Seeds were sown in pots kept under insect proof conditions and date of germination was noted. First inoculation was given one week after germination by releasing 25 viruliferous whiteflies per seedling. Then the pots were transferred to a field near the glass house and kept the plants exposed to natural environmental conditions.

The subsequent inoculations were also done by the same method and thus all the five inoculations were given. All the plants were sprayed with 0.1% quinalphos at weekly intervals to avoid vector infestations. The following observations were recorded in this experiment.

1. Height of plants
2. Number of leaves
3. Length of leaves
4. Breadth of leaves
5. Number of branches

6. Number of flowers
7. Number of pods

Results

RESULTS

Symptomatology

The prominent characteristic symptoms of the disease was the abaxial curling of the leaves. During the initial stages of infection the leaves turned dull green or pale green in colour, which finally became dark green. Gradually the size of leaves got considerably reduced. In severe cases of infection the margins of the leaves rolled inwards. The leaves turned brittle, leathery, with thickening of the veins on the undersurface of the leaves and the plants remained stunted.

Flower production was very much reduced when the infection occurred during early stages of plant growth. When infected during later stages there was development of flowers and pods but to a considerably lesser extent when compared with the healthy plants.

In some cases the development of leaves was severely affected resulting in the production of strap shaped leaves.

When the infection occurred during the early stages of plant growth the size of the leaves was found to be greatly reduced. Internode length also became very much reduced and the leaves appeared crowded at the apex. Gradually the leaves started drying and finally premature death of the plants occurred.

Plate 1. Severe field infection by sesamum leaf curl virus

Plate 2. Initial symptoms of sesamum leaf curl disease

Plate 3. Plants showing advanced stage of sesamum leaf curl disease

Plate 4. A mature plant infected by sesamum leaf curl virus

In the variety Maran, there was no downward curling of leaves when infected with sesamum leaf curl virus. In this particular case, the leaves turned pale green with vein thickening on the undersurface of the leaves and sometimes with a slight upward curling of the leaves.

Under glass house conditions a slight difference in the symptoms was observed in all the sesamum plants. Before vein thickening occurred there developed a glossy appearance on the undersurface of the leaves. Later on, other symptoms like vein thickening, leathery nature of the leaves etc. appeared. Generally the leaves did not turn as brittle as that observed in plants kept outside the glass house. Similarly downward curling was also not so severe. When infected during early stages of growth, the plants started drying soon after the appearance of glossiness on the leaves. Unlike in the field, in the glass house the plants were not very much stunted. In general, the appearance of symptom was not so severe as that found in the field conditions.

Transmission of the virus

I. Sap transmission

Sap transmission experiments were conducted using concentrated sap, standard sap, sap extracted in phosphate buffer, citrate buffer and borate buffer as mentioned under

materials and methods. There was no development of the symptoms of leaf curl disease in any of the sap inoculated sesamum plants.

II. Graft transmission

Side grafting and wedge grafting were done and the results of establishment of grafts and percentage of transmission of the disease among the established grafts are presented in Table-1. In all the attempts in which transmission occurred symptoms appeared within a period of 7 - 15 days. There was 100% transmission when there was successful establishment of grafts.

Table 1

Graft transmission of sesamum leaf curl virus

Type of grafting	Number of grafts established / Number of plants grafted	Per cent establishment	Per cent transmission
Side	18/20	90	100
Wedge	15/20	75	100

III. Seed transmission

Out of the 120 and 190 seeds sown as first and second experiments it was found that 106 and 172 seeds, respectively

have germinated. None of these seedlings showed any symptoms of leaf curl disease.

IV. Insect transmission

Insect transmission studies were conducted by using the whitefly, Bemisia tabaci Genn. It has been observed that the whitefly is capable of transmitting the virus. Once inoculated the plants developed symptoms within a period of 7-15 days. When all the conditions were favourable 100 per cent transmission was obtained.

Vector-virus relationships

a) Minimum acquisition feeding period

Non-viruliferous whiteflies were given acquisition feeding on leaf curl disease affected sesamum plants for specified periods followed by 48 h inoculation feeding periods on healthy sesamum seedlings at the rate of 20 whiteflies/seedling.

The results showed that a minimum acquisition feeding period of 10 min was sufficient to make the vector viruliferous and as the duration of acquisition feeding period increased the percentage of transmission also increased (Table 2) when the acquisition feeding period was 4 h or more 100 per cent transmission was obtained.

Table 2

Acquisition feeding period for the transmission of sesamum leaf curl virus

Acquisition feeding period	Number of plants infected / Number of plants inoculated		Per cent transmission
	Replication-I	Replication-II	
5 min	0/5	0/5	0.00
10 min	0/5	1/5	10.00
15 min	1/5	1/6	18.18
30 min	2/5	3/6	45.45
1 h	3/5	3/5	60.00
2 h	4/5	5/5	90.00
4 h	5/5	6/6	100.00
6 h	5/5	4/4	100.00

b) Incubation period in the vector

Non-viruliferous whiteflies were allowed to feed on sesamum plants showing typical symptoms of leaf curl disease for 24 h and transferred separately to different sets of healthy sesamum plants.

It was found that when an acquisition feeding period of 24 h was given the whiteflies became viruliferous only after another 4 h to give at least 10 per cent transmission (Table 3). When the incubation period in the vector was further increased the per cent transmission was also found to increase and after 10 h incubation 100 per cent transmission was obtained.

c) Minimum inoculation feeding period

Non-viruliferous whiteflies were given an acquisition feeding period of 48 h followed by specified periods of inoculation feeding on healthy sesamum seedlings at the rate of 20 whiteflies per plants.

Results showed that a minimum inoculation feeding period of 30 min was necessary to get at least 10 per cent transmission. When the inoculation feeding period was increased the per cent transmission was also found to increase and after an inoculation feeding period of 6 h there was 100 per cent transmission (Table 4).

Table 3

Incubation period of sesamum leaf curl virus in the vector

Incubation period	Number of plants infected / Number of plants inoculated		Per cent transmission
	Replication-I	Replication-II	
1 h	0/5	0/5	0.00
2 h	0/5	0/5	0.00
3 h	0/5	0/5	0.00
4 h	1/5	0/5	10.00
6 h	2/5	3/5	50.00
8 h	3/5	4/5	70.00
10 h	5/5	5/5	100.00

Table 4

Inoculation feeding period for the transmission of sesamum leaf curl virus

Inoculation feeding period	Number of plants infected / Number of plants inoculated: Replication-I	Number of plants infected / Number of plants inoculated: Replication-II	Per cent transmission
5 min	0/5	0/5	0.00
10 min	0/5	0/5	0.00
15 min	0/5	0/5	0.00
30 min	1/5	0/5	10.00
1 h	1/5	2/5	30.00
2 h	2/5	2/5	40.00
4 h	4/5	4/5	80.00
6 h	5/5	5/5	100.00

d. Retention of infectivity by the vector

Non-viruliferous whiteflies were allowed to feed on leaf curl affected sesamum plants for 24 h and serially transferred at 24 h intervals to new sets of healthy seedlings at the rate of one insect per seedling. It was observed that the whiteflies once became viruliferous could transmit the virus throughout their life period, the maximum duration of which on sesamum plants was found to be only 8 days (Table 5).

e. Minimum number of whiteflies required for virus transmission

After 24 h acquisition feeding on leaf curl disease affected sesamum plants, a known number of adult whiteflies were allowed inoculation feeding of 24 h as described under materials and methods. The results showed that a single viruliferous whitefly could transmit the virus successfully to 10 per cent of the plants inoculated (Table 6), when the number of whiteflies was increased the per cent transmission was also found to increase and when 15 whiteflies or more were used 100 per cent transmission was obtained.

Host range

Out of 49 species of plants belonging to 12 different families tested, 9 species of plants belonging to 6 families were found to be susceptible to infection by sesamum leaf curl virus and produce distinct symptoms.

Table 5

Retention of segamum leaf curl virus by *Bemisia tabaci* Genn.

Sl.No. of white-flies	Number of days of retention of the virus									
	1	2	3	4	5	6	7	8	9	10
1	+	+	+	D						
2	-	-	-	-	D					
3	-	-	-	-	-	-	-	D		
4	+	+	+	+	+	+	+	+	D	
5	+	+	+	D						
6	-	-	-	-	-	D				
7	+	+	D							

\+ transmission

\- no transmission

D Death of the whitefly

Table 6

Minimum number of whiteflies required for transmission of sesamum leaf curl virus

Number of whiteflies	Number of plants infected / Number of plants inoculated		Per cent transmission
	Replication-I	Replication-II	
1	1/5	0/5	10.00
3	1/5	2/5	30.00
5	3/5	4/5	70.00
10	4/5	5/5	90.00
15	5/5	5/5	100.00
20	5/5	5/5	100.00

a. Compositae

1. Zinnia linneares L.

The symptoms appeared first on the developing young leaves after a period of about 7-10 days. The leaves turned dark green, brittle and curled downwards and the veins became thickened. Sometimes the leaves assumed a twisted appearance. Leaf area was very much reduced. At a later stage even the branches produced also became twisted in appearance. The plants were stunted and flower production was considerably reduced.

2. Zinnia elegans Jacq.

Here also symptoms appeared after a period of about 7-10 days. Newly formed leaves turned dark green, brittle and curled downwards. The leaf area was considerably reduced. Unlike in Z.linneares in Z.elegans there was no twisting of the leaves or branches. The plants were stunted and flower production was completely inhibited.

b. Euphorbiaceae

Acalypha indica L.

The inoculated plants showed the symptoms within 7 to 10 days after inoculation. The newly formed leaves turned

dark green, leathery and brittle. General stunting of the plants, reduction in size of leaves, crinkling and distortion of lamina were also observed.

c. Papilionaceae

Dolichos lablab L.

The inoculated plants showed symptoms within 5 to 7 days after inoculation. Newly formed leaves turned dark green, leaf area very much reduced, and sometimes strap shaped leaves were also produced. Length of vines was also reduced. Flower and fruit production was considerably reduced and the plants appeared stunted.

d. Scrophulariaceae

Scoparia dulcis L.

Symptoms first appeared on the newly formed leaves within 4 to 6 days after inoculation. Leaves turned dark green, laminae crinkled distorted and stood erect and often there was downward curling. The plants were stunted and there was no flowering and fruiting.

e. Solanaceae

1. Capsicum annuum L.

The newly formed leaves of the plants showed symptoms within 5 to 7 days after inoculation. The major symptoms

were downward curling of the leaves, leathery and brittle appearance of leaves. The size of the leaves was very much reduced, flower and fruit production was completely suppressed and plants remained stunted.

2. Nicotiana tabacum L.

Newly formed leaves of the infected plants turned dark green leathery and brittle the veins became thickened, leaves curled downwards, size of the leaves was very much reduced, and plants remained stunted. The incubation period in the plant was found to be 10-15 days.

3. Lycopersicon esculentum L.

Symptoms produced were similar to those of tomato leaf curl and it appeared after a period of 10-15 days after inoculation. Leaves turned dark green, leathery and brittle. There was downward curling of the leaves and vein thickening on the undersurface of the lamina. Flower and fruit production were partially or completely suppressed. The plants stunted and gradually died.

4. Verbanaceae

Stachytarpheta indica Vahl.

Newly formed leaves developed symptoms within 7 to 10 days after inoculation. Symptoms first appeared as downward

Plate 5. Sesamum leaf curl virus on *Acalypha indica*

Healthy Diseased

Plate 6. Sesamum leaf curl virus on *Dolichos lablab*

Plate 7. Sesamum leaf curl virus on *Stachytarpheta indica*

Healthy Diseased

Plate 8. Sesamum leaf curl virus on *Scoparia dulcis*

Healthy Diseased

Plate 9. Sesamum leaf curl virus on *Zinnia elegans*

Healthy Diseased

Plate 10. Sesamum leaf curl virus on *Zinnia linnearis*

curling of the leaves. Leaves turned brittle and dark green in colour and the plants were stunted. Flowering and fruiting were not found much affected.

Pattern of spread

The spread of leaf curl disease at weekly intervals was described by the equation.

$Y' = Y'_0 A^{B^X}$, which is the equation to a Gompertz growth curve where

Y' = the expected spread of disease

A^B = rate of spread of disease

X = weeks and

Y'_0 = is the point at which the spread approaches a maximum, called the asymptote.

The above relationship was estimated from the data as

$\log Y' = \log Y'_0 + (\log A)^{B^X}$

ie $\log Y = 2.0980 - 1.5539 \times 0.3343^X$

The estimated number of plants according to the above relation and the observed number of plants were presented in table 7.

All the estimated number of plants except for 2nd week agree with the observed number of plants during the consecutive weeks.

Fig.2 gives the graphical representation of the curve.

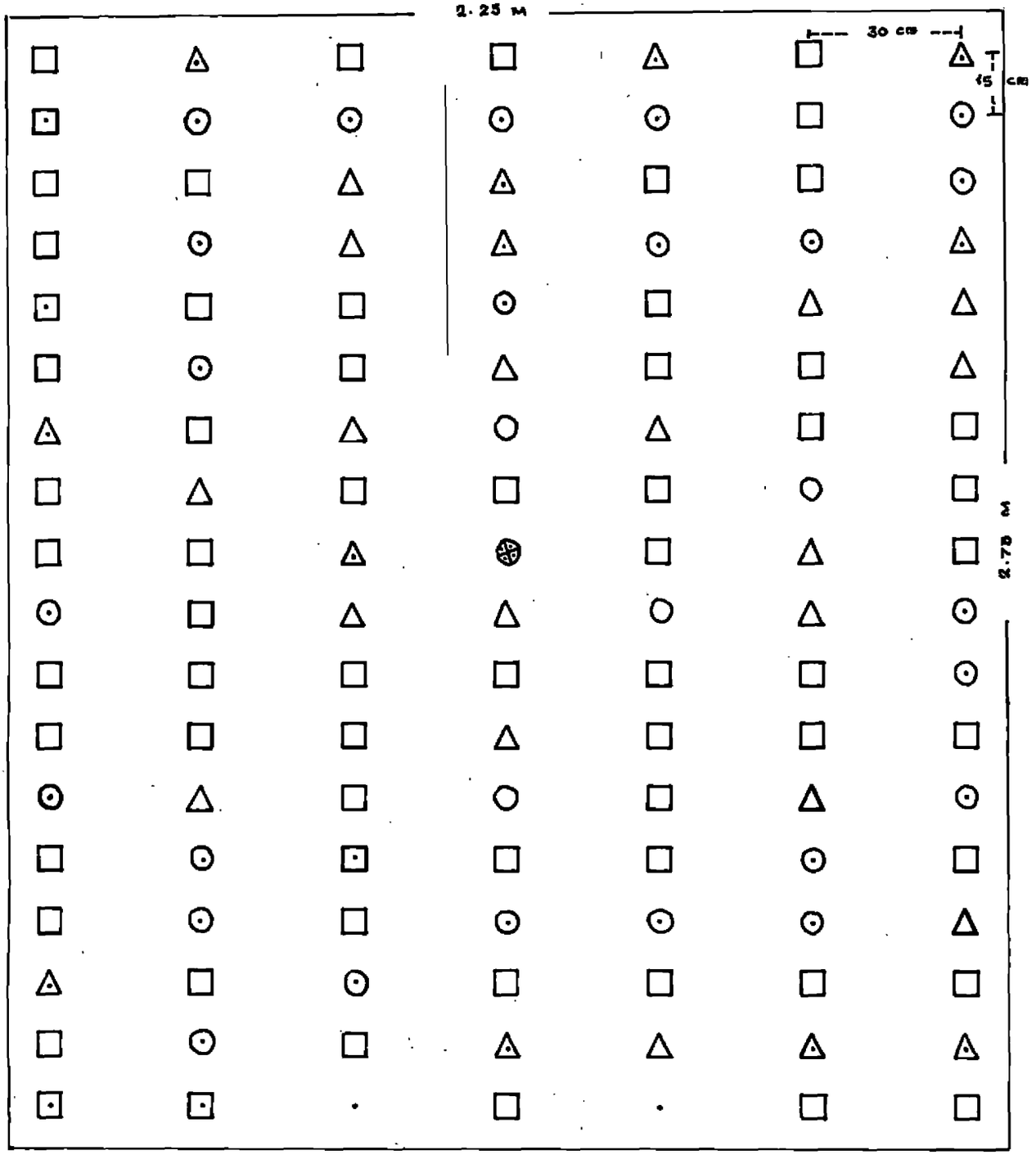

FIG: 1 PATTERN OF SPREAD OF SESAMUM LEAF CURL VIRUS

Table 7

Observed and estimated number of diseased plants

X(Week)	Observed number of diseased plants	Estimated number of diseased plants
1	3.5	5.5
2	20.5	37.2
3	83.0	83.0
4	110.0	108.9
5	119.5	119.5
6	123.5	123.3

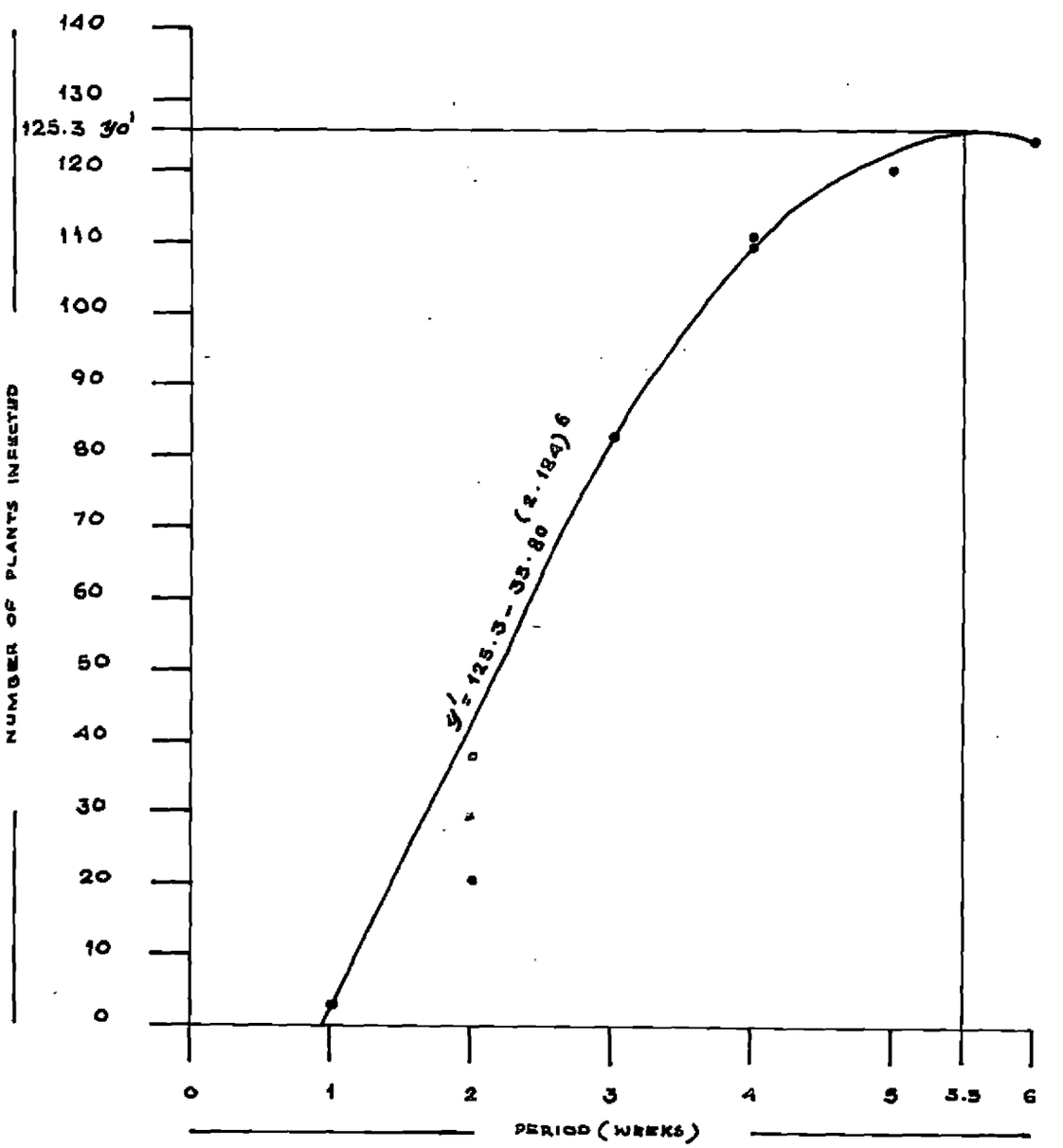

FIG: 2 TREND OF PATTERN OF SPREAD OF SESAMUM CURL VIRUS

Estimation of yield loss

a. Effect of leaf curl virus infection on height of plants

The results showed that the virus infection has adversely affectdd the height of the segamum plants (Table 8). Inoculation on the 7 day old seedlings was found to have more effect than other treatments. Inoculations on the 14 and 21 day old plants did not differ significantly in the effect on the height of plants. Similar was the case of inoculations on 21 day and 28 day old plants. But plants were less affected when the inoculation was done on 35 day old plants.

b. Effect of infection on the number of leaves

The data showed that the inoculation of seven day old plants reduced the number of leaves significantly as compared to control and other treatments (Table 9). The extent of reduction was of the same magnitude when inoculations were done on 21 and 28 day old plants. The extent of reduction was comparatively less when inoculated on 35 day old plants.

c. Effect of infection on length of leaves

The data showed that the inoculation of 7 day old plants reduced the length of leaves significantly as compared to control and other treatments (Table 10). The length of leaves of other treatments were also reduced and the extent of reduction decreased with the increase in age of the plants.

Table 8

Effect of infection on the height of the plants
(Mean height in cm)

Treatments	Varieties				Mean
	V_1	V_2	V_3	V_4	
T_0	131.00	118.33	94.33	110.33	113.50
T_1	14.33	23.00	20.67	19.33	19.33
T_2	38.67	35.00	40.00	40.00	38.42
T_3	46.67	47.33	58.33	51.67	51.00
T_4	63.00	55.00	51.67	69.33	59.75
T_5	106.67	80.00	61.67	88.33	84.17

C.D. for comparison between treatment means = 14.24

Inference = T_0 T_5 $\overline{T_4\ T_3}$ T_2 T_1

T_0 - Control
T_1 - Inoculation 7 days after germination
T_2 - Inoculation 14 days after germination
T_3 - Inoculation 21 days after germination
T_4 - Inoculation 28 days after germination
T_5 - Inoculation 35 days after germination

V_1 - Kayamkulam - 1
V_2 - Kayamkulam - 2
V_3 - KRR-1
V_4 - PT-35

Table 9

Effect of infection on the number of leaves

Treatments	Varieties				Mean
	V_1	V_2	V_3	V_4	
T_0	137.33	130.67	155.00	130.00	140.75
T_1	14.67	23.00	15.67	11.33	16.17
T_2	48.00	39.00	30.33	48.33	41.42
T_3	70.33	46.67	72.33	67.67	64.25
T_4	94.00	67.33	48.00	85.00	73.58
T_5	125.00	111.67	90.00	130.00	114.17

C.D. for comparison between treatment means = 18.65

Inference: T_0 T_5 $\overline{T_4\ T_3}$ T_2 T_1

Table 10

Effect of infection on length of leaves

Treatment	Varieties				Mean
	V_1	V_2	V_3	V_4	
T_0	5.83	7.90	7.23	6.83	6.95
T_1	1.83	1.50	2.63	1.73	1.93
T_2	1.90	2.17	2.40	2.50	2.24
T_3	2.40	1.83	3.00	2.23	2.37
T_4	2.67	2.10	2.57	2.33	2.42
T_5	3.03	3.50	2.83	2.67	3.01

C.D. for comparison between treatment means = 1.18

Inference - T_0 $\overline{T_5\ T_4}$ $\overline{T_3\ T_2}$ T_1

d. Effect of infection on the breadth of leaves

Here also as in the above case there was considerable reduction in the breadth of leaves when compared with the control. The extent of reduction for the 7 and 14 day old plants was of the same degree. Similarly for 14 and 21 day old plants, 21 and 28 day old plants and 28 and 35 day old plants also the extent of reduction was of the same degree.

e. Effect of infection on the number of branches

The results showed that there was considerable reduction in the number of branches produced when inoculated 7, 14, 21 and 28 day old plants (Table 12).

f. Effect of infection on flower production

It was observed that when 7 day old plants were inoculated flowering was completely suppressed (Table 13). Inoculation of 14, 21, 28 and 35 day old plants caused a reduction in the number of flower significantly over the control.

g. Effect of infection on pod formation

Flower and pod formation was absent when 7 day old plants were inoculated. When plants were inoculated at subsequent stages of growth, there was significant reduction of pod formation over the control.

Table 11

Effect of infection on the breadth of leaves

Treatments	Varieties				Mean
	V_1	V_2	V_3	V_4	
T_0	5.67	9.00	7.33	7.83	7.46
T_1	0.70	1.50	0.67	1.10	0.99
T_2	0.53	1.43	1.63	1.13	1.18
T_3	0.93	0.87	1.20	1.73	1.18
T_4	1.30	2.83	1.27	4.33	2.43
T_5	3.33	3.57	3.33	3.00	3.31

C.D. for comparison between treatments means = 1.16

Inference: T_0 $\overline{T_5\ T_4\ T_3\ T_2\ T_1}$

Table 12

Effect of infection on the number of branches

Treatments	Varieties				Mean
	V_1	V_2	V_3	V_4	
T_0	10.00	10.00	9.00	6.33	8.83
T_1	0.67	0.00	0.00	0.67	0.33
T_2	1.33	2.67	1.67	2.00	1.92
T_3	3.33	2.67	4.00	3.33	3.33
T_4	5.33	2.33	2.00	3.33	3.25
T_5	4.67	7.00	5.67	6.67	6.00

C.D. for comparison between treatment mean = 2.06

Inference - T_0 T_5 $\overline{T_3\ T_4}$ $\overline{T_2\ T_1}$

Table 13

Effect of infection on flower production

Treatments	Varieties				Mean
	V_1	V_2	V_3	V_4	
T_0	91.33	93.33	91.33	10.00	94.00
T_1	0.00	0.00	0.00	0.00	0.00
T_2	4.33	6.00	3.33	3.00	4.17
T_3	20.00	9.33	26.67	12.00	16.17
T_4	27.33	13.67	15.67	39.00	23.08
T_5	29.33	27.33	42.00	31.00	32.42

C.D. for comparison between treatment means = 11.11

Inference: T_0 $\overline{T_5\ T_4\ T_3}$ $\overline{T_2\ T_1}$

Table 14

Effect of infection on pod formation

Treatment	Varieties				Mean
	V_1	V_2	V_3	V_4	
T_0	82.67	90.33	89.00	90.67	88.17
T_1	0.00	0.00	0.00	0.00	0.00
T_2	1.67	1.33	0.67	0.67	1.08
T_3	7.33	2.33	9.33	3.00	5.50
T_4	10.67	6.00	5.33	24.00	11.50
T_5	22.67	14.67	27.00	23.67	22.00

O.D. for comparison between treatment means = 9.93

Inference: T_0 T_5 $\overline{T_4\ T_3\ T_2}$ T_1

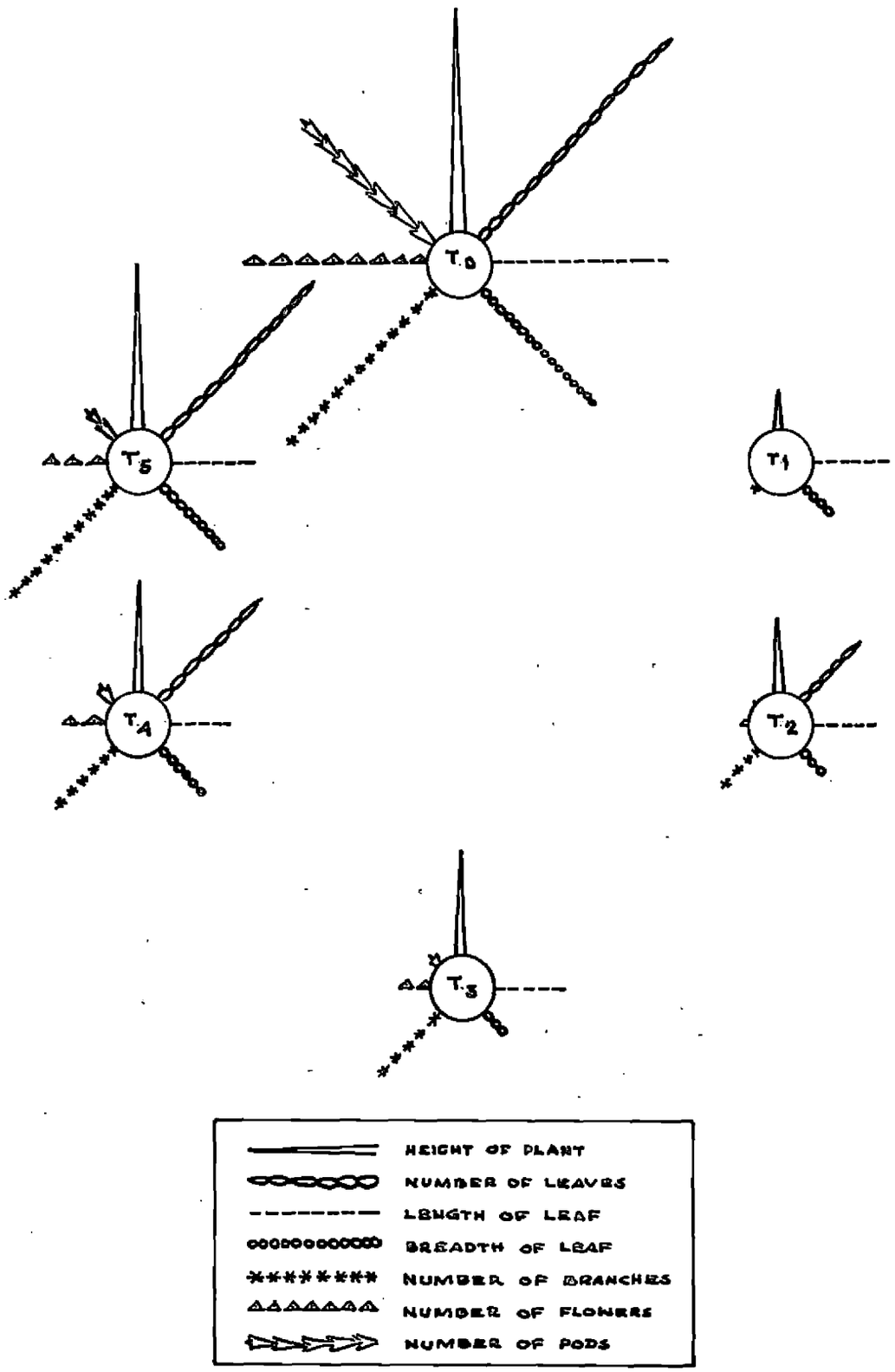

FIG: 3 EFFECT OF LEAF CURL VIRUS INFECTION ON YIELD ATTRIBUTES OF SESAMUM

Discussion

DISCUSSION

The virus causing leaf curl disease of sesamum (Sesamum indicum L.) was investigated. The disease was found to be widespread in Kerala. The symptoms of this disease were similar to those of the leaf curl diseases of sesamum, tomato and chilli as described by Sahambi (1958), Vasudeva and Sam Raj (1948) and Mishra et al.(1963) respectively. The major symptoms of leaf curl disease of sesamum were abaxial curling, reduction in size, thickening of veins and leathery appearance of leaves. But in variety Maran the abaxial curling was absent and moreover, sometimes there was an adaxial curling of leaves. This is only a varietal response to the virus infection because on transmission to other susceptible varieties the typical symptoms of sesamum leaf curl were produced. This shows that both the viruses are one and the same. This type of difference in the symptoms of leaf curl of sesamum in a variety of sesamum has not been reported so far.

The virus was found to be transmitted by grafting and by whitefly transmission. In the case of graft transmission the results indicated that side grafting was superior to wedge grafting in terms of percentage success in the establishment of graft. When wedge grafting was done, since stock and scion were young plants there was a mucilaginous exudation from the

cut ends of both the stock and scion and probably this might have resulted in the poor establishment of the graft union. In the case of side grafting the stock was fairly mature plants and so the mucilagenous exudate was very less which resulted in the better establishment of the graft union.

Attempts to transmit the virus by sap inoculation had failed showing that the sesamum leaf curl virus was not mechanically transmissible by the methods employed in the present studies. Similar was the result in the case of seed transmission trials also. So far there is no report of positive mechanical or seed transmission of sesamum leaf curl virus.

Transmission of sesamum leaf curl virus by the whitefly, Bemisia tabaci was reported by Sahambi (1958). Almost all the leaf curl viruses are transmitted by B.tabaci eg. tobacco leaf curl virus (Pruthi and Samuel 1939), tomato leaf curl virus (Vasudeva and Sam Raj, 1948), chilli leaf curl virus (Mishra et al. 1963), cotton leaf curl virus (Nair et al., 1964) etc.

Studies on the vector-virus relationships showed that the vector, B.tabaci could acquire the virus with a minimum acquisition feeding period of 10 min. It has been reported that the vector could acquire the virus in 15 minutes in the case of tobacco leaf curl virus (Pruthi and Samuel, 1939;Pruthi, 1944) and tomato yellow leaf curl virus (Cohen and Nitzany, 1966) and

31 min in the case of tomato leaf curl virus (Butler and Rataul, 1977). This shows that the minimum acquisition feeding period for sesamum leaf curl virus is lesser than that of the other common leaf curl viruses. As the acquisition feeding period was increased the efficiency of transmission of the virus was also increased and after a period of 4 h it reaches its maximum (Table 2). Increase in the efficiency of transmission with the increase in the acquisition feeding period has been reported in the case of many leaf curl diseases including tomato leaf curl diseases (Reddy and Yaraguntaiah,, 1981).

It has been found that the vector requires an incubation period of 28 h to become viruliferous. A minimum of 21 h incubation period was reported for tomato yellow leaf curl virus (Cohen and Nitzany, 1966), but a period of only 6 h was required in the case of tomato leaf curl virus (Reddy and Yaraguntaiah, 1981).

The whitefly could transmit the virus with a minimum inoculation feeding period of 30 min. This is similar to cotton leaf curl virus (Krikpatrick, 1931), tomato yellow leaf curl virus (Cohen and Nitzany, 1966) and tomato leaf curl virus (Reddy and Yaraguntaiah, 1981). But a minimum inoculation feeding period of only 15 min was reported for tobacco leaf curl virus (Pruthi and Samuel, 1939; Pruthi, 1944).

In leaf curl of certain weeds viz., Acanthospermum hispidum, Blainvillea rhomboidea, Flaveria australasia etc. a minimum inoculation feeding period of 1 h was required for successful inoculation (Mariappan and Narayanaswamy, 1977). As in the case of acquisition feeding period here also as in the time increased the efficiency of transmission also increased (Table 4).

In the case of retention of infectivity by the vector it has been observed that once the vector acquires the virus it could retain the infectivity throughout its life period. This is similar to that reported for tomato leaf curl virus (Reddy and Yaranguntaiah, 1981). The results of the present studies indicate that the transmission of sesamum leaf curl virus by B.tabaci is similar to circulative manner with the possibility of multiplication of the virus in the vector. Detailed further investigations are required for conclusively proving this.

The minimum number of whiteflies needed to produce infection was found to be one (Table 6) and the optimum number to obtain maximum infection was 15. Reddy and Yaraguntaiah (1981) while describing tomato leaf curl virus reported that a single viruliferous whitefly could transmit the virus successfully. Mathew (1981) who reported the similar results for leaf curl of Ageratum conizoides, Stachytarpheta indica and Synedrella nodliflora.

Inoculation of sesamum leaf curl virus at different growth stages of sesamum plants showed that the vegetative growth and yield are affected severely when inoculated at an early stage while the effect of virus inoculation was not so significant at later stages of infection. There was significant reduction on the number of leaves and size of leaves, when the plants were inoculated at different growth stages. The effect was not so pronounced when the plants were infected at later stages of growth.

The height of the plants was considerably reduced when 7, 15 and 21 day old plants were inoculated resulting in stunting of the plants. Similar results were obtained in the case of number of branches also.

It was observed that early inoculation of plants resulted in complete failure of flowering and fruit set resulting in complete loss in yield. Subsequent inoculations reduced significantly the number of flowers and pods formed. It has been found that the per cent crop loss varied depending on the growth stage of plants.

In the present studies inoculations were conducted upto 35 day old sesamum plants and as the inoculations were delayed the adverse effect of virus infections on the plants become lesser. Inoculations studies have to be conducted after 35 days also to conclusively prove that there is no need of any control measures against sesamum leaf curl disease if the infection occurs after this stage.

Out of 49 species of plants belonging to 12 different families 9 species of plants belonging to 6 families were found to be susceptible to the virus. The virus could produce typical leaf curl symptoms in Acalypha indica, Capsicum annuum, Dolichos lablab, Lycopersicon esculentum, Nicotiana tabacum, Scoparia dulcis, Stachytarpheta indica, Zinnia linnearis and Z.elegans. This is the first report showing that these plants can act as collateral hosts of sesamum leaf curl virus. Capsicum annuum, Lycopersicon esculentum, Scoparia dulcis and Zinnia elegans were reported as collateral hosts of tobacco leaf curl virus (Pruthi and Samuel, 1939, 1942).

The results of the present studies show that sesamum leaf curl virus produced the typical tomato leaf curl, chilli leaf curl and tobacco leaf curl diseases. Based on the symptomatology and host range studies it can be concluded that these diseases are caused by the same virus or similar viruses.

In the case of pattern of spread the Gompertz curve fits accurately the observed data on spread of the disease during weekly intervals. This indicates the possibility of utilizing Gompertz curve in forecasting the extent of spread of sesamum leaf curl disease. Such advance information may help in adopting timely control measures for the disease by preventing the spread of the disease by rouging or by the application of insecticides to destroy the vector.

Summary

SUMMARY

Leaf curl disease of sesamum, a major virus disease affecting sesamum was investigated. Various aspects like symptomatology, methods of transmission, vector-virus relationships, host range, pattern of spread of the disease under field conditions and the extent of loss caused by the disease at various stages of growth of the plants were subjected to detailed studies.

Studies on symptomatology revealed that this disease is similar to leaf curl of chilli, tobacco and tomato. Major symptoms were severe abaxial curling of the leaves, leathery appearance of leaves and thickening of veins on the lower surface of the leaves. Severely affected plants remained stunted and produced only very few pods. In the variety Maran there was adaxial curling instead of the abaxial curling observed in other varieties.

This particular virus was transmitted by grafting and by the whitefly, Bemisia tabaci Genn. and not by seed or sap. The vector-virus relationship was found to be similar to circulative type with a minimum acquisition feeding period of 10 min, inoculation feeding period of 30 min and incubation period of 28 h in the vector.

Among the 49 species of plants belonging to 12 different families studied 9 species of plants belonging to 6 families

viz. Acalypha indica (F.Euphorbiaceae), Dolichos lablab (F.Papilionaceae), Capsicum annuum, Lycopersicon esculentum and Nicotiana tabacum (F.Solanaceae), Zinnia linneares and Z.elegans (F.Compositae), Scoparia dulcis (Scrophulariaceae) and Stachytarpheta indica (F.Verbenaceae) were found to be susceptible to the virus.

Inoculation of sesamum leaf curl virus at different growth stages of sesamum plants showed that the vegetative growth and yield were severely affected when inoculated at an early stage. As the age of the plant increases the extent of loss decreases. Even the 35 day old plants, when inoculated, showed significant reduction in yield, but the extent of reduction was less when compared with the 7 day old plants.

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* ORIGINALS NOT SEEN

Appendices

Appendix-I

Analysis of variance - Height of plants

Source	df	M.S.
T	5	13537.49*
V	3	491.43
V x T	15	319.30
Error	48	301.24

* Significant at 1.00 per cent

Appendix-II

Analysis of variance - Number of leaves

Source	df	M.S.
T	5	25353.22*
V	3	848.33
V x T	15	476.67
Error	48	516.81

* Significant at 1.00 per cent

Appendix-III

Analysis of variance - Length of leaves

Source	df	M.S.
T	5	43.05*
V	3	0.837
V x T	15	0.726
Error	48	0.723

* Significant at 1.00 per cent

Appendix - IV

Analysis of variance - Breadth of leaves

Source	df	M.S.
T	5	73.39*
V	3	5.27
V x T	15	2.02
Error	48	2.01

* Significant at 1.00 per cent

Appendix - V

Analysis of variance - Number of branches

Source	df	M.S.
T	5	110.72*
V	3	1.22
V x T	15	4.03
Error	48	6.33

* Significant at 1.00 per cent

Appendix - VI

Analysis of variance - Flower production

Source	df	M.S.
T	5	14138.82*
V	3	111.91
V x T	15	120.27
Error	48	183.28

* Significant at 1.00 per cent

Appendix - VII

Analysis of variance - Pod formation

Source	df	M.S.
T	5	13631.26*
V	3	56.60
V x T	15	65.52
Error	48	146.42

* Significant at 1.00 per cent

STUDIES ON LEAF CURL DISEASE OF SESAMUM

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ABSTRACT OF A THESIS
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ABSTRACT

Leaf curl disease of sesamum, its symptomatology, mode of transmission, vector-virus relationships, the pattern of spread under field conditions and the extent of loss caused by the disease were investigated.

Major symptoms of the disease were abaxial curling of the leaves, thickening of the veins on the under surface of the leaves, leathery appearance of the leaves and reduction in the size of leaf lamina. The plants remained stunted and produced few flowers and pods when infection occurred during the early stages of the plant growth. When infection occurred during later stages there was production of flowers and pods but to a limited extent.

This particular virus could be transmitted by wedge and side grafting and by the whitefly Bemisia tabaci Genn. The minimum acquisition feeding period was found to be 10 min and the minimum inoculation feeding period was 30 min. The vector required an incubation period of 28 h to become viruliferous. Even a single whitefly was found to be capable of transmitting the virus. Once the vector acquired the virus it would retain it till its death.

Negative results were obtained in the case of sap and seed transmission showing that this particular virus was not sap and seed transmissible.

Host range studies showed that this particular virus could infect 9 species of plants belonging to 6 different families. They were Acalypha indica (F.Euphorbiaceae), Capsicum annuum, Lycopersicon esculentum, Nicotiana tabacum (F.Solanaceae), Dolichos lablab (F.Papilionaceae), Scoparia dulcis (F.Scrophulariaceae), Stachytarpheta indica (F.Verbanaceae), Zinnia elegans and Z.linneares (F.Compositae).

Under field conditions this particular virus did not show any regular pattern of spread. But the trend followed in the pattern of spread of the virus was that of Gompertz curve.

The extent of loss caused by this particular virus on yield of sesamum was investigated. The results showed that when inoculated on seven day old plants there was complete reduction in yield. The extent of loss decreased with the increase in the age of the plants. Even when 35 day old plants were inoculated there was significant reduction in yield when compared with the control.

The symptoms, modes of transmission and host range of sesamum leaf curl disease indicated that the disease is caused by the same virus which causes the leaf curl disease of chilli and tomato.