Proc. Indian Acad. Sci. (Anim. Sci.), Vol. 93, No. 4, June 1984, pp. 397–406.
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# Plant virus diseases transmitted by whiteflies in Karnataka

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**Abstract.** Whiteflies (*Bemisia tabaci*) transmitted yellow mosaic, yellow vein mosaic and leaf curl diseases of economically important crops. Horsegram yellow mosaic virus and cowpea mild mottle virus have been isolated and characterised in India. Except these two viruses the causal agents of other whitefly transmitted diseases are not known.

**Keywords.** Whitefly; *Bemisia tabaci*; yellow mosaic; yellow vein mosaic; leaf curl; geminivirus; horsegram yellow mosaic virus; cowpea mild mottle virus; ELISA.

## 1. Introduction

Pathogens transmitted by whiteflies have been known to occur more abundantly in tropical and subtropical countries and less abundantly in temperate countries (Bird and Maramorosch 1978; Costa 1976; Duffus and Flock 1982; Goodman and Irwin 1981; Hildebrand 1959; Muniyappa 1980; Nene 1972; Varma 1963).

The whitefly-borne diseases occur on economically important crop plants, causing substantial yield losses every year in India (Butter and Rataul 1981; Muniyappa 1980; Nene 1972; Sastry and Singh 1973).

The importance of whitefly transmitted diseases in Karnataka was suggested by Govindu (1964). Since then progress has been made on transmission, host range and some aspects of epidemiology and control. A brief account of work done on whitefly transmitted diseases in Karnataka is discussed in this paper.

## 2. Diseases

### 2.1 *Yellow mosaic of bambara groundnut*

A yellow mosaic disease characterised by faint yellow discolouration of young leaves and bright yellowing of older leaves was observed on *Voandzeia subterranea* (bambara groundnut) (caused by horsegram yellow mosaic virus) during summer of 1981 at the Agricultural Farm, University of Agricultural Sciences, Bangalore. The agent could be acquired by *Bemisia tabaci* in 10 min and required a minimum of 4 hr latent period and a 10 min inoculation access period. The *B. tabaci* transmitted the disease agent to *Canavalia ensiformis*, *Glycine max*, *Macrotyloma uniflorum* cv. HH-2, *Phaseolus lunatus*, *P. vulgaris* cv. contender and *Vigna radiata* cv. PIMS-3 (Muniyappa *et al* 1984 in press).

### 2.2 *Yellow mosaic of Dolichos lab-lab*

Yaraguntaiah and Govindu (1964) observed yellow mosaic in *Lab-lab purpureus* (syn. *Dolichos lab-lab*). The disease agent was transmitted by *B. tabaci* but the percentage of transmission was low. The per cent incidence in the fields in summer was 1% to 5% (Annapurna and Muniyappa unpublished).

Mosaic symptoms were observed on young leaves in the form of scattered irregular yellow spots. The size of the spots increased gradually and eventually the leaves became completely yellow (Maramorosch and Muniyappa 1981). Two hundred and forty-eight germplasm lines tested were susceptible to the disease (Muniyappa and Chandrashekaraiah 1980).

### 2.3 *Yellow mosaic of french bean*

The disease was characterised by a bright yellow mosaic pattern on the leaves and downward rolling of leaves. Plants became stunted and leaves were reduced in size. The infected plants produced few pods (Maramorosch and Muniyappa 1981). During summer bean plants were severely affected and infection reached 50% to 80% (Annapurna and Muniyappa unpublished).

The disease agent infected experimentally *G. max*, *M. uniflorum*, *P. lathyroides*, *P. lunatus* and *V. radiata*. *B. tabaci* acquired the virus after feeding for 10 min and inoculated it into healthy plants after 15 min. Infectivity was retained by vectors for 18 days (Maramorosch and Muniyappa 1981). The disease is caused by horsegram yellow mosaic virus (Muniyappa *et al* unpublished). Several insecticides were used for controlling whitefly vector in experimental farm (Singh *et al* 1981).

### 2.4 *Yellow mosaic of groundnut*

Diffused yellow discolouration appeared on young leaves and later yellow mosaic mottling appeared. Sometimes entire leaves became bright yellow. The incidence of disease during summer in fields was less than 1%. The disease was not so serious in groundnut. The virus was transmitted by *B. tabaci* from groundnut to groundnut, *M. uniflorum*, *P. lunatus* and *V. radiata* (Annapurna and Muniyappa unpublished). The yellow mosaic disease of groundnut is caused by horsegram yellow mosaic virus (Muniyappa *et al* unpublished).

### 2.5 *Yellow mosaic virus of horsegram*

The incidence of yellow mosaic virus in horsegram was 100% during summer and early kharif and the incidence was low from July to December. The incidence was correlated with the abundance of the whitefly *B. tabaci* population in the field (Muniyappa *et al* 1975, 1978; Muniyappa 1983).

Faint yellow discolouration appeared on young leaves and as the disease progressed yellow mosaic mottling appeared. Subsequently the mottling enlarged and the entire leaves became bright yellow and eventually became completely bleached (Muniyappa *et al* 1975).

The virus was transmitted by *B. tabaci* to *Cajanus cajan*, *Centrosema* sp., *G. max*,

*P. aconitifolius*, *P. atropurpureus*, *P. lathyroides*, *P. lunatus*, *P. vulgaris*, *V. mungo*, *V. radiata*, *Teramnus uncinatus* and *Indigofera hirsuta* (Muniyappa and Reddy 1979; Muniyappa *et al* 1976a, 1977; Nagaraj 1982). Individual whiteflies were able to transmit the virus. The minimum acquisition and inoculation access periods were 30 min and 10 min respectively. Incubation period in the vector was 6 hr. Infectivity was retained for 12 days (Muniyappa and Reddy 1976). Several resistant and tolerant horsegram lines have been identified which are successfully used in breeding for disease resistance (Kallesh *et al* 1983; Muniyappa *et al* 1976b, 1979).

The virus particles resembling geminate particles measuring 15–18 × 30 nm have been isolated and characterised from yellow mosaic infected horsegram (Muniyappa *et al* unpublished).

### 2.6 *Yellow mosaic of jute*

The disease agent was transmitted by *B. tabaci* to *Corchorus capsularis* and *C. olitorius* producing bright yellow patches on leaves. The infected plants were slightly dwarfed and leaves were reduced in size (Maramorosch and Muniyappa 1981).

### 2.7 *Yellow mosaic of lima bean*

The disease was noticed in 1964 by Govindu in some parts of Karnataka. Faintly discoloured patches appeared on leaves which subsequently turned bright yellow. The infected plants continue to grow. Hundred per cent infection was observed in fields during summer (Annapurna and Muniyappa unpublished). Single *B. tabaci* was able to transmit the disease agent. Acquisition, inoculation and incubation periods were 1 hr, 15 min, and 8 hr respectively. The virus infected *P. aborigineus*, *P. coccineus*, *P. lathyroides*, *P. lunatus*, *G. max*, *M. uniflorum*, *V. mungo* and *V. radiata* (Maramorosch and Muniyappa 1981). The disease is caused by horsegram yellow mosaic virus (Muniyappa *et al* unpublished).

### 2.8 *Yellow mosaic of mungbean*

The disease causes serious loss and affects several legumes. The incidence of disease in fields varied from 30% to 80% during summer (Annapurna and Muniyappa unpublished). First symptoms appeared on young leaves, forming mild scattered yellow specks or spots that later enlarged. Severely infected plants were stunted and the yield was considerably reduced. *B. tabaci* transmitted the virus to *Cajanus cajan*, *G. max*, *M. uniflorum*, *P. acutifolius*, *P. aconitifolius*, *P. lathyroides*, *P. lunatus*, *P. vulgaris*, *V. mungo*, and *V. radiata*. Acquisition, inoculation and incubation periods in the vector *B. tabaci* were 20 min, 15 min, and 4 hr respectively. The whiteflies were found in nature throughout the year but the population was highest during summer and lower during kharif and rabi seasons (Maramorosch and Muniyappa 1981). All the cultivated varieties were susceptible to yellow mosaic (Muniyappa *et al* 1976c). *P. calcaratus* was immune to yellow mosaic (Nagaraj *et al* 1980) and it was utilized in breeding for disease resistance. Crosses between *P. calcaratus* and *V. radiata* resulted in number of lines which were resistant to yellow mosaic (Satyan *et al* 1983). The disease is caused by horsegram yellow mosaic virus (Muniyappa *et al* unpublished).

### 2.9 *Yellow mosaic of patchouli*

The infected leaves of patchouli plants showed yellow irregular patches in addition to systemic mottle. Some varieties produced diffused mosaic mottling and chlorotic spotting on the young leaves. The incidence of disease ranged from 43 % to 76 % at the experimental farm of Indian Institute of Horticultural Research, Bangalore. The disease agent was transmitted by *B. tabaci* to *Pogostemon patchouli*, *P. purpurascens* and *Ocimum basilicum* (Sastry and Vasanthakumar 1981).

### 2.10 *Yellow mosaic of pigeonpea*

The virus was transmitted by *B. tabaci* to *G. max*, *M. uniflorum*, *P. lunatus* and *V. radiata*. Yellow diffused spots on the leaves gradually enlarged to form broad yellow patches (Maramorosch and Muniyappa 1981). The incidence of yellow mosaic under field conditions varied from 1 % to 8 % (Annapurna and Muniyappa unpublished). The disease is caused by horsegram yellow mosaic virus (Muniyappa *et al* unpublished).

### 2.11 *Yellow mosaic of soybean*

Faint yellow discolouration appeared on young leaves and later turned into bright yellow patches. In highly susceptible varieties the leaves exhibited complete yellow, plants stunted and reduced in pod size (Maramorosch and Muniyappa 1981). The incidence of disease under field conditions during summer varied from 10 % to 40 % (Annapurna and Muniyappa unpublished). *G. formosana* and *G. weightii* were resistant to yellow mosaic virus (Muniyappa *et al* 1983b). The disease is caused by horsegram yellow mosaic virus (Muniyappa *et al* unpublished).

### 2.12 *Chlorotic ring spot of jasmine*

The disease agent transmitted by *B. tabaci* induced yellow chlorotic spots of varying size and shape intermingled with the normal green colour of the leaves (Maramorosch and Muniyappa 1981; Jagadishchandra *et al* 1979).

### 2.13 *Yellow vein mosaic of Ageratum conyzoides*

The characteristic symptoms were vein clearing, yellowing of veins and slight reduction of leaf size and in the height of the plants. Curling of the leaves was also observed. Single *B. tabaci* was able to transmit the disease agent (Maramorosch and Muniyappa 1981).

### 2.14 *Yellow vein mosaic of bhendi*

Yellow vein mosaic of bhendi is a very serious disease affecting the growth and yield of the crop (Govindu 1964; Singh 1980). Characteristic symptoms of the disease were clearing of the veins, yellowing and vein enlargement on the lower leaf surface. Flowering was sparse and few fruits were formed. The disease agent was transmitted by *B. tabaci* (Maramorosch and Muniyappa 1981; Singh 1980). The incidence of disease

was correlated with vector population in the field. The incidence of disease was more in summer (February to early June) and lower from late June to December (Singh 1980). Singh *et al* (1977) suggested several methods for the control of the disease.

### 2.15 *Yellow vein mosaic of Croton sparsiflorus*

*C. sparsiflorus* a common weed was infected with yellow vein mosaic disease. The disease symptoms included vein clearing, vein yellowing, reduction in leaf size and slight stunting and bushy appearance. The disease agent was transmitted by *B. tabaci* (Maramorosch and Muniyappa 1981).

### 2.16 *Yellow vein mosaic of Eclipta alba*

The symptoms of the disease included vein clearing, yellowing of the veins and complete chlorosis of laminae in advanced stages. The disease agent was transmitted by *B. tabaci* (Maramorosch and Muniyappa 1981).

### 2.17 *Yellow vein mosaic of Leucas*

Vein clearing and yellowing were observed in *L. asper*. The disease agent was transmitted by *B. tabaci* from *L. asper* to *L. asper* (Maramorosch and Muniyappa 1981).

### 2.18 *Yellow vein mosaic of Malvastrum coromandelianum*

The disease agent produced vein clearing, yellowing of the veins and slight reduction in leaf size. The agent was transmitted by *B. tabaci*. The vector acquired the disease agent in 20 min and transmitted it after an incubation period of 4 hr. Infectivity was retained for 10–16 days (Maramorosch and Muniyappa 1981).

### 2.19 *Leaf curl of chilli*

Leaf curl is one of the serious diseases of chillies in Karnataka causing substantial yield losses every year (Govindu 1964; Singh *et al* 1979a). Based on host range and transmission the disease has been reported to be caused by the agent of tobacco leaf curl. The incidence of disease during February to June was 70% to 100% and from July to December it was 10% to 25% (Singh *et al* 1979a). Curling of the leaves was accompanied by puckering and blistering of interveinal areas and thickening and swelling of the veins. Axillary buds were stimulated to produce clusters of leaves that were reduced in size. Infected plants were stunted and bushy in appearance. The disease agent was transmitted by *B. tabaci* to *Capsicum annuum*, *C. frutescens*, *C. microcarpum*, *Lycopersicon esculentum* and *Nicotiana tabacum* (Maramorosch and Muniyappa 1981). Furadon (1·5 kg ai/ha), disulfoton (1·5 kg ai/ha) and oxydemeton-methyl (0·05%) were found effective in reducing whitefly population and leaf curl incidence to a great extent (Singh *et al* 1979a).

### 2.20 *Leaf curl of papaya*

The disease which occurs sporadically in Karnataka (Govindu 1964) produced severe curling, crinkling and distortion of leaves, vein clearing and reduction of leaf size. Based on host range and transmission the disease has been reported to be caused by the agent of tobacco leaf curl. The leaf margins were rolled backward and inward, the veins thickened and turned dark in colour. Leaves became leathery and brittle and infected plants bore few flowers. The disease agent was transmitted by *B. tabaci* (Maramorosch and Muniyappa 1981).

### 2.21 *Leaf curl of sesamum*

The causal pathogen transmitted by *B. tabaci* induced curling of the leaves inward and backward, leathery appearance of the leaves and thickened veins on the underside of the leaves. Severely affected plants remained stunted and produced few fruits (Maramorosch and Muniyappa 1981).

### 2.22 *Leaf curl of tobacco*

The disease occurs throughout the state causing substantial yield losses (Govindu 1964). The disease produced curling and puckering of the leaves, clearing and thickening of the veins, twisting of petioles and enations on the veins or the undersurface of the leaves. The leaves were reduced in size. The disease agent was transmitted by *B. tabaci* to *Acanthospermum hispidum*, *C. annuum*, *Carica papaya*, *Datura stramonium*, *L. esculentum*, *N. tabacum* and *N. glutinosa* (Maramorosch and Muniyappa 1981).

### 2.23 *Leaf curl of tomato*

Leaf curl is a very serious disease throughout Karnataka and caused great damage to the crop (Govindu 1964; Sastry and Singh 1973). Hundred per cent infection was observed in summer causing yield losses ranging from 27 % to 90 % depending on the age at which infection occurred (Sastry and Singh 1973; Sastry *et al* 1978a; Seetharama Reddy 1978).

The disease agent produced pronounced dwarfing and puckering of the leaves sometimes vein clearing and excessive branching. Early infected plants were severely stunted and flowers dropped off. Infected plants produced few fruits of small size (Seetharama Reddy 1978; Maramorosch and Muniyappa 1981). Variations in leaf curl symptoms were observed and based on the symptoms on tomato they were grouped into five isolates (Seetharama Reddy *et al* 1981).

*B. tabaci* transmitted the disease agent to *Datura stramonium*, *L. esculentum*, *L. hirsutum*, *L. peruvianum*, *L. pimpinellifolium*, *L. pississi* and *N. tabacum* (Seetharama Reddy 1978; Maramorosch and Muniyappa 1981). Single whitefly was able to transmit the causal agent. The minimum acquisition and inoculation access periods were 30 min each. A minimum incubation period of 6 hr was observed to be essential for transmission. The whiteflies which acquired the virus could transmit the disease agent throughout their life span (Seetharama Reddy and Yaraguntaiah 1981a).

Spraying various insecticides such as dimethoate, methyl parathion, oxydemeton-

methyl, phorate, and phosphamedon from the nursery stage reduced whitefly population and also incidence of disease (Sastry and Singh 1971, 1974; Sastry *et al* 1974, 1976; Singh *et al* 1979b). Foliar application of DPB at 75 ppm was effective in reducing the infection by 50 % (Thirumalachar *et al* 1973). Three sprays of agricultural spray oil (1 %) or furadon 50 kg/ha one at the time of planting reduced the leaf curl incidence and increased the yields (Sastry *et al* 1974, 1978b; Singh *et al* 1975a, b). Furadon was proved to be effective in reducing the incidence of leaf curl (Seetharama Reddy and Yaraguntaiah 1981b). A combined treatment of nylon net covering for tomato nursery beds and 2–3 sprays of monocrotophos or dimethoate or cypermethrin (fenom) after transplanting in the field was effective in reducing the spread of leaf curl in tomato (Muniyappa and Saikia 1983). Incidence of leaf curl can be reduced to a certain extent by planting six rows of either sunhemp or maize as border crops. Border crop combined with three applications of dimethoate (0·05 %) as foliar spray not only reduced the incidence of leaf curl but also increased the yield of tomatoes (Sastry *et al* 1977).

### 2.24 *Cassava mosaic*

The disease was observed in Dakshina Kannada and Kodagu districts of Karnataka and also in experimental farm of GKVK campus, University of Agricultural Sciences, Bangalore. Young infected leaves show chlorotic areas and mosaic symptoms. In severely infected plants the leaves were reduced in size, distorted and deformed and have bright yellow areas alternating with normal green areas. The causal agent was transmitted by whitefly *B. tabaci* but the transmission rate was very low (Muniyappa unpublished).

### 2.25 *Cowpea mild mottle virus*

The incidence of cowpea mild mottle virus (CMMV) on soybean varied from 0·25 % to 15·5 % and on groundnut it was less than 1 % (Iizuka *et al* 1984 in press; Muniyappa *et al* 1983a). Infected soybean plants showed vein clearing and vein necrosis of leaves followed by downward curling of leaves. The newly emerged leaves showed mosaic and puckering (Iizuka *et al* in press; Muniyappa *et al* 1983a). Leaf dip and purified preparations from peanut and soybean showed slightly flexuous rods of 15 nm diameter with a modal length of 610 nm (Iizuka *et al* 1984 in press). CMMV was shown to be transmitted by the whitefly *B. tabaci* in a non-persistent manner. Individual adults of *B. tabaci* acquired CMMV in 10 min from soybeans and transmitted it within 5 min to soybeans. Irrespective of the length of acquisition, CMMV was retained by the adult whiteflies for four successive inoculation access periods of 5 min each. Attempts to detect CMMV by enzyme-linked immunosorbent assay in adults that were allowed acquisition access periods of 1 to 8 hr were unsuccessful (Muniyappa and Reddy 1983). CMMV was transmitted by mechanical sap inoculation. Seed transmission in soybean varied from 0·5 % to 1·66 %. The virus has been transmitted to 15 Leguminosae and Chenopodiaceae hosts (Iizuka *et al* 1984 in press; Muniyappa *et al* 1983a).

## 3. Conclusions

It is evident that whitefly transmitted diseases are economically very important in several crops causing great loss every year in Karnataka. Most diseases have been described based on symptoms, host range and transmission. Only horsegram yellow mosaic virus and cowpea mild mottle virus are isolated and characterised in India. Except these two viruses the causal agents of other whitefly transmitted diseases are not known. Yellow mosaics occurring on bambara groundnut, french bean, groundnut, lima bean, mung bean, pigeonpea and soybean are all caused by horsegram yellow mosaic virus. This would open new possibilities for epidemiological studies and testing varieties for resistance.

An accurate information is required on the loss due to these diseases. There is a need for more efficient methods of disease assessment. Forecasts of very serious diseases are also required so that insecticides are used only when necessary against vectors. Information on migrating vectors and the timing, magnitude, distance and direction of dispersal is essential for forecasting.

Effective control measures depend on a thorough knowledge of virus epidemiology and vector ecology. Effect of cropping systems on virus incidence and vector population has to be understood for better control.

Relationships of whitefly transmitted diseases in different geographical regions are not known.

The above cited diseases are reported to be transmitted by only one species of whitefly *Bemisia tabaci*. There may be other whitefly species transmitting the agents of these diseases.

## References

Bird J and Maramorosch K 1978 Viruses and diseases associated with whiteflies; *Adv. Virus Res.* **22** 55–109

Butter N S and Rataul H S 1981 Control strategies in whitefly borne viruses—a review; *Pestology* **5** (12) 7–14

Costa A S 1976 Whitefly transmitted diseases; *Ann. Rev. Phytopathol.* **14** 429–449

Duffus J E and Flock R A 1982 Whitefly transmitted disease complex of the desert southwest; *Calif. Agric.* **36** 4–6

Govindu H C 1964 A review on virus diseases of crop plants. Information Pamphlet No. 2 (Research Series). Directorate of Agriculture, Bangalore. 13 pp

Goodman R M and Irwin M E 1981 Whitefly transmitted viruses in tropical agriculture (abstract). in *International workshop on pathogens transmitted by whiteflies* July 31, (Oxford: Association of Applied Biologists, Wellesbourne)

Hildebrand E M 1959 A whitefly *Trialeurodes abutilonea* an insect vector of sweet potato feathery mottle in Maryland; *Plant Dis. Rep.* **43** 712–714

Iizuka N, Rajeshwari R, Reddy D V R, Goto T, Muniyappa V, Bharathan N and Ghanekar A M 1984 Natural occurrence of cowpea mild mottle virus on groundnut (*Arachis hypogaea*) in India; *Phytopathol. Z.* 108 (in press)

Jagadishchandra K, Sastry K S and Bhupal Rao J V R 1979 Screening of *Jasminum* species against yellow ring mosaic virus; *Curr. Sci.* **48** 77–78

Kallesh H G, Shashidhar H E, Muniyappa V and Shivashankar G 1983 Resistance to horsegram yellow mosaic virus in horsegram (abstract); *Virology Conference*, December 19–20, Hissar. p. 23

Maramorosch K and Muniyappa V 1981 Whitefly transmitted plant disease agents in Karnataka, India. In *International workshop on pathogens transmitted by whiteflies*. July 31, (Oxford: Association of Applied Biologists, Wellesbourne)

Muniyappa V 1980 Whiteflies. In *Vectors of plant pathogens* (eds) K F Harris and K Maramorosch (New York: Academic Press) pp. 39–85

Muniyappa V 1983 Epidemiology of yellow mosaic disease of horsegram (*Macrotyloma uniflorum*) in southern India. In *Plant Virus Epidemiology* (eds) R T Plumb and J M Thresh (Oxford: Blackwell Scientific Publications) pp. 331–335

Muniyappa V and Chandrashekaraiah S C 1980 Response of *Dolichos lab-lab* germplasm collections to yellow mosaic disease; *Curr. Res.* **9** 203–204

Muniyappa V and Reddy D V R 1983 Transmission of cowpea mild mottle virus by *Bemisia tabaci* in a non-persistant manner; *Plant Dis.* **67** 391–393

Muniyappa V and Reddy H R 1976 Studies on the yellow mosaic disease of horsegram (*Dolichos biflorus* Linn.). I. Virus vector relationships; *Mysore J. Agric. Sci.* **10** 605–610

Muniyappa V and Reddy H R 1979 *Indigofera hirsuta* a natural reservoir of horsegram yellow mosaic; *Madras Agric. J.* **60** 350

Muniyappa V and Saikia A K 1983 Prevention of the spread of tomato leaf curl disease (Abstract); *Indian Phytopathol.* **36** 183

Muniyappa V, Chandrashekaraiah S C and Shivashankar G 1979 Horsegram cultures tolerant to yellow mosaic; *Indian J. Genet. Plant Breeding* **38** 148

Muniyappa V, Reddy H R and Mustak Ali T M 1978 Studies on the yellow mosaic disease of horsegram (*Dolichos biflorus*). IV. Epidemiology of the disease; *Mysore J. Agric. Sci.* **12** 277–279

Muniyappa V, Reddy H R and Shivashankar G 1975 Yellow mosaic disease of *Dolichos biflorus* Linn. (horsegram); *Curr. Res.* **4** 176

Muniyappa V, Reddy H R and Shivashankar G 1976a Studies on the yellow mosaic disease of horsegram (*Dolichos biflorus* Linn.). II. Host range studies; *Mysore J. Agric. Sci.* **10** 611–614

Muniyappa V, Reddy H R and Shivashankar G 1976b Studies on the yellow mosaic disease of horsegram (*Macrotyloma uniflorum* syn. *Dolichos biflorus*). III. Evaluation of germaplasm for the disease; *Curr. Res.* **5** 52–53

Muniyappa V, Setty B A S and Shivashankar G 1977 Reaction of *Phaseolus* species to horsegram yellow mosaic; *Indian J. Genet. Plant Breeding* **37** 488–490

Muniyappa V, Gururaja Rao M R, Ravi K S and Shivashankar G 1984 The natural occurrence of a yellow mosaic disease of bambara groundnut (*Voandzeia subterranea*) transmitted by whiteflies; *Int. J. Trop. Plant Dis.* **2** (in press)

Muniyappa V, Rajeshwari R, Bharathan N and Sundaresh N 1983a Cowpea mild mottle virus in soybean in India. *4th Int. Plant Pathol. Cong.*, Melbourne August 17–24. Abstract No. 126. pp. 32

Muniyappa V, Reddy H R, Shivashankar G and Sreekantaradhya R 1976c Varietal response of greengram (*Phaseolus aureus* Roxb.) to the greengram yellow mosaic disease; *Curr. Res.* **5** 100–101

Muniyappa V, Viswanath S R, Sigamani N and Sundaresh H N 1983b Resistance source for yellow mosaic of soybean (Abstract); *Ann. Conf. Soc. Mycol. Plant Pathol.* April 18–22, Bangalore

Nagaraj N C 1982 *Studies on horsegram (Macrotyloma uniflorum) yellow mosaic disease.* M.Sc. (Agric.) Thesis, University of Agricultural Sciences, Bangalore. 125 pp

Nagaraj N C, Muniyappa V and Satyan B A 1980 Resistance source for mungbean yellow mosaic virus *Proc. Natl. Sem. Dis. Res. Crop Plants*, Coimbatore 69–72

Nene Y L 1972 A survey of viral diseases of pulse crops in U.P. G.B. Pant University of Agriculture and Technology. 191 pp

Sastry K S and Vasanthakumar T 1981 Yellow mosaic of Patchouli (*Pogostemon patchouli*) in India; *Curr. Sci.* **50** 767–768

Sastry K S, Sastry K S M and Singh S J 1974 Influence of different insecticides on tomato leaf curl incidence in the field; *Pesticides* **8** 41–42

Sastry K S M and Singh S J 1971 Effect of different insecticides on the control of whitefly (*Bemisia tabaci* Genn.) population in tomato crop and the incidence of the tomato leaf curl virus; *Indian J. Hortic.* **28** 304–309

Sastry K S and Singh S J 1973 Assessment of losses in tomato by tomato leaf curl virus; *Indian J. Mycol. Plant Pathol.* **3** 50–54

Sastry K S M and Singh S J 1974 Control of the spread of the tomato leaf curl virus by controlling the whitefly (*Bemisia tabaci*) population; *Indian J. Hortic.* **31** 178–181

Sastry K S M, Singh S J and Sastry K S 1976 Density of plant population together with the application of insecticides in relation to the incidence of tomato leaf curl virus; *Indian J. Mycol. Plant Pathol.* **6** 8–13

Sastry K S M, Singh S J and Sastry K S 1977 Effect of border cropping and the use of insecticides in relation to the incidence of tomato leaf curl virus (TLCV); *Indian J. Hortic.* **34** 319–322

Sastry K S M, Singh S J and Sastry K S 1978a Studies on the epidemiology of tomato leaf curl virus; *Indian J. Hortic.* **35** 269–277

Sastry K S M, Singh S J and Sastry K S 1978b Efficacy of krishi oil in relation to the control of whitefly population and the spread of tomato leaf curl virus (TLCV); *Pesticides* **12** 28–29

Satyan B A, Prakash K S, Muniyappa V, Shivashankar G and Gopala Reddy P 1983 Incorporation of yellow mosaic resistance in mungbean through interspecific hybridization. *XV. International Congress of Genetics*, New Delhi, December 12–21, Part II. Abstract No. 1097. Oxford and IBH Publishing Co., New Delhi.

Seetharama Reddy K 1978 *Studies on leaf curl virus disease of tomato* (*Lycopersicon esculentum* Mill.). Ph.D. thesis. University of Agricultural Sciences, Bangalore. 134 pp.

Seetharama Reddy K and Yaraguntaiah R C 1981a Virus-vector relationships in leaf curl disease of tomato; *Indian Phytopathol.* **34** 310–313

Seetharama Reddy K and Yaraguntaiah R C 1981b Effect of granular insecticides on the tomato leaf curl virus disease; *Indian Phytopathol.* **34** 291–295

Seetharama Reddy K, Yaraguntaiah R C and Sastry K S 1981 Strains of leaf curl virus of tomato in India; *Z. Pflanzenkr. Pflanzenschutz* **88** 400–404

Singh S J 1980 Studies on epidemiology of yellow vein mosaic virus of okra; *Indian J. Mycol. Plant Pathol.* **10** 35

Singh S J, Sastry K S and Sastry K S M 1977 Yellow vein mosaic of bhendi (okra) and methods to control; *Indian Hortic.* **22** 14–15

Singh S J, Sastry K S and Sastry K S M 1979a Combat leaf curl virus disease of chilli; *Indian Hortic.* **24** 9–10

Singh S J, Sastry K S and Sastry K S M 1979b Efficacy of different insecticides and oil on the control of leaf curl virus disease of chillies; *Z. Pflanzenkr. Pflanzenschutz* **86** 253–256

Singh S J, Sastry K S and Sastry K S M 1981 Field tests with insecticides and mineral oil for the protection in french beans from yellow mosaic virus disease; *Gartenbau Wissenschaft* **46** 88–90

Singh S J, Sastry K S M and Sastry K S 1975a Effect of oil spray on the control of tomato leaf curl virus in field; *Indian J. Agric. Sci.* **43** 669–672

Singh S J, Sastry K S M and Sastry K S 1975b Effect of alternate spraying of insecticides and oil on the incidence of tomato leaf curl virus; *Pesticides* **9** 45–46

Thirumulachar M J, Govindu H C and Yaraguntaiah R C 1973 Chemotherapeutic control of tomato leaf curl virus disease; *Indian Phytopathol.* **26** 330–332

Varma P M 1963 Transmission of plant viruses by whiteflies; *Bull. Nat. Inst. Sci. India* No. 24, 11–33

Yaraguntaiah R C and Govindu H C 1964 Virus disease of *Dolichos lab-lab* var. *typicum* from Mysore; *Curr. Sci.* **33** 721–722