DISTRIBUTION AND EPIDEMIOLOGY OF CHILLI VIRUSES IN KARNATAKA

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CERTIFICATE

This is to certify that the thesis entitled "DISTRIBUTION AND EPIDEMIOLOGY OF CHILLI VIRUSES IN KARNATAKA" submitted by Mr. V.B. BIDARI, for the degree of DOCTOR OF PHILOSOPHY in PLANT PATHOLOGY of the University of Agricultural Sciences, Bangalore, is a record of bonafide research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Affectionately Dedicated
to my father
late Sri Basappa Bidari

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V.B. BIDARI

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CHAPTER I

INTRODUCTION

The Portuguese brought Capsicum to India from Brazil prior to 1585. It became an important crop in India grown for fruits which are used as condiment both when green and ripe dried. Among the several species, Capsicum annuum Linn., and C.frutescens Linn., are cultivated. Most of the varieties both pungent and sweet peppers cultivated in India originated from C.annuum.

The chilli is known for its flavour and pungency. Both ripe and green chilli is used for imparting pungency. Sweet peppers are used as salad, stuffed with meat or as vegetable. In India, unripe chillies are consumed as a bite with meals, used for making pickles, chutneys, frying, etc. The pungency is due to an active principle, capsicin, contained in the pericarp and placenta. It is also a source of Vitamins A and B to some extent. The juice is claimed to be a sure cure for toothache and digestive disturbances.

This is an important cash crop of India and is grown both for home market and export. Important foreign markets for Indian chilli are Sri Lanka, Kuwait, Iran and the United Kingdom. It is mostly exported in the form of curry powder and curry paste. Prominent exporting countries besides India are Spain, Japan and Thailand.

Chilli crop is raised over 1.72 million hectares in the world both for green and ripe dry chilli, producing about 7.2 million tonnes. Major chilli growing countries in the world are India, China, Korea and Pakistan. Highest production per unit areaain Japan, followed by Italy and Egypt. In India, it is grown throughout the country in almost all the states, over an area of 0.8 million hectares with a production of 0.64 million tonnes of dry chilli. Nearly 70 per cent of the total cultivated area lies in Deccan Plateau. Andhra Pradesh tops in the production of dry chilli. The production per unit area is higher in Andhra Pradesh, Tamil Nadu and Orissa because, the crop is grown under irrigated condition. The major chilli growing districts in India are Dharwad, Ramanathpur, Tirunelveli, Nagpur, Tiruchinapalli, Nanded and Guntur (Anonymous, 1979).

Karnataka occupies third position in area under chilli (1,38,655 ha) and is one of the four states in producing maximum quantity of dry chilli (43,816 tonnes) (Anonymous, 1979). In area and production, among the 19 districts in Karnataka, Dharwad occupies first (53,957 ha and 12,896 tonnes) followed by Belgaum (14,196 ha and 6,417 tonnes), Shimoga (12,376 ha and 4,926 tonnes), Chitradurga (9,626 ha and 3,215 tonnes), Mysore (8,217 ha and 3,780 tonnes) and Gulbarga (6,069 ha and 1,135 tonnes).

Irrigated area under chilli in the State is about 24,850 ha. Major irrigated area in Karnataka is found in the districts of Belgaum (4,280 ha) followed by Bijapur (3,488 ha), Gulbarga (2,273 ha) and Dakshina Kannada (2,625 ha).

Though the area under chilli in Karnataka is more, its production is very low as compared to other states. Among the various biotic and abiotic factors which affect the production, virus diseases can be considered to be very important. A mosaic disease of chilli was first reported by McRae (1923) and Kulkarni (1924) in the erstwhile Bombay Province in India. Later, nine viruses causing mosaic disease on chilli have been reported by several workers. The most frequent symptoms produced by these viruses on chilli are slight to severe mosaic, mottling, vein clearing, vein banding, curling and marginal rolling of leaves, rat tailing, small and filiform leaves. Some viruses cause chlorotic to necrotic lesions, shedding of leaves, reduced number of flowers and fruits, and death of plants. Farmers call some symptomes due to viruses etc. by different names as Churda-murda, or Chandiroga in Karnataka, where leaf distortion and leaf reduction are prominent.

Considering the susceptible nature of the plant to a large number of viruses on artificial inoculation many more can be expected to be present in nature. Further, the symptom picture differs with varieties, climatic factors

and the viruses involved. It is necessary to find out a diagnostic key for a large number of chilli viruses. There are some keys developed by earlier workers with limited number of viruses. Therefore, studies on the chilli viruses in major chilli growing areas in the state have been taken up with the following objectives:

1. A systematic survey for the incidence of mosaic in major chilli growing districts like Dharwad, Belgaum, Shimoga, Mysore and Gulbarga.

2. To identify and group the different viruses involved in causing mosaic.

3. To develop a diagnostic key based on the reactions of differential hosts in comparison with particle morphology, serology and transmission.

4. To know the distribution of different viruses involved, in different areas, cultivars and in crops with different cultivation practices

5. To study the effect of the most prevalent and severe virus isolates in Karnataka on different chilli cultivars.

6. To study the epidemiology of the viruses in relation to vectors and meteorological factors.

7. To study the nature of spread of an important virus causing mosaic disease in field.

8. To find out the etiological agents involved in Murda syndrome.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The chilli plant is subject to the attack by a large number of viruses in nature besides being susceptible to artificial infection by many others. Scanning through the literature one could notice as many as 42 viruses mechanically or otherwise transmitted to Capsicum spp. Twenty two of them are found to occur naturally and twenty viruses can infect on artificial inoculation. If one takes virus strains also into consideration the number will be much more.

Ramakrishnan (1959 and 1961) described 18 different viruses reported from all over the world to occur naturally on chilli viz. alfalfa mosaic virus, aster ring spot virus, beet curly top virus, cranberry false blossom virus, cucumber mosaic virus, Indian chilli mosaic virus, Italian pepper mosaic virus, pepper vein banding virus, pepper yellow leaf virus, potato virus Y, Puerto Rican pepper mosaic virus, Trinidad pepper vein banding virus, tobacco leaf curl virus, tobacco etch virus, tobacco mosaic virus, tomato spotted wilt virus, Trinidad pepper mosaic virus and potato virus-X. Later, four other viruses viz., pepper veinal mottle virus (Brunt and Kenten, 1971), tobacco rattle virus (Semancik, 1966), tobacco streak virus (Gracia and Feldman, 1974) and tobacco ring spot virus (Prasad Rao, 1976) have been reported.

There are 20 viruses which are only artificially transmitted to chilli. Ramakrishnan (1961) listed 16 viruses which are artificially transmitted to chilli. These are Trinidad tomato twisted-leaf virus, Trinidad tomato bronze leaf virus, Trinidad egg plant mosaic virus, tomato yellow mosaic virus, tomato necrosis virus, tomato bushy stunt virus, tomato ring spot virus, potato aucuba mosaic virus, potato leaf roll virus, potato stunt virus, sweet potato mosaic virus, radish stunt virus, carrot motley dwarf virus, sunflower mosaic virus, yam mosaic virus and broad bean vascular wilt virus. In addition, four other viruses viz. pelargonium virus (Reinbert *et al.*, 1960), strawberry virus (Reed and Felix, 1961), coconut wilt virus (Shanta and Menon, 1961) and potato spindle tuber virus (PSTV) (O'Brien and Raymer, 1964), have been reported. However, PSTV is now established as a viroid and the nature of coconut wilt virus is not confirmatively established.

A mosaic disease of chilli was first reported in India by McRae (1924) and Kulkarni (1924) from Bombay Province. Later several viruses causing mosaic on chilli have been reported by a number of workers from time to time (Jha and Raychaudhuri, 1956; Ramakrishnan, 1961; Kandaswamy *et al.*, 1963; Anjaneyaulu and Appa Rao, 1967; Jeyarajan and Ramakrishnan, 1969; and Prasad Rao, 1976). Among the 22 viruses reported to occur naturally on chilli throughout the world,

only nine have been reported from India viz., cucumber mosaic virus (Anjeneyulu and Appa Rao, 1967), tobacco leaf curl virus (Husain, 1932; and Vasudeva, 1954), Indian chilli mosaic virus (McRae, 1924; and Jha and Rayachaudhuri, 1956), Potato virus Y (Jeyarajan and Ramakrishnan, 1961 and 1969; and Joshi and Bhargava, 1962), Potato virus X (Ramakrishnan, 1959; and Rao et al., 1970) and tobacco mosaic virus (Kandaswamy et al., 1963; Mathur, et al., 1966). Prasada Rao(1976) reported tobacco ring spot virus, pepper veinal mottle virus and pepper vein banding virus, naturally occurring on chilli. Shukla and Shri Ram (1977) reported the mosaic due to complex of CMV+TMV on C.frutescens and PVY on C.annuum from Rajasthan.

A review of all the viruses which induce mosaic symptoms on chilli in India was made but literature on eight sap transmissible viruses and other reports pertaining to the present study is reviewed here.

1) Potato virus Y (PVY)

David and Stormer (1941) described the symptoms of PVY on chilli and stated that it produced indefinite number of flecks on the leaves and a slight swelling of the veins on the larger expanded young leaves. Later entire leaf developed a dark green mottling with wavy margin. Jeyarajan and Ramakrishnan (1969) reported PVY on chilli which produced

vein clearing, mosaic mottling and reduction in leaf size, stunting and reduction in number of flower buds and fruits. Ran et al. (1971) observed a veinal necrosis strain of PVY on pepper characterized by extensive necrosis of leaf veins and axial organs, accompanied by pimply, thickened and brittle leaves with mosaic patterns of varying intensity. Mariappan et al. (1973) described a mosaic disease on chilli caused by a strain of PVY characterized by severe leaf mosaic and blistering. Lockhart and Fischer (1974) reported that PVY in pepper caused severe systemic mottling of leaves and fruit deformation, stunting and epinasty of the plant with reduced fruit setting. Osaki et al. (1975) reported that the PVY isolated from Capsicum cultivars showed symptoms of green vein banding, interveinal chlorosis or mottling on the leaves and chlorotic stripes on the leaves, stems and fruits. Prasada Rao (1976) described the symptoms of PVY on chilli as slight vein clearing of the expanding leaves seven to ten days after inoculation followed by mosaic mottling. Later, the leaves developed an irregular and discontinuous green vein banding symptoms. The midrib and veins became wavy, resulting in upward curling and crinkling. The plants were stunted and flower formation was much reduced.

Costa and Alves (1950) reported that PVY on chilli was transmitted by Myzus persicae (Sulz.), Macrosiphom solanifolii (Ashm.) and two other unidentified aphids.

Simons (1959) reported that M.persicae transmitted PVY in pepper. Laird and Dickson (1963) found that potato virus Y was transmitted from pepper by M.persicae, Aphis gossypii Glov., M.solanifoli, Macrosiphom pisi Kalt. and Aphis spiraecola Patch. Jeyarajan and Ramakrishnan (1969) reported that only A.gossypii transmitted PVY on chilli. Brunt and Kenten (1971) reported that PVY on C. annuum and C.frutescens, in Ghana was transmitted by M.persicae and A.gossypii. Giorda and Nome (1975) found that PVY on C.annuum was transmitted by M.persicae. Mariappan et al. (1973) reported that PVY on C.annuum was transmitted by A.gossypii, Aphis cracoivora Koch, Aphis nerii B.d.F and M.persicae. Lockhart and Fischer (1974) reported that PVY on C.annuum was transmitted most frequently by M.persicae. Prasad Rao (1976) reported that A.gossypii and M.persicae were unable to transmit PVY in chilli.

Kahn and Bartels (1968) opined that A-6 potato(Solanum demissum L.,XSolanum tuberosum L.,) acted as an indicator plant and Datura stramonium L. as immune to PVY. Jeyarajan and Ramakrishnan (1969) reported that PVY on pepper had a very limited host range. It produced symptoms only on Glyricidia maculata L, Nicotiana tabacum L. and Nicotiana glutinosa L. It did not infect C.chinensis, L, Capsicum chocoense, Capsicum pubescens and Chenopodium amaranticolor Coste and Reyn. Prasad Rao (1976) reported that PVY on chilli produced systemic symptoms on Datura metal L., Physalis

floridana Rydb, Physalis peruviana L., Petunia hybrida Vilm, Nicandra physaloides Geartn, Solanum nigrum L., S.tuberosum, N.tobacum cv. "White Burley", "Xanthi" and "Samsun", Nicotiana rustica L., Nicotiana solanifolia Walpers, Nicotiana simulans Burbidge, Nicotiana sylvestris Speg. & Comes and Nicotiana Occidentalis Wheeler, and local lesions on C.amaranticolar, Chenopodium quinoa Willd., Chenopedium album L., N.debneyi Domin and detached leaves of 'A_6' potato.

Sakimura (1953) observed that PVY on pepper had a thermal inactivation point from 53 to 56°C, dilution end point from 1:300 to 1:1000 and longevity in vitro for 48 to 72 hrs at 25 to 29°C and 66 to 82 days at 0 to 3°C. Jeyarajan and Ramakrishnan (1969) found that PVY on chilli had a thermal inactivation point from 50 to 55°C, dilution end point from 1:1000 and was active in vitro for two days at room temperature and also at 4°C. Mariappan et al. (1973) reported that the PVY on chilli had a thermal inactivation point of 55°C, dilution end point from 1:1000 to 1:2000 and was active in vitro for five to eight hours between 23 and 28°C. Lockhart and Fischer (1974) found that PVY from pepper had a thermal inactivation point between 55 and 60°C. Prasada Rao (1976) reported that PVY on chilli had a thermal inactivation point from 55 to 60°C, dilution end point between 1:500 and 1:1000, longevity in vitro for 16 hrs at room temperature.

Laird et al. (1964) reported that PVY consisted of flexuous rod shaped particles measuring 694 nm whereas Purcifull et al. (1970) observed flexuous rods of PVY measuring about 730 nm in length. Nelson and Wheeler (1972) however, reported that the Arizona pepper virus, a strain

of PVY, consisted of flexuous rod shaped particles measuring 722 ± 22 nm in length. Prasada Rao (1976) reported the presence of flexuous rod shaped particles of PVY measuring 776 nm x 13 nm.

2. Pepper vein banding virus (PVBV)

Simons (1956) reported that PVBV infecting chilli produced the initial symptoms in seven to ten days after inoculation which were of vein clearing, followed by a characteristic vein banding on young leaves. Subsequently, plants showed various types of mosaic mottling and deformation of the leaves. Lopezcardet and Blanco (1972) reported that PVBV on C.annuum showed stunted growth, deformed leaves with chlorotic streaks, mosaic and dark green bands. Fruits were small and malformed. Prasad Rao (1976) reported PVBV on chilli which produced faint vein clearing on the young leaves, eight to ten days after inoculation, followed by dark green continuous vein banding, a characteristic symptom of this virus. The plants were moderately stunted. Flower formation and fruit setting were delayed. The fruits formed by such plants were distorted.

Simons (1956) and Prasad Rao (1976) found that M.persicae and A.gossypii were efficient in transmitting this virus.

Simons (1956) reported that PVBV from pepper produced systemic symptoms on Solanum gracile L., Zinnia elegans, Jacq., Lycopersicon esculentum Mill., N.glutinosa, N.tabacum var. Turkish and P.peruviana. Prasad Rao (1976) reported that PVBV on chilli produced systemic symptoms on D.metel, P.floridana, P.peruviana, S.nigrum, N.tabacum var. 'White Burley' and 'Samsun', N.rustica and N.solanifolia.

Simons (1956) reported that PVBV on pepper had the dilution end point between 1:1,000 and 1:20,000, thermal inactivation point of 60°C and longevity in vitro of 10 to 15 days at 23°C. Lopezcardet et al. (1972) reported that the PVBV on pepper had the thermal inactivation point from 72 to 73°C, dilution end point of 1:1,100 and longevity in vitro for 75 hrs. Prasada Rao (1976) observed that the PVBV on chilli having the dilution end point from 1:5,000 to 1:10,000, thermal inactivation point between 55 and 60°C and longevity in vitro of eight hours at 21 to 28°C.

Prasad Rao (1976) reported that electron micrograph of purified preparations of PVBV consisted of flexuous rods measuring 759 nm x 13 nm in size.

3. Pepper Veinal Mottle Virus (PVMV)

— Lana et al. (1975) reported that PVMV on C.annuum produced inter veinal yellowing, mottling which occasionally developed into vein banding. Leaves often developed dark green spots. Fruiting in infected plants were reduced with

evident distortion. Prasad Rao (1976) described PVMV on chilli which produced vein clearing and mosaic mottling after inoculation, later, dark green patches developed on the leaf lamina in an irregular fashion and subsequent leaves were distorted. The characteristic symptoms of this disease was extreme narrowing of the leaf lamina as if only the midrib was present. The internodal length of the plant was drastically reduced giving the plant compact bushy appearance. Fruits were small and distorted.

Wijs (1973) reported that this virus was transmitted by Toxoptera citricidus (Kirkaldy), A.gossypii and A.spiraecola. Kana et al. (1975) showed that PVMV was transmitted by A.craccivora and A.gossypii. Zitter (1973) showed that the PVMV was transmitted by M.persicae whereas Prasad Rao (1976) found that M.persicae and A.gossypii were able to transmit PVMV.

Wijs (1973) found that the PVMV was first transmitted from C.frutescens to P.floridana by aphids and subsequently maintained by mechanical sap inoculation on P.floridana and N.megalosiphan. The hosts were mainly solanaceous plants. Prasad Rao (1976) reported that PVMV had an extremely limited host range infecting only P.hybrida, S.nigrum and Nicotiana clevelandii Gray belonging to solanaceae. It is systemic in P.hybrida, N.rustica, N.glutinosa, N.megalosiphan, N.physaloides, P.floridana. But D.stramonium , D.esculentum,

Solanum melongena L. and S.tuberosum were not infected by mechanical inoculation (Brunt and Kenten, 1971).

Lana et al. (1975) observed that PVMV had thermal inactivation point of 62°C, dilution end point from 1:1,000 to 1:10,000 and longevity in the expressed sap was three days at 20 to 25°C. Prasada Rao (1976) reported that the thermal inactivation point of this virus was between 60 and 65°C, the dilution end point was between 1:5,000 and 1:10,000 and longevity in vitro was 24 hrs at 21 to 28°C.

Presence of flexuous rods measuring 735 nm x 14 nm of PVMV was observed under electron microscope by Lana et al. (1975). Prasad Rao (1976) reported that the purified preparation of PVMV consisted of flexuous rod shaped particles measuring 776 nm x 13 nm.

4. Tobacco Etch Virus (TEV)

Tobacco etch virus has been reported to cause a serious disease of pepper in Georgia and Alabama (Greenleaf, 1953 and 1956), and in Central Florida, USA, (Anderson and Corbett, 1957). The disease is called 'Vein banding Crinkle' in Central Florida and is said to be the most widespread disease of pepper in that state.

In Alabama several Tabasco variety pepper plants wilted in the field because of this disease (Greenleaf, 1953). The first visible symptom following infection, in Tabasco pepper

was faint yellow flecking on the young leaves and vein clearing in 4-21 days after inoculation accompanied by wilting of the plants within a few days. Wilting was usually followed by death but a few young plants showed partial recovery. Such seedlings became severely defoliated but maintained an apical tuft of leaves and produced new shoot growth bearing a few fruits. These plants remained severely stunted. Many additional symptoms on pepper produced by TEV have been described by McKeen (1954). Three or four days after inoculation chlorotic spots appeared, which became rugose. The first evidence of a systemic invasion by the virus was prominent vein clearing of the youngest leaves, six to eight days after inoculation. The leaves became mildly chlorotic and showed prominent to moderate cupping. Two or three weeks after inoculation the young leaves showed prominent broad, dark green bands along the veins particularly at the base of the leaves. Sometimes there was a laminal narrowing and marginal waviness. Much flagging of older leaves on infected plants was noticed. There was severe root necrosis in younger plants and wilting on hot days. Infected plants sometimes showed stunting and bushy growth. On plants bearing fruits at the time of inoculation, characteristic fruit symptoms of ring and line pattern developed. On green fruits, chlorotic shrivelled areas were found more on the side exposed to bright sun. On ripe or ripening fruits various green, orange or brownish colours

were found. Some plants, with prolonged infection, were dwarfed or developed mishappen fruits. Weinbaum and Milbrath (1976) described symptoms as mild mosaic, severe fruit distortion and fruit discoloration in commercial Capsicum crops. Several strains of TEV were reported to occur in Ontario. All the strains produced crystalline intranuclear inclusions (McKeen, 1954).

The virus was easily sap transmissible. In Ontario M.persicae is believed to be the principal field vector (McKeen, 1954). Baird and Dickson (1963) reported the transmission of virus by M.persicae, A.gossypii, M.solanifolii, M.pisi and A.spiraecola. A.craccivora transmitted the virus in a persistant manner (Kassanis, 1944; and Herold, 1970).

Johnson (1930) reported that TEV infected C.frutescens P.hybrida and L.esculentum. Holmes (1946) reported 83 plant species among 310 tested as susceptible to TEV. It produced yellow spots surrounded by single or double etched rings and Gomphrena globosa L. remained symptomless (Greenleaf, 1953). The virus was reported to occur on Solanum carolinense L., Cirsium vulgare L., and C.album in nature in the field (Weinbaum and Milbrath, 1976). It induced a severe mosaic and leaf distortion symptoms on D.stramonium. Cassia tora L., and Z.elegans was not susceptible. But these plants were

reported as hosts for TEV by Holmes (1946). It has been reported from India on brinjal (Verma and Lal, 1964).

Zitter (1972) confirmed different naturally occurring TEV strains on the basis of reaction on D.stramonium. TEV caused severe leaf distortion and mosaic pattern on D.stramonium (Villalon, 1975).

Verma and Lal (1964) worked out physical properties of this virus in brinjal i.e., TIP=54-58°C, DEP=1:1,000 to 1:5,000 and LIV=8 days. Bawden and Kassanis (1941) reported that the severe etch virus had a DEP around 1:5,000, TIP of 58°C, and LIV of 13 days. Herold (1970) reported TIP of TEV as of 52-55°C.

Herold (1970) reported the length of TEV particles as 754 nm. Weinbaum and Milbrath (1976) carried out the purification and electron microscopy of the virus. A partially purified preparation of TEV was obtained by combining Polyethylene Glycol precipitation of the virus followed by equilibrium density gradient centrifugation. Negatively stained virus preparations obtained from infected pepper leaves contained flexuous rods approximately 730 nm in length. Villalon (1975) also reported the size of the virus particles of TEV as 730 nm. Brandes and Wetter (1959) classified TEV in the group showing flexuous rods measuring

730 nm in length. Purcifull (1966) found model length as 750 nm in purified preparation.

5. Tobacco mosaic virus (TMV)

As early as in 1923, Palm reported the transmission of tobacco mosaic virus to C.annuum and C.frutescens in Indonesia and Palm and Joachems (1924) reported this virus on pepper from the same country.

Four kinds of symptoms on different varieties of pepper infected with TMV were reported by Holmes in 1937. These were systemic chlorosis, local lesions on leaves and their consequent shedding, a delayed necrosis combined with a systemic mosaic mottling and systemic necrosis with stem streaking, which under certain conditions resulted in the death of the plant. In inoculation tests on young seedlings, the TMV isolates caused defoliation and necrosis. Nakata and Takimoto (1940) reported a ring strain of TMV on pepper which produced bright yellow mottling on the leaves. Kovachevsky (1942) described acute and chronic types of symptoms due to TMV infection on pepper. Infected leaves showed yellowing along the veins six to seven days after inoculation and in some cases shedding of leaves and death of young plants occurred. Chamberlain (1947) reported that TMV, a strain of tomato streak virus infected pepper plants causing mottling and stunting. Murakishi (1960) reported a

new strain of tobacco mosaic on Hangarian sweet pepper which caused a slightly raised reddish brown streaks on the fruit. Fletcher (1963) observed the symptoms of main vein necrosis of leaves followed quickly by leaf loss of Capsicum frutescens infected with tobacco mosaic virus. Greenleaf et al. (1964) reported a strain of TMV from Capsicum in Alabama and Florida which induced severe systemic leaf mottling and crinkling symptoms in eight to thirteen days after inoculation accompanied by primary and secondary necrotic patterns and various degrees of necrosis of upper stem. Farray and Ramakrishnan (1969) reported TMV on chilli, which caused chlorosis of leaves. Adsuar et al. (1971) reported a strain of TMV, tentatively named as virus producing local lesions on tobacco causing mottling, chlorosis, leaf wrinkling and retarded growth in C.annuum. Ragozzino et al. (1972) reported two strains of TMV on pepper. The tomato strain of tobacco mosaic virus, the more widespread of the two strains caused bright yellow mosaic, reduction in size of leaves, stem necrosis, defoliation, stunting, deformation and yellow spots on fruits and the tobacco strain induced similar symptoms, with a light interveinal mosaic. Kalamra and Dubey (1975) isolated a strain of TMV from chilli which produced typical mosaic mottling, puckering, blistering and smalling of leaves. Prasad Rao (1976) observed that a strain of TMV producing necrotic

lesions on the inoculated leaves of chilli two to three days after inoculation. The dark streak which appeared on the stem extended further, killing the plant. The plants that survived were pale with yellowish irregular patches on leaves, flowering was delayed and fruit setting was considerably reduced. The fruits produced by such plants were distorted and mottled. On inoculation to young seedlings, the TMV isolates caused defoliation and necrosis (Sutic et al., 1978).

Transmission of a number of strains of TMV by mechanical sap inoculation from chilli was reported by several workers (Palm, 1923; Holmes, 1937; Nakata and Takimoto, 1940; Doolittle and Beecher, 1942; Kovachevsky, 1942; Kohler and Panjan, 1944; Chamberlain, 1947; Zabala and Dellacosta, 1947; McKinney, 1952; Newton, 1953; Miller and Thornberry, 1958; Murakishi, 1960; Fletcher, 1963; Greenleaf, et al., 1964; Eskarous, 1971; Adsuar et al., 1971; Feldman and Oremianer, 1972; and Ragozzino et al., 1972). McKinney (1952) reported a seed borne strain of TMV on a pepper variety, P.I.40252.

Greenleaf et al. (1964) reported that Samsun latent TMV produced local lesions on N.tabacum var. samsun and xanthi, N.rustica, Nicotiana repanda Willdrow, N.sylvestris,

N.glutinosa, D.stramonium and C.amaranticolor while L.esculentum remained unaffected. In 1979, Kamra and Dubey reported symptoms on N.tabacum, N.glutinosa and N.rustica and local lesions on D.metel, Phaseolus vulgaris L. and C.amaranticolor. Prasada Rao (1976) reported a strain of TMV on chilli which produced chlorotic local lesions on G.globosa, C.amaranticolor, C.quinoa, C.album and Nicotiana longsidorffii Weinmann., necrotic lesions on P.vulgaris var. pinto, D.metel, D.stramonium, N.glutinosa, N.rustica and N.rependa and the necrotic lesions followed by systemic symptoms in N.tabacum 'Xanthi'-nc, N.solanifolia, N.simulans, N.sylvestris and N.debneyi and only systemic symptoms were observed on P.floridana, P.peruviana, L.esculentum, N.physaloides, Solanum nodiflorum Jacq., N.tabacum var. 'White Burley' and 'Samsun', N.clevelandii and N.occidentalis Wheeler.

Nakata and Takimoto (1940) reported that ring spot strain of TMV had a thermal inactivation point of 90°C and dilution end point of 1:10,00,000. Zabala and Dellecosta (1947) described six strains of TMV on pepper, four strains remained active even after exposure to a temperature of 80°C for ten minutes while the other two were inactivated. In 1950, Miller and Thornberry reported tomato atypical mosaic virus, a strain of TMV having dilution end point of 1:10,00,00,000 and thermal inactivation point of 72°C

whereas, in 1964 Greenleaf et al. described a Samsun latent TMV which had a thermal inactivation point between 85 and 90°C and dilution end point from 10,00,000 to 1,00,00,000. Eskurous (1971) described a leaf curling strain of TMV of pepper which was inactivated at 94°C and had a dilution end point, more than 10,00,000 and was infectious for 50-55 days at 23 to 28°C only. Pepper unusual strain of TMV had a thermal inactivation point from 85 to 90°C, dilution end point from 10,00,000 to 30,00,000 and longevity in-vitro of five years at room temperature (Feldman and Oremianer, 1972). A strain of TMV on chilli had a dilution end point from 1:1,00,000 to 1:2,00,000, thermal inactivation point of 85°C and longevity in-vitro of more than two weeks (Kamra and Dubey, 1975). Prasada Rao (1976) reported a strain of TMV on chilli having a dilution end point from 1:1,00,000 to 1:5,00,000, thermal inactivation point between 90 and 95°C and longevity in-vitro of thirteen weeks at 21-28°C. Sandhu and Chohan (1978) reported a new strain of TMV which differed in its physical properties from the other strains reported in India.

Miller and Thornberry (1958) reported that the tomato atypical mosaic virus, a strain of TMV, consisted of rod shaped particles measuring 300 nm x 15 nm. Kamra and Dubey (1975) stated that the purified preparation of a strain of TMV from chilli consisted of rigid rods measuring 230 nm x 17 nm. Prasada Rao (1976) reported that the electron

micrograph of a strain of TMV from chilli showed rod shaped particles measuring 300 nm x 15 nm.

6. Cucumber mosaic virus (CMV)

As early as 1921 Doolittle showed that the cucumber mosaic virus could infect chilli plants. Doolittle and Walker (1923 and 1925) described the symptoms on naturally infected chilli.

Many workers have described the symptoms on chilli produced by different strains of CMV that occur naturally. The description of symptoms that were reported to be produced by a single virus or its strains on the same host differed with different workers since several biotic and abiotic factors might have influenced symptom production.

The young leaves of infected chilli plants showed downward curling along the midrib with the basal portion of the leaves showing lighter green colour than that at the top, leading to mottling within a short period. Leaf-size and internodal length were reduced and the leaves were abnormally narrowed and drawn out into filiform fashion. In a few cases, the fruits showed warty, dark green outgrowth (Doolittle and Walker, 1923 and 1925).

Wellman (1934a), identified southern celery mosaic virus, a strain of CMV, occurring naturally on C.annuum, causing stunted growth of the plants with greyish dull colour markings on leaf lamina. Flowers dropped off and plants showed starved appearance. If the fruits set before infection, they were malformed.

Kovachevsky (1940 and 1942) described a "rosette disease" of pepper occurring in Bulgaria, the symptoms being similar to those described by Doolittle and Walker (1925). Kovachevsky, however, observed certain additional symptoms such as, distortion of the leaves which became asymetrical and the appearance of necrotic patches on the young stems of affected plants. Those necrotic patches on young stems appeared as more or less elongated and linearly arranged, while on the older stems, the necrosis was superficial and corky. The fruit setting was sharply reduced and a few that were set being badly deformed showing necrotic streaks.

Doolittle and Zaumeyer (1952&53) described a ringspot disease of pepper, caused by a strain of CMV. Large chlorotic rings and oak leaf pattern on older leaves and concentric yellow rings on the fruits were the striking symptoms on pepper. Systemically infected leaves developed pale green, concentrically ringed spots measuring two to three mm

in diameter. These spots coalesced and produced an intricately mottled pattern. In later stages the leaves were faintly mottled with light green flecks and were slightly misshapen and more pointed.

In 1967, Anjaneyulu and Appa Rao described a mosaic disease of chilli from India showing mosaic mottling and various types of leaf distortion and filiform tip. The infected plants showed marked stunting and severe reduction in size of leaves and warty swellings on fruits.

In 1976, Prasada Rao described a strain of CMV on chilli where the symptoms produced resembled those produced by an isolate described by Doolittle and Walker (1925).

Doolittle and Walker (1923) transmitted CMV from pepper to pepper by mechanical sap inoculation. Similarly, Doolittle and Zaumeyer (1953) reported a ring spot strain of CMV which was mechanically sap transmitted. However, Kovachevsky (1940) was unsuccessfull in transmitting by sap inoculation. Several aphid species have been reported to transmit this virus. Kovachevsky (1940) reported that M.persicae, could transmit the virus. Simons (1955) observed that A.gossypii, M.persicae and Aphis rumicis Linn., as the vectors of CMV in pepper. Transmission of this virus through M.persicae, Aphis nasturtii Kaltenback and A.craccivora, was reported by Szalay Marzso and Solymossy (1963) and

only through A.gossypii by Anjaneyulu and Appa Rao (1967). Prasada Rao (1976) reported A.gossypii and M.persicae as vectors in chilli.

Wellman (1934a) reported that southern celery mosaic, a strain of CMV isolate from pepper, infected Commelina nudiflora L., Commelina communis L., Zinnia sp. and Vigna sinensis (Torner) Savi. Jha and Rayachaudhuri (1956) stated that the virus was sap transmissible and produced systemic symptoms on N.tabacum, N.glutinosa, Solanum nigrum L., P.hybrida, Cucumis melo L., var. Utilissimus, Safflower, D.stramonium and potato. Anjaneyulu and Appa Rao (1967) reported that the naturally occurring CMV on chilli produced systemic symptoms on N.tabacum, N.glutinosa, S.nigrum, P.floridana, Cucumis sativus L., C.melo, Luffa acutangula (L.) Roxb., Trichosanthes anguina L., and Z.elegans. However, it produced necrotic lesions on V.sinensis and C.amaranticolor and chlorotic lesions on Beta vulgaris L. Lochart and Fischer (1976) recorded Brassica nigra, Amaranthus retroflexus L. and some common weeds as the principal reservoirs of CMV.

Prasada Rao (1976) reported a strain of CMV producing chlorotic local lesions on C.amaranticolor and necrotic local lesions on V.sinensis var. "Black Eye". It produced systemic symptoms on C.sativus, N.physaloides, Vinca rosea L., P.floridana, S.nigrum, L.esculentum, N.tabacum var. "White Burley" and "Samsun", N.glutinosa and D.stramonium.

Wellman (1935a) reported that southern celery mosaic had a thermal inactivation point of 75°C and a dilution end point of 1:10,000 and was active in-vitro for six to eight days at room temperature. Doolittle and Zaumeyer (1952) reported that the ring spot strain had a thermal inactivation point of 70-72°C, dilution end point of 1:10,000 and the virus remained active in-vitro for four days at 18°C. Jha and Mayachaudhuri (1956) stated that the virus was active upto a temperature of 55°C and standard samples remained infective even after fifteen days in-vitro at 15 to 32°C. CMV on chilli reported by Anjaneyulu and Appa Rao (1967) had a thermal death point of 55 to 60°C, dilution end point between 1:250 and 1:500 and was active for twelve to eighteen hours at 21 to 28°C and 36 hours at 10°C. Prasada Rao (1976) reported that CMV on chilli had a thermal inactivation point of 65 to 70°C, dilution end point of 1:10,000 to 1:50,000 and longevity in-vitro of 48 hours at 21 to 28°C.

Prasada Rao (1976) reported that the purified preparation of a strain of CMV on chilli had spherical particles measuring 28 nm in diameter.

7. Tobacco Ringspot Virus (TRSV)

Prasada Rao (1976) reported for the first time in India, tobacco ring spot virus on Capsicum spp. producing vein clearing on leaves of pepper, giving a net pattern

followed by chlorotic rings, later showing mosaic mottling and narrowing of leaves.

There are several reports about the transmission of tobacco ring spot virus by Nematode; Xiphinema americana (Cobb) (Fulton, 1962, 1967; Sauer, 1966); Aphids; M.persicae and A.gossypii (Shyama Rani et al., 1969), M.persicae (Smith, 1931; Smith and Brierly, 1955), but the virus studied by them was different. It was not transmitted by any of the aphid species tried by Prasada Rao (1976).

According to Prasada Rao (1976) the virus had a wide host range of plant species belonging to the families Chenopodiaceae, Compositae, Cucurbitaceae, Leguminosae and Solanaceae. It produced local lesions on leaves of C.amaranticolor, C.quinoa and V.sinensis; systemic mottle on Z.elegans, C.sativus, C.melo, Cucurbita maxima Duch, Cassia occidentalis L., P.floridana, P.peruviana, S.melongena, L.esculentum, N.tabacum cvr. "Xanthi" and "Samsun" and N.rustica and chlorotic rings on N.tabacum cvr. "White Burley" and D.stramonium.

The virus had a thermal inactivation point between 60 and 65°C, dilution end point between 1:10,000 and 1:50,000 and longevity in vitro of 48 hours at 21-28°C (Prasada Rao, 1976). This resembles in some of its properties such as host range, mode of transmission and physical properties of Tobacco ring spot isolated from Solanum capsicastrum L.,(Smith,

1931), Anemone coronaria L. (Hollings, 1965), Gladiolus (Randles and Francki, 1965) and those reported by Shyamarani et al., (1969), Gilmer et al. (1970), McDaniel et al. (1971).

Tobacco ring spot virus from A.coronaria, Gladiolus and brinjal plants has been purified and observed under the electron microscope by several workers (Hollings, 1965; Randles and Francki, 1965; Sastry, 1974). But there are no reports of such purification and isolation of TRSV from Capsicum spp. so far. Prasada Rao (1976) also did not succeed in purification of virus from chilli for electron-microscopy.

8. Tomato spotted wilt virus (TSWV)

McRae (1932) reported it for the first time on tomato in India. Artificial transmission of this virus to pepper has been reported by Smith (1932, 1936) and van Schreven (1935). The latter observed that pepper plants stopped growth three weeks after inoculation with this virus.

The virus has been reported to occur naturally on peppers in Mexico (Kloper, 1948), and U.S.A. (Chupp, 1937; Kendrick, et al., 1951). This disease caused moderate to heavy losses (Kendrick et al., 1951). Pirone (1935) reported that pepper plants affected by this virus developed large ring spots on fruits and leaves especially on the

California Wonder variety. The ring spots on pepper closely resembled those produced on tomato by the same virus. Needle prick inoculations on pepper plants produced marked dwarfing together with considerable mottling and slight deformation of the leaves. Chupp (1937) reported that in California there was a 100% infection by this virus in 1936. However, in 1937 when the weather was unusually wet and warm during August there was no incidence of the disease.

Sakimura (1940) reported TSWV on bell pepper which was transmitted by Thrips tabaci Lind. It produced concentric zonations on older leaves of bell pepper and mosaic mottling on terminal young leaves with dense coalescense of small rings, spots and concentric rings. It was not found to be seed borne. In warmer valleys the earlier necrotic symptoms are followed by stunting, mottling and leaf distortion, while in cooler regions the necrosis may kill the plants (Gardner and Whipple, 1934).

Pittman (1927), Samuel et al. (1930) and Bald and Samuel (1931) demonstrated that this virus in tomato was transmitted by T.tabaci and Frankliniella lycopersici And., also by rubbing method of mechanical inoculation with expressed plant juice. Best (1937) reported the transmission of this virus through T.tabaci, Frankliniella insularis, Frankliniella occidentialis Perg and F.moultoni Hood. A

disease of peppers caused by this virus is called "Peste blanca" in Mexico. Ploper (1948) reported the transmission and spread by F.paucispinosa and found that adults were unable to become infective. Later it was reported to be transmitted by T.tabaci in tomato (Todd et al., 1975), by Frankliniella schultzei Tribom. and Scirtothrips dorsalis Hood. in tomato (Chaneker et al., 1979) and by S.dorsalis in groundnut (Prasada Rao et al., 1980).

It is not found to be seed transmitted in tomato, pepper and Datura. By rubbing it was transmitted to tomato, Datura, Potato, egg-plant, Physalis, Nicandra, N.glutinosa, N.rustica, tobacco, petunia, lupine, broad bean, dahlia, aster, zinnia, chrysanthemum, cinerria and lettuce (Gardner and Whipple, 1934). Sakimura (1940) transmitted TSWV to spinach, broad bean, celery, potato, egg plant, bell pepper, tomato, tobacco, N.glutinosa, D.stramonium, Petunia, chicory, endive, lettuce, pineapple, pea, and Emilia from Capsicum. Sakimura (1940) concluded that both pineapple yellow spot and tomato spotted wilt were caused by TSWV.

According to Le (1964) TSWV had a TDP of 42-45°C, DEP of 1:10,000, and LIV of 5 hrs at 20°C. Prasada Rao et al. (1980) reported that TSWV on tomato had DEP of 10^{-3}, TIP of 45-50°C, and LIV of 1-2 hrs at room temperature (10-28°C).

Le (1964) reported that TSWV consisted of spherical shaped particles of about 70 nm in diameter. van Kammen et al.

(1966) observed that some particles of TSWV have tails suggestive of those like bacteriophages. Prasada Rao et al. (1980) worked on electron microscopy of TSWV on tomato and found that the diameter was 70-90 nm whose morphology resembled with those reported by Milne (1970) and Paliwal (1974).

9. Attempts in identifying plant viruses and virus strains

Ainsworth (1935) identified three viruses of cucumber by using C.sativus, Citrullus vulgaris Schrad. and Cucurbita pepo D.C. He also used transmission and physical properties in identifying the viruses.

Pierce (1935) differentiated seven viruses of legumes by using ten differential host plants. Ainsworth (1935) differentiated seven plant viruses using seven differential hosts. Certain physicochemical properties of virus were also employed in identifying these viruses.

On the basis of physical properties and insect transmission and electron microscopy, viruses infecting cucumbits were divided into two groups (Lindberg et al., 1956). On the basis of differential reactions of ten hosts, eight viruses were identified in squash group and six in melon group.

Cohen and Nitzany (1963) differentiated viruses affecting cucurbits in Israel on the basis of differential

reactions, insect transmission and physical properties.

Horvath (1969) developed a key for the differentiation of viruses pathogenic to tobacco based on transmission and differential host reactions.

Krylov (1969) recommended Lycopersicon pimpinellifolium L. and hybrid A6 potato as indicator plants for potato virus-A, Solanum rostratum L., for potato virus-S, N.debneyi, G.globosa and V.sinensis for potato Virus M and N.glutinosa, C.annuum and Solanum miniatum for potato Virus F.

Seneviratne et al (1970) identified plum decline virus, plum line pattern virus and ring spot virus from plum-trees based on symptoms produced on differential hosts. Smith (1970) reported five strains of TEV on Capsicum based on the reaction of pepper cultivars.

Milbrath (1971) differentiated and identified five viruses on pepper, occurring in Hawaii, based on reactions on eight selected indicator plants.

Zitter (1972) identified PVY and TEV, from pepper, by their reaction on D.stramonium and Tabasco Pepper. TEV infected D.stramonium whereas PVY did not. TEV caused wilt in Tabasco, whereas PVY caused mosaic mottles. He diffe-

rentiated strains of PVY (PVY-C and PVY-S), and TEV (TEV-D, TEV-M and TEV-S) mainly based on the reaction of pepper cultivars. Further studies revealed that tobacco etch Virus C, tobacco etch Virus A, potato Virus C and pepper mottle virus were the common viruses infecting pepper in Florida (Zitter, 1973). These viruses or strains were identified by their reactions on selected pepper cultivars.

Makkouk and Gumpf (1974) identified six viruses singly or in combination infecting pepper in California by using nine differentials. Strainal differentiation of TEV was based on resistant or susceptible reactions on pepper cultivars. Strainal differentiation of PVY was based on reactions on cultivars like Chilli Yolo Y, Casco-Dura, Avelar, Agronomico 8-76, Ambato, PI-342947 and PI 264281. In addition to host differential reactions, serology was also employed in identifying the viruses and their strains.

Conti and Masenga (1977) identified different chilli viruses in northwest Italy. They obtained the multiple virus infections three to four times more frequent in market and kitchen gardens than in commercial either protected or outdoor fields. The frequent components of multiple infection were CMV and PVY.

Prasada Rao and Varguntaiah (1979) identified TRSV, PVBV, PVMN, TMV, CMV and PVY viruses from Capsicum plants

in south India. They developed a dichotomous key using five hosts to differentiate the above viruses.

10. Reaction of Capsicum genotypes against viruses

The majority of garden pepper (C.frutescens) varieties tested showed mottling to the typical TMV. A few varieties (C.frutescens var. Tabasca and Capsicum minimum L.) responded with localized necrosis and these varieties were immune to the severe systemic effects of TMV infection (Holmes, 1934, 1937). Kovachevaky (1940) observed that the typical symptoms of "rosette" disease were observed on the pepper varietal group known as 'Scipki' (with small pointed fruit). In other varieties, the crowding of branches and leaves and the abnormal development of leaves were pronounced.

Jha (1953) reported that chilli varieties, NP 20 and NP 23 were more resistant to chilli mosaic virus amohg the 52 varieties tested by him. In Alabama, Greenleaf (1953) found that two varieties of Capsicum pendulum Wild., P.I. 152234 (Orange coloured fruit)and P.I.152235 (Red coloured fruits), pepper varieties P.I.152217 and P.I.152221 from Peru and the commercial variety Serrano were tolerant to TEV. The pepper varieties P.I.152222 from Peru and P.I.152453 from Brazil, Santanaka, Red chilli, Mexican chilli and

Burlington were more severely affected. Capsicum microcarpum Cav. from Argentina was also severely affected by TEV.

McKeen (1954) in Ontario classified the pepper varieties he studied as mild symptom varieties and severe symptom varieties against chilli virus TEV. Cook and Anderson (1959) reported a strain of C.annuum i.e., P.11 showing multiple virus resistance to TMV, TEV and PVY., while the varieties California Wonder, Florida Giant, Improved World Beater and Yolo Wander were susceptible. Anand et al. (1961) have screened 132 varieties of chilli belonging to six different species. Varieties Puri Red, Puri orange, Kondiverum, G_2 and a local variety have been reported to be resistant against chilli mosaic virus. Cultivars, Puri Red, Puri orange, G-2 and Kondiverum are known to be resistant to mosaic by artificial inoculation (Anand et al., 1961; Singh, 1973). Saccardo (1973) found that eight lines out of 53 of C.annuum, ten lines out of 12 C.frutescens and one line of C.pendulum, C.microcarpum, and C.chinense were resistant to CMV and 13 lines of C.annuum showed tolerance. Ramanujam et al. (1965) studied the inheritance of resistance in chilli. They reported that Puri Red as resistant to leaf mosaic.

Fletcher (1963) tested pepper varieties against TMV and reported that Yolo Wonder and Pine Tree had some resis-

tance. No resistance to Samsun latent strain of TMV was found in 124 foreign C.accessious and in 17 commercial varieties (Greenleaf et al., 1964). Cook (1966)reported that Yolo Y, a bell pepper derived from Yolo Wonder,showed a high degree of resistance to PVY and TMV. Jeyarajan and Ramakrishnan (1969) reported that, out of 22 varieties tested 15 showed resistance against PVY.

Milbrath and Cook (1971) reported that in Hawaii plants of 57 cv of pepper were susceptible to three isolates of spotted wilt virus. No resistance to spotted wilt virus was found. Nagai (1971) reported the resistance of new varieties, Agronomico 9 and 10 to PVY, obtained by multiple crossing between the C.annuum varieties, CaSCO Dura, Mogi Das Cruzes, Puerto Rico Wonder, Moura, Ikedo, Yolo Wonder, Modesto and P.11.

Some perennial types with small pungent fruits in Tarai region of Uttar Pradesh were found to be immune to viruses. Selections from crosses between this perennial local type and NP-46A have been released under the names Pant C-1, and Pant C-2 which were known to be resistant to leaf curl virus (Mathai et al., 1971). Singh (1973) screened 105 different varieties and five species of chilli against chilli mosaic under field conditions. The results indicated that the varieties Puri Red, Puri Orange, C-2, Kondiverum and Suryamukhi were resistant.

NP-46A, a well known commercial variety bred at IARI, New Delhi, is mosaic resistant. Selection made from NP-46A x Puri Red is known to be mosaic resistant and has been released as 'Jwala' in 1973 (Tewari and Ramanujam, 1974; Tewari and Anand, 1977).

Ungs et al. (1977) screened 50 plant introductions against beet curly top virus out of which four showed apparent resistance but none appeared resistant. Cook et al. (1977) reported that Detray Bell cv. of C.annuum was found to be resistant to pepper mottle virus, TEV and PVY. Gahukar and Mariani (1980) screened chilli plants against strains of CMV. They found that a local unidentified variety having small fruits of 1.8 cm to 2.5 cm length and 0.8 cm diameter, bright red in colour and compact was found to be immune to all the three strains of CMV. And X-196 of Capsicum sp. and EC 31352 were found to be tolerant to all the three strains of the virus. Singh and Thakur (1980) reported that out of 96 genotypes 17 were found to be resistant to CMV.

11. Effect of viruses on growth of Capsicum cultivars

Generally stunting is a common syndrome in many virus affected plants. There are several reports on the reduction of growth in plants due to virus infection (Jeyarajan and Ramkrishnan, 1961).

Aillaud (1971) reported that C.annuum plants inoculated with CMV developed abnormal flowers in addition to classical symptoms.

Villalon (1972) studied the effect of tobacco etch virus on growth and yield of bell pepper C.annuum 'Yolo-Wonder A' inoculated with TEV at weekly intervals for five weeks beginning with four weeks after seedling. Total yield reduction ranged from 6-53 per cent, fruits of inoculated plants were not marketable and plants were not vigorous.

Imoto (1975) reported that the total yield was severely reduced when the crop was infected during early growth or if symptoms were seen at harvest.

Joshi and Dubey (1976) noticed more number of stomata per unit area in infected chilli plants as compared to healthy ones, thus allowing more water to pass out in diseased plants. They have also reported that the growth of Capsicum plants was affected adversely by a mild and a severe strain of CMV, particularly by the latter. Less moisture and more dry matter contents were found in diseased plants as compared to healthy plants (Joshi and Dubey, 1977).

Kalman and Newari (1977) studied the effect of CMV on the productivity of C.annuum and reported that the gross production rate and severity of infection were inversely

proportional. The gross production rate in infected leaves was reduced by both mild and severe strains.

Marsh et al. (1977) studied the effect of PVMV on Capsicum and quoted report of Lamptey and Bonsi that Capsicum plants inoculated with PVMV upto 8 weeks after transplanting were stunted, sparsely branched and with leaves greatly reduced in size. Plants inoculated eight weeks after transplanting developed tip blight but later recovered temporarily. Leaves produced after recovery were reduced and showed strong veinal mosaic symptoms. The time taken for systemic symptoms to appear increased with age of the plant at the time of inoculation. Inoculated plants produced more flowers than uninoculated, but flower and fruit abscission in infected plants were higher, resulting in lower fruit production. Fruits produced by inoculated plants were smaller, lighter in weight, distorted and unevenly ripened. This virus caused losses of 46-90 per cent depending upon the time of inoculation (Marsh et al., 1977).

Prasada Rao (1976) reported that when Capsicum plants were inoculated with PVY at varying intervals of 15-90 days after sowing, the maximum effect was obtained with the youngest plants which were severely stunted and produced no yield. Plants inoculated at 90 days showed, no effect.

Most of the cultivated varieties of chilli (Capsicum spp.) in India are susceptible to chilli mosaic virus and Tobacco leaf curl virus. The highly resistant Jwala (NP46-A X Puri Red) gave significantly higher yield of dry fruits than NP 46A in infected plots (Tewari and Anand, 1977). Deol and Rataul (1978) reported that NP 46-A showed that plant age at inoculation was correlated with yield loss. This ranged from 100 per cent in plants inoculated at 10-20 days to 1.1 per cent in those inoculated at 120 days. Singh and Thakur (1980) reported that out of 96 genotypes of C.annuum only 17 were found to be resistant to CMV.

Chauhan and Srivastava (1981) reported pollen sterility, dehiscent and non-dehiscent anthers in plants inoculated with CMV at different growth stages of C.annuum.

12. Epidemiology of plant viruses

According to Kennedy et al. (1962) out of the 247 plant virus diseases only 159 were stated to be transmitted by aphids belonging to 180 species. The real number of potential vectors was expected to be much larger, since only 9 per cent of the estimated total aphid fauna has so far been tested with any virus (Kennedy et al., 1962). Harris and Maramorosch (1977) discussed in detail about aphids as virus vectors. According to them aphids are known to transmit 164 viruses. Aphids form the largest group of

insect vectors both because of the large number of species (about 300) involved and the large number of viruses (about 200) that they could transmit. M.persicae alone is estimated totransmit about 100 viruses while many others transmit more than 30 viruses each. Some of the aphids, on the contrary, can transmit only one virus each (Mandahar,1978). For instance 22 of the 62 known viruses of solanaceae are transmitted by aphids. Toxoptera aurantii B.d.F, Aphis fabae Scop., A.gossypii and M.persicae are more polyphagus(Harris and Maramorosch, 1977).

We have little detailed understanding of stability and change in field populations of aphids but only certain features of aphid population dynamics have been revealed (Dixon, 1977). Extraordinary weather conditions, particularly temperatures can have a marked effect on aphid numbers than has previously been appreciated. Qualitative changes in aphics induced by crowding appears to be the most probable regulating factor. Natural enemies can influence the rate of build up of aphids and by interacting with other factors can shape the dynamics of certain aphid species (Dixon, 1977).

Factors affecting movement of vectors are a complex of biotic and physical factors. For the aphids, Davies (1935) demonstrated with controlled laboratory experiments,

that high humidities inhibited flight of M.persicae and temperatures from 70° to 90°F were the most favourable. Carter (1961) studied in detail ecological aspects of aphids. Increase in relative humidity retarded the flight activity, and changes to a lower level increased the activity, but aphids adjusted to humidities between 50 and 80 per cent and flew readily at these humidities with temperature of 80°F. High humidity and high temperature (90°F) some times innibited flight. Light intensity between 100 and 1,000 ft.c. made little difference in flight, but below that ft.c flight activity declined rapidly, Forty three, twenty and eleven take off per minute of Brevicoryne brassicae (L.) were observed with full sunshine, thin clouds and dense clouds respectively (Carter, 1961). The lowest temperature at which any aphid was observed to take off was 15.5°C (Swenson, 1968).

Flying aphids will land on any available plant regardless of species. Many aphids are attracted by yellow or yellowish green colour (Moericke, 1950; and Muller, 1964). Aphids are unable to distinguish host plants from non-hosts before landing (Muller, 1962). Host selection occurs after arriving on plant surfaces (Swenson, 1968). The enormous reproductive potential and the behavioural patterns of aphids ensure their wide dispersal among populations of virus host plants. The numbers and distribution of plants infected with

aphid borne viruses reflect the numbers and activity of aphid vectors (Swenson, 1968). The intensely dispersive type of host finding behaviour in M.persicae, A.fabae and B.brassicae may be common among aphididae. It seems ideal for the dissemination of non-persistent plant viruses, more particularly among the less favoured host plants of each aphid. Aphids repeatedly alighting, brief probing and re-take off from hosts and non-hosts is a common pattern among migrant aphididae. Such an intensely dispersive pattern of host finding is plainly wasteful of individuals most of which die during the process. But given enough individuals this crude behaviour achieves a coverage of the available host plants that is notoriously efficient. It is a performance typical of parasites; and aphids are parasitic. This fits aphids for the general dissemination of non-persistent plant viruses (Kennedy et al., 1959). Polyphagous aphids are better fitted than oligophagous aphids for the field spread of many different non-persistent viruses, because the former have many moderate and border line hosts on which they probe just enough for transmission (Kennedy et al., 1959).

A.fabae and B.brassicae occurred in large proportion in simultaneous collections of all aphids alighting and probing on and taking off from a host plant and a non-host and behaved similarly when approaching and leaving them in the

same condition. Most alights took off again from leaf of both kinds within a few minutes (Kennedy et al., 1950). Some winged aphids may at least probe before their first flight and that species may differ in this behaviour (Swenson, 1968).

The effectiveness of pesticide application depends on the success of predicting the pest numbers in defining an economic injury threshold and in timing the necessary control measure. Rothamsted suction traps have been used to monitor the time of alate aphid flight and the total number of various aphids (Zitter and Simons, 1980).

In the field, aphids avoid visiting the infected plants because of their stunting caused by virus infection (Bald et al., 1946). The spread of beet yellows appears to depend largely on the number of aphids which move from plant to plant within the crop, so that A.fabae which moves infrequently from plant to plant, spreads yellows a little. Spread of beet mosaic virus on the other hand depends on movement of vectors from a nearby infected source, movement from plant to plant cannot affect it because the feeding periods are usually too long. Therefore, in spreading beet mosaic A.fabae is as effective as M.persicae. With mosaic the most important factor is probably the number of aphids from the infected source and A.fabae which often

breeds in sufficient numbers to damage the seed crop gains a numerical advantage which outweighs its inferiority as a vector (Watson and Healy, 1953). Aphid species migrating to and colonizing lettuce plantings were sampled to assess their importance in field spread of lettuce mosaic virus under conditions existing in New York State. Large number of lettuce mosaic infected plants were detected only in late August and September and this corresponded closely with peak number of alate aphid populations captured in Moericke traps. A close correlation was found between incidence of diseased plants and peak number of alates of green peach aphid, M.persicae. Infected plants appeared in an apparent random pattern. It is indicated that this disease was spread chiefly by the alate aphids (Gonzalez and Rawlins, 1969).

Zitter (1971) reported a virus disease of pepper in south Florida caused by PVY and TEV. Epidemic spread of virus disease in 1970-71 followed early with massive increase in aphid population, mainly M.persicae.

The rate at which a virus spreads between plants varies widely according to the type of virus, crop, environment and mode of transmission. In extreme instances, large plantings become almost totally infected within a few weeks. By contrast, the spread of many viruses, among woody plants

is relatively slow. Some viruses spread solely from sources outside crop, there being no plant to plant spread within the crop, at least during the first year. Other viruses spread both into and within crops and newly infected plants soon become foci for secondary spread (Thresh, 1974a). He discussed in detail on temporal pattern of virus spread. The cantaloup plantings were almost totally infected with Water Melon mosaic Virus 2 by an early and heavy influx of aphids from a nearby source. By contrast there was little secondary spread of leaf roll of potatoes when aphid infestations occurred late in the season. Therefore most viruses spread into and within crops and cause diseases of the compound interest type. However, such diseases seldom spread for long in a manner closely analogous with the logarithmic increase of capital at compound rates of interest. With virus diseases the m total amount of infection (X) usually increases in a sigmoid manner with time (t) (Thresh, 1974a). Thresh (1974b) reported that the early appearance and rapid spread of non-persistent viruses depended upon the occurrence of local sources of infection within the crop or nearby distribution of such primary infection determined the pattern of spread. 'Pools' of infected plants develop around foci within crops whereas there are steep gradients of infection from outside sources.

Initial phase of spread is truely logarithmic in virus disease when the number of new infections that appear is directly proportional to the total infection already present. Values of 'r' i.e. rate of spread, are usually greatest during early spread when there is a progressively increasing number of infected plants from which further spread can occur and a corresponding decrease in the importance of outside source. Spread is facilitated especially in annuals by increase in plant size and also the number and activity of vectors (Thresh, 1974a).

Adlerz (1978) reported that the aphids transmitting watermelon mosaic virus 2 within the field were detected when infection in water melon reached 4 per cent. Final mosaic incidence was 99 per cent. Of all the aphids trapped within the watermelon planting, 87 per cent were Anuraphis middletoni, a consistent natural vector, i.e. secondary spread of virus.

Deol and Rataul (1978) reported that in field tests in India surrounding plots of transplanted Capsicum with sunflower, sesame, sorghum or Pennisetum americanum (Linn.) K.Scham., crops reduced CMV incidence and increased yield. Wellman (1935) studied the celery mosaic virus on squash, pepper and celery. Commelina nudiflora L., growing on the

edge of the vegetable field was the principal weed host and M.persicae the important vector. The disease appeared initially on the edge of the pepper field near an infected weed patch. After introduction into the field the disease spreads inwardly but did not necessarily extend to make a fanshaped pattern, neither was there a frontier border nor spread progressing in an unbroken line as wave would spread (Wellman, 1935). Simons (1957) tested the effect of physical barriers on field spread of vein banding virus on pepper. Nightshade (Solanum gracile) was the primary source of the virus in the field. It was observed that a distance of 150 feet between plants could effectively limit the spread of the virus. The effect of placing a vertical physical barrier between the source of inoculum and the crop was studied. Use of sunflower as a barrier plant resulted in a significant decrease in virus spread (Simons, 1957). Imoto (1975) reported that earlier the transplanting, the greater was the total yield since the harvest period was then longer. Total yield was reduced when the crop was infected during early growth or if symptoms were seen at harvest. Therefore aphids on Capsicum from 50-60 days after planting in the early and from 30-40 days after in the later transplanting plots, should be controlled.

Ong et al. (1979) studied the spread of chilli veinal mottle virus in Peninsular Malaysia. The disease caused by the chilli veinal mottle virus is endemic and prevalent in all cultivars of C.annuum and C.frutescence grown in Peninsular Malaysia. Studies there, showed that in order of decreasing efficiency of transmission, the vectors were A.craccivora, T.citricidus, A.citricola v.d. Goot (Spiraecola patch), A.gossypii, M.persicae, Rhopalosiphum maidis (Fitch) and Hysteroneura setariae (Thomas). The alates of these species were chiefly responsible for the field spread of the virus, infected plants were most frequently found in rows nearest to the previously infected chilli plants. Limited data also indicated a direct correlation between the numbers of alates trapped and the field incidence of the virus (Ong et al., 1979).

Demski (1979) studied the epidemiology of TEV of Capsicum. He reported that an epidemic of TEV in Capsicum developed more rapidly if the virus source was Capsicum than if it was Cassia obtusifolia, a weed near the field. It seems that this weed is a secondary host to TEV i.e. the virus moved primarily from Capsicum to C.obtusifolia rather than the latter serving as a virus source (Demski, 1979).

Laird and Dickson (1963) reported that TEV and PVY from southern California were transmitted by M.persicae,

A.gossypii, M.solanifolii, M.pisi and A.spiraecola. The rapidity of the viruses' primary spread was not dependent on vector numbers, virus reservoir numbers or nearness to fields, but apparently on certain intrinsic vector habits. Secondary spread was correlated with M.persicae population on peppers 30 days previous to the median date of maximum disease increase. M.persicae is the important vector in both primary and secondary spread (Laird and Dickson, 1963).

Ossiannilsson (1966) reported that after probing or after brief feeding attempts most recently emerged alates take off again from both host and non-host plants and after a short flight alight somewhere else on the same or another plant, a behaviour which will clearly facilitate the spread of stylet borne viruses. The occurrence and development of insect transmitted viruses in field depends on the appearance and the build up of the vector population in nature (Danko and Praslicka, 1969; Gonzalez and Rawlins, 1969; Srivastava et al., 1971; and Zitter, 1971). Gonzalez and Rawlins (1969) observed the relation of aphid population to the field spread of lettuce mosaic virus in New York. Macrosiphum euphorbiae Essig., was found to be predominant species colonizing lettuce. Larger number of infected plants were detected only in later August and September, the time at which the greatest number of alates were captured in yellow Moericke water pan traps. Danko and Praslicka(1969)

studied the occurrence of aphids particularly, M.persicae and A.nasturtii and their importance as vectors of CMV on Capsicum and reported positive correlation between flight of winged aphids observed before flowering of Capsicum and the incidence of CMV. Mariappan et al. (1973) reported that all the four species viz., A.gossypii, A.craccivora, A.neri and M.persicae were found to transmit PVY, but A.gossypii was found to be most efficient.

Kemp and Troup (1978) studied the epidemiology of aphid transmitted virus disease of pepper in Niagara Peninsula. Theyreported that the incidence of non-persistent viruses of Capsicum at the end of August was closely correlated with accumulated degree-days plus total bright sunshine hours in April. Virus disease incidence agreed closely with predictions from a simple regression equation based on these weather factors for 1970-77. Risk years for these diseases can be forecasted accurately for this region in advance of spring planting (Kemp, and Troup, 1978).

A significant correlation can usually be demonstrated between the number of winged aphids trapped and per cent of virus infection for variety of crops and viruses (Heathcote, 1974; Dewijs, 1974; and Watson and Healy, 1953). Other workers found that aphid numbers alone do not indicate the likely incidence of a particular virus. Plumb (1976) found

that never more than 11.5 per cent of the annual catch of any species transmitted BYDV and the production fluctuated from week to week and between seasons in different years. The particular species of aphids trapped rather than total numbers may also be a significant factor (Dickson and Laird, 1959; and Broadbent, et al., 1951). Other factors considered important are the high potential and early migration associated with aphid vectors (Gill, 1970), the direction of aphid migration (Adlerz, 1978), and the long distance flights of viruliferous aphids (Wallin and Loonan, 1971).

Many workers have sighted aphid activity or flight habits as replacing aphid numbers as the most important factor. This was expressed by Kennedy in 1950, and was felt to be important in the spread of papaya ring spot virus (Ishii, 1972). M.persicae is widely associated with virus spread due to vector activity. The alate of green peach aphid is a very nervous insect, seldom remaining on even a preferred host after its initial flight. This restless nature was cited as contributing to the spread of beet yellows virus in sugarbeet fields and to the spread of lettuce mosaic virus (Dickson and Laird, 1959). The effectiveness of M.persicae as a vector was cited as the likely explanation for the spread of carrot thin leaf virus (Zitter and Simons, 1980).

van Hoof (1977) studied the infection pressure of potato virus - Y^N in a crop of ware potatoes in the centre of the Netherlands. The first PVY^N infected tobacco plants were found in mid May. The course of infection of the tobacco plants was not correlated with the flight of M.persicae, which started towards the end of June. Aphid species other than M.persicae presumably were responsible for the infection observed early. R.padi (L.) and Acyrthosiphon pisum (Harris) flew much earlier than M.persicae and were vectors of PVY^N (van Hoof, 1977). Beemster (1954) emphasized the importance of aphids that start flying in May and June long before mature plant resistance to viruses develop. The infection pressure of this non-persistently transmitted aphid-borne virus i.e. PVY not only depends on the type and prevalence of its sources of infection, but also on its spread from these sources. In Poland, Gabriel (1961) found A.nasturtii to be a much more important vector of PVY than M.persicae. In contrast, Rasocha (1966) in Czechoslovakia noted a correlation between the occurrence of potato virus Y in tobacco bait plants and the flight of M.persicae but not that of A.nasturtii during 1962-64 in potato plots. van Hoof (1979) studied the infection pressure of PVY in plots with beet, wheat and seed potatoes. No differences were found either between PVY^N infection in the border and that in the middle of a field planted with ware potatoes, although in-

fection pressure was clearly higher here than in the plot with seed potatoes. A barrier crop of 10 rows of wheat did not decrease the infection pressure of the virus. In 1976 and in 1977 virus spread was detected before the flight of M.persicae as determined with yellow Moericke traps. Infection pressure of PVY can be measured more efficiently by the tobacco test than by aphid trapping (van Hoof, 1979).

13. Etiology of 'Murda' complex of chilli

Among the several pests and diseases that occur on chilli 'Murda' is one of the serious maladies that hampers the cultivation by reducing the yield considerably. Kulkarni as back as in 1922 reported its prevalence in most parts of erstwhile Bombay Presidency, complete failure of the crop in Baramati Valley, Bijapur, Gokak, Kollapur, Khed, Analsand and Anand.

'Murda' disease is called by several names in different regions of India as Murda, Gaja, Macoda, and Mirya in Deccan; Chandiroga, Multagiroga or Murda in Karnataka; Kakdva in Gujarat and Mudath or Korovi (Bunt fagget) in Telangana. The ultimate chief symptoms of the malady is curling of leaves, the litteral meaning of the word 'Murda' (Puttarudraiah, 1959).

Several causes have been attributed to 'Murda' syndrome comprising of mites, thrips, and viruses. In Sri Lanka, leaf malformations was due to feeding of thrips and mites (Park and Fernando, 1938; Johnpulle, 1939).

Leaf curl consisted of several types of manifestations viz., dark green mottling and crinkling as observed in Spain; mosaic like as seen in Bulgaria and Malaya; mottling, stunting and malformation of fruits as encountered in Puerto Rico; chlorosis along edges of apical leaves, reduction to boat shaped as noticed in parts of Russia; curling of leaf margin without roughened lamina, great reduction of leaf size, vein clearing as observed in India, Sri Lanka, southern Africa, USA and Brazil (Puttarudraiah, 1955 and 1959).

Involvement of thrips and mites in most cases, viruses in rare cases is the cause of this malady in Karnataka as reported by Puttarudraiah (1959). Though more than 9 viruses have been reported to occur on chilli in nature from India the relationship of these viruses to 'murda' syndrome was not well established except whitefly transmitted leaf curl virus reported by Hussain (1932), Vasudeva (1954), Mishra et al. (1963), Capoor (1967) and Dhanraj et al. (1968).

Moghe (1971) investigated the causes of Churda Murda (malformation) disease. Symptoms on C.annuum include curling, crinkling, mottling and puckering of leaves. He opined that in addition to thrips and mites infestation, sometimes infection was accompanied by a virus serologically related to CMV.

Recently Amin (1979) concluded that chilli leaf curl symptoms i.e. 'churda murda' syndrome were produced by feeding of thrips and mites and not by an infectious agent.

Mishra et al. (1963) observed ± resistance in Puri Red and Puri Orange to their isolate of leaf curl virus. Capoor (1967) also observed that no variety was resistant to leaf curl virus.

14. Preservation and Storage of Plant Viruses

Best and Gallus (1953) successfully preserved TSWV for 36 days by quick freezing of infected tissues. Best (1961) lengthened the storage period of this virus by freezing and storing the infected tissue at -69° C. Here the containers of leaf bits were dipped into melted wax to seal their tops and immediately transferred to a Dry Ice Storage Box. This method surpasses all others for preservation of TSWV (McKinney and Silber, 1968). Dewijs and Bachmann(1979) preserved PVY from red peppers for 2-4 years deep frozen at -18°C. Deep frozen inocula at -18°C showed in general

a loss of infectivity within a month of storage compared to fresh sap.

Lyophilization or rapid freeze drying in vacuum received its greatest impetus from demands of World War II, but it still has not been widely used for the preservation of plant viruses. Dykstra and DuBug (1942) found potato vein banding mosaic virus and potato Canada streak virus highly active for at least 4 months, when plant juices were extracted in an atmosphere of carbon-dioxide, lyophilized and stored in sealed glass tubes held at room temperature. Hidaka and Tomaru (1960) reported good retention of activity of CMV in lyophilized infected tobacco tissue even after 14 months storage at 0-5°C. Timian and Klosterman (1962) reported the storage of barley stripe mosaic virus at -15°C in lyophilized expressed sap without loss of infectivity for 12 months. Toler and Hebert (1964) reported that lyophilized extracts of oat mosaic virus stored at -20°C were active even after 234 days. Hollings and Lelliott (1960) used the centrifugal freeze drying method to preserve 46 isolates of 39 viruses. All cultures except potato virus A were active even after 4-11 months storage.

Hollings and Stone (1970) reported that out of 75 only 57 viruses survived at least 1 year and 19 of them over 10 years by lyophilization. Serological activity of

13 plant viruses were retained for extended periods in freeze dried crude extracts from infected plant leaves (Purcifull et al., 1975). Rochow et al. (1976) reported no loss of infectivity of two barley yellow dwarf isolates during four years storage of virus concentration lyophilized and stored at 4, -70 or -196°C. Hollings and Stone (1970) reported that freeze dried sap of N.glutinosa that contained active PVY after more than 10 years of storage at 4°C. According to Dewijs and Bachmann (1979) freeze drying is superior than deep freezing in PVY which remained active for four years at 4°C.

A simple but effective means of preserving many plant viruses is by dehydrating the infected tissue chemically near 1°C (McKinney, 1953; McKinney, et al., 1965). McKinney (1953) deserves credit for having developed a simple method to retain the infectivity of sap transmissible viruses after relatively rapid desiccation of finely chopped pieces of infected leaves over $CaCl_2$ and stored near freezing temperature. Chemical dehydration of virus containing plant tissue, a virus preservation method developed by McKinney et al. (1965) proved to be as good or even better for the long term preservation of PVY and several other viruses (Bos, 1969) than freeze drying of clarified sap but a decrease in infectivity still occurred with PVY and other viruses. Bos (1969)

published some sucessful results obtained in Netherlands with a collection of 21 plant viruses in leaf material dried and stored over $CaCl_2$. According to McKinney (1953) the weight of $CaCl_2$ should be double the weight of water in the leaf tissue to be dried.

Recently Bos and Benetti (1979) reporting the storage of plant viruses in leaf material dried and stored over $CaCl_2$ suggested the use of the material directly for electron mioroscopy and serology. They observed that most of the 43 viruses stored this way could easily to be detected directly in 53 put of 66 leaf samples for varying periods up to 20½ years.

Ragetti et al. (1973) showed that direct inoculation with powdered dry material from leaves affected with ten different viruses resulted in high infectious rates.

CHAPTER III

MATERIAL AND METHODS

Raising seedlings

Chilli cv. California Wonder plants were used in all the experiments unless mentioned, which is hereafter referred to as pepper or California Wonder. The seedlings were raised from the seeds in the seed pan and transplanted at three to four leaf stage in polyethylene bags filled with mixture of soil and manure.

Transmission Studies

a) Sap inoculation

i) Preparation of inoculum: Young leaves of pepper showing typical good symptoms were collected, washed thoroughly in running tap water and dried between the folds of blotting paper. They were then macerated using sterilized mortar and pestle using 1 ml of buffer per gram of leaf tissue. The buffer consisted of 0.067 M mono and dibasic sodium phosphates with pH 7 containing 0.5 per cent sodium sulphite. The resultant pulp was squeezed through double layers of muslin cloth and used as standard inoculum for all inoculations and also for studying the properties of the viruses.

ii) Method of inoculation: Celite (600 mesh) was added to the inoculum at 0.025 g/ml as an abrasive. Hands were washed thoroughly with liquid carbolic soap. A small piece of sterilized absorbent cotton wool soaked in the extract was gently rubbed on the upper surface of the leaves. The inoculated leaves were washed immediately with a jet of distilled water using a squeeze bottle to remove the excess of sap and the plants were kept under observation.

b) Insect transmission

Five aphid species viz., M.persicae, A.gossypii Glov., A.craccivora Koch, Rhopalosiphum maidis Fitch and Hysteroneura setariae Thomas were used for transmission studies. The healthy (virus free) colonies of aphid species were first raised on their respective healthy host plant species from which they were collected initially (A.gossypii on Solanum nigrum, A.craccivora on cowpea, M.persicae on cabbage; R.maidis on maize and H.setariae on ragi). Apterous aphids from these colonies were collected separately in petri plates and were allowed to starve for 90 minutes and then they were liberated on virus infected plants for twenty minutes to acquire the virus. These aphids were transferred to healthy test plants to feed for 24 hours. They were then killed by spraying 0.2 per cent

Dimethoate and the plants were kept under observation in the glass house for 60 days. Two species of thrips viz. Thrips tabaci from [illegible] tobacco and onion, and Scirtothrips dorsalis from chilli were also used for transmission studies. The thrips included both adults and nymphs selected from the healthy colonies and reared on their respective hosts. These were allowed to feed on young leaves showing the symptoms for acquisition (5 days). For each inoculation, 25 nymphs per plant were allowed in each cage for 10 days and killed with an insecticide.

c) Seed transmission

Seeds were collected from the fruits of virus infected California Wonder plants, showing typical symptoms, and sown in seed pans at the rate of 50 seeds per pan, under insect proof conditions. The total number of seeds germinated was recorded and the plants were kept under observation for two months. At the same time leaf samples at four different stages, from these at two and six to eight leaf, flowering and after fruit formation were taken and were used for inoculation to the indicator plants to detect the presence of virus.

Physical Properties

a) Dilution end point (DEP)

In order to determine the dilution end point of the

representative isolates of each virus groups, a series of dilutions of the standard extract were prepared by adding calculated volume of distilled water. The uniform and vigorously growing young California Wonder seedlings were inoculated, starting from the highest dilution to the undiluted standard extract.

b) Thermal inactivation point (TIP)

The standard extract of the representative isolate of each virus group was prepared separately. Two ml of the extract was transferred into thin walled test tubes (1 cm diameter) of uniform size with a sterile 2 ml pipette taking precaution to avoid the contact of the sap with the inner wall of the tubes. Each test tube with the extract was held in a water bath maintained at a particular temperature for 10 minutes, taking care to see that the portion of the tube containing the extract was completely immersed in the water bath. Immediately after removing from the water bath, the tubes were cooled by holding them in a beaker containing ice cold water. The treated extract at different temperatures were inoculated to a set of test plants after adding celite along with an untreated extract as control.

c) Longevity in vitro (LIV)

The standard extract of the representative isolate of each virus group was transferred separately into small test tubes and were stoppered to prevent evaporation of moisture and stored at room temperature (21-26°C). Inoculations were made on a series of test plants with the stored extract immediately after preparation and subsequently at different intervals of 1/2, 2, 4, 8, 16, 24, 48, 72 hrs, 4 and 5 days. Those samples which exceeded the maximum limit of time were stored further and inoculated at an interval of seven days.

Purification by polyethylene glycol (PEG) precipitation method

It is a modified method adopted by Fischer and Lockhart (1976 a,b), Lima and Nelson (1975) and Hollings et al., (1968). Twentyfive to thirty grams of infected leaves were mixed in an equal volume of phosphate buffer (pH 7.2, 0.5 M) containing 0.2 per cent 2-Mercaptoethanol. The homogenate was squeezed through a double layered muslin cloth and 8.5 per cent n-butanol added to the final volume. Then, this mixture was kept over night at 4°C and then subjected to centrifugation at 3,000 rpm for 40 min. The resultant pellet was discarded. Four to eight per cent PEG (6,000 molecular weight) and four per cent sodium chloride

were added to the resultant supernatant while stirring constantly in cold for 30 to 40 min. Then this mixture was centrifuged at 15,000 rpm for 40 min. The resulting pellet was dissolved in 2 ml of 0.1 M phosphate buffer containing 0.5 per cent sodium sulphite. This suspension was centrifuged at 5000 rpm for 15 min.and the resultant supernatant containing virus was used for electron microscopy and serology.

Electron microscopy

a/ Purified preparation

The purified preparation of both healthy and diseased leaves of California Wonder plants were sprayed by means of a nebulizer on the copper grids previously coated with thin collodion film. The grids when dried were shadow casted with vaporised palladium on the specimen under vacuum. The specimen grids were then observed with the Hitachi HU-11E electron microscope at various magnifications. The photographs of the virus particles were taken and size of the particles was calculated by the following formula:

$$\text{Actual size of a particle in } \mu = \frac{\text{Size of the particle in the electron micrograph}}{\text{Magnification}}$$

b) Dip preparation

Two per cent phosphotungstic acid was prepared freshly in distilled water and the pH adjusted to 6.5 by using weak sodium hydroxide solution. A small drop of the stain was placed on a carbon coated grid and the freshly cut end of the infected piece of leaf tissue dipped into it for 2-3 seconds. The excess stain was drained off at the edge of the grid with the aid of filter paper strip. The grids were then dried in a desiccator for 20 min and observed under the electron microscope.

Serology

This study was taken up to know the possible relationship of the virus groups under study with the different available standard antisera. The antisera used were potato virus Y^{VN}, pepper vein banding virus, pepper veinal mottle virus, tobacco mosaic virus, cucumber mosaic virus, tobacco ring spot virus, potato virus S, potato virus X, raspberry ring spot virus, alfalfa mosaic virus and tobacco mosaic virus-tomato strain. Agar gel double diffusion test (Ouchterlony, 1968), was followed for this study.

This test was performed in Petri dishes. The agar medium containing one per cent Difco special agar, 0.85 per-cent sodium chloride and 0.5 per cent sodium dodycyl sul-

phate buffered with 0.02 M phosphate buffer was used. The agar, sodium chloride, and sodium dodycyl sulphate in 100 ml buffer in a flask were heated in a water bath. The molten agar was allowed to cool to 45°C and then 0.025 percent sodium azide was added while stirring. The warm agar medium was poured into scratchless, sterilized flat bottomed Petri dishes so as to form a thin layer of 3-4 mm (15-20 ml per plate). When the medium solidified, wells were cut by means of a template which cuts one central well and six peripheral wells at an equidistance of 0.8 cm apart. The bottoms of these wells were sealed by placing a small drop of the same medium by means of a capillary tube. The middle well was filled with the antiserum and the surrounding wells with different antigens, the viruses. The Petri dishes were inoubated at 37°C for two days. Observations were made by looking at the plates illuminated from one side against a dark background.

Survey and collection of chilli mosaic isolates

The survey for chilli mosaic diseases and collection of isolates were under taken in the following districts after considering the total cultivated area under chilli during the last six years (Appendix I)(Fig.1). Further, survey was conducted in areas where chilli is cultivated extensively within the district when the crop was between

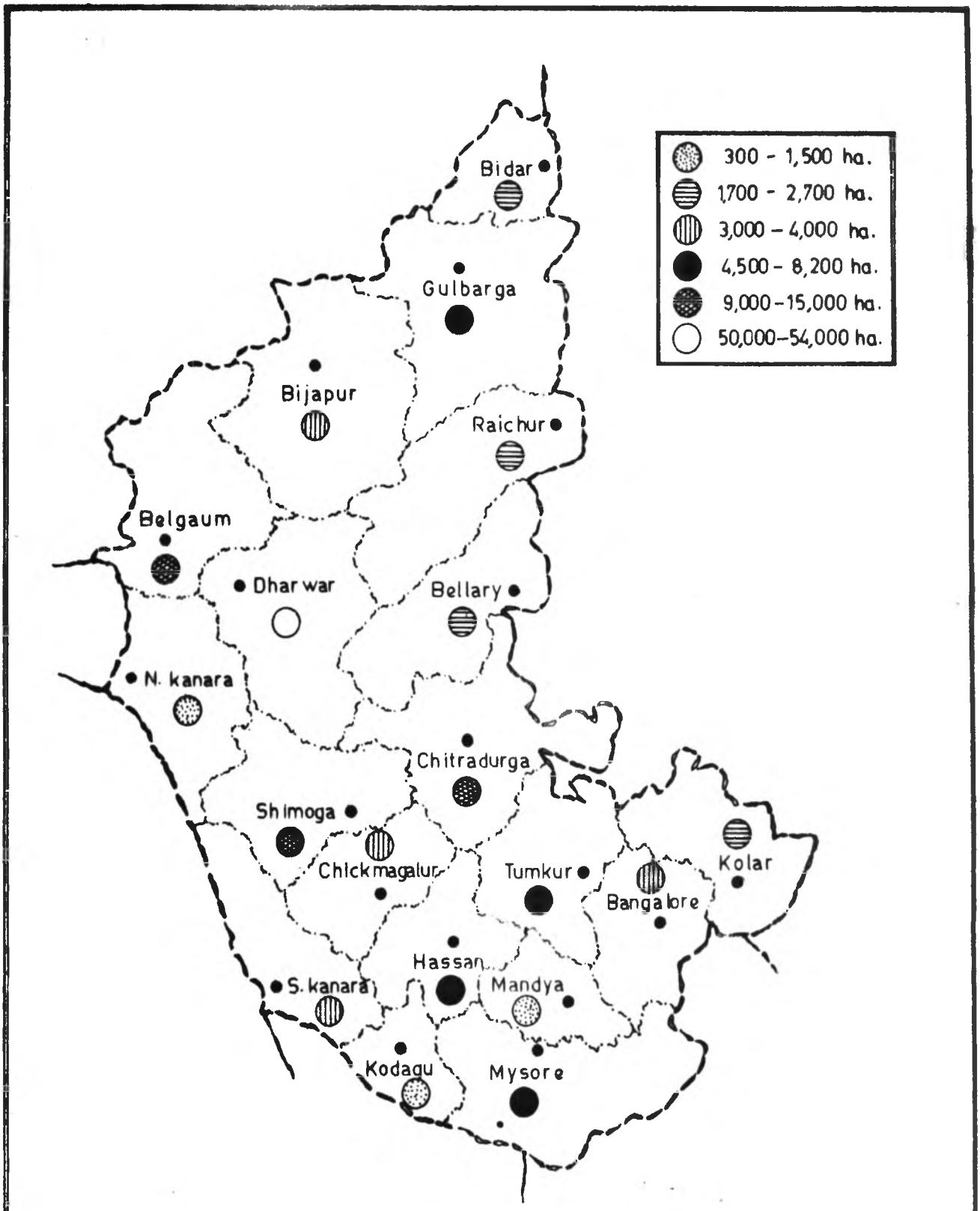


FIG.1. AREA UNDER CHILLI IN KARNATAKA DURING 1978-79

two and four month old. At village level, in the field, every fifth field was selected to make the needed observations and collections not taking into account the size of the field. The survey and collection of isolates were made in the following taluks of different districts in Karnataka:

1) Dharwad district: Dharwad, Byadgi, Haveri, Hirekerur, Hubli and Kundagol.

2) Belgaum district: Bailhongal, Belgaum, Chikkodi, Hukkeri and Raibag.

3) Shimoga district: Channagiri, Honnali , Shikaripur, Shimoga and Sorab.

4) Mysore district : Heggadadevanakote, Kollegal, Mysore, and Nanjangud.

5) Gulbarga district: Aland, Chincholi, Chitapur and Sedam.

A total of 122 fields in 28 villages were surveyed and samples of isolates collected.

The survey was conducted with two objectives, firstly to know the extent of incidence of mosaic irrespective of any specific virus responsible and secondly to sample the areas to assess the distribution of different viruses. So in each of the field five lines were randomly selected and total number of plants and number of plants showing mosaic and other associated symptoms, were counted and recorded to calculate the percentage of diseased plants. Similarly, disease incidence in irrigated and rainfed crops and also in different chilli cultivars were recorded.

MATERIAL AND METHODS

Simultaneously two plants, at random, in each of these five rows were selected to collect leaf samples. From the selected plants, four to five young leaves showing symptoms were removed with the help of a polyethylene bag which was used for packing that sample in order to avoid contamination in case the bare hands were used repeatedly. The bags containing leaf samples were sealed by heating and placed in a thermos flask containing ice (Fig.2). The samples collected for five days were brought to the laboratory and each isolate was inoculated to the seedlings of C.annuum cvr. California Wonder and Byadgi. Inoculation and establishment of the viruses were done under insect proof conditions in the glasshouse.

Grouping of the isolates

All the isolates that were collected were inoculated on to three pepper plants each of 3-4 weeks old. The development of symptoms by each isolate was carefully recorded upto one month after inoculation. The isolates were then initially grouped based on the similarity of symptoms.

Initial differentiation of isolates into virus groups

Initially, differentiation of isolates into different groups of viruses was made by using differentials reported by earlier workers detailed in results. Further, host range studies were made to know the susceptibility of

Fig. No.2. Collection kit for diseased plant leaves

Fig.2

additional plant species if any to these viruses ultimately to identify the other viruses which were not reported earlier in India. Sixty four species of plants belonging to nine families were tested against the representative isolates of each virus group. Minimum of five plants were inoculated in each species or cultivar. The observations were made daily after inoculation upto 40 days. The plants exhibiting the symptoms, after inoculation, were noted. Those which did not exhibit the symptoms even 30 days after inoculation were indexed back on healthy pepper plants to know whether they were symptomless carriers.

Effect of severe isolate of the most prevalent virus on Capsicum genotypes

The most severe isolate of the virus was maintained on pepper. Here also the seedlings of the cultivars were raised in seed pan. Four week old seedlings were transplanted individually in polyethene bags containing five kg manure-soil mixture. These seedlings were inoculated with the standard extract of the virus isolate. Totally five seedlings in each cultivar were inoculated and kept in the glass-house for further observation. Throughout the study 0.2% Kelthane and 0.05%. Bavistin were sprayed once in ten to fifteen days on the plants to avoid mites and powdery mildew. The plants which were not showing symptoms even upto ten days were reinoculated with the same virus isolate.

Symptoms and other observations were made on 5, 10, 15, 30, 45, 75 and 90 days after inoculation. Lastly, percentage disease index was calculated based on the degree of leaf malformation and size as presented in Fig.3. The ratings were based on the proportion of total leaf area reduced by the virus on individual plant by visual observations:

0 = Healthy
1 = 0-30 % Leaf area reduced
2 = 31-70 % - do -
3 = 71 and above - do -

Per cent Disease Index (PDI) was then obtained, by using the formula:

$$PDI = \frac{\text{Sum of individual ratings}}{\text{Total number of leaves observed}} \times \frac{100}{\text{Maximum disease category (3)}}$$

In addition, other parameters viz., flowering time, height, girth of stem, number of leaves, number, size and green and dry weight of fruits etc., were analysed to identify the resistant cultivars against the severe isolate.

EPIDEMIOLOGY

A. Population dynamics of different aphid species and aphid vectors on Hebbal farm

To know the prevalence of different aphid species and aphid vectors on the Hebbal farm during the year 1980-81, the

Fig. No.3. Grades for reduction in leaf area

Fig.3

aphids were trapped throughout the year. In order to trap the aphids, a funnel trap was devised (Fig.4, 5). Here, water was maintained in the yellow coloured funnel mounted on a wooden pole at five feet height. The Funnel was filled with water and a few drops of formaldehyde and liquid soap to avoid microbial growth and to sink the trapped aphids. Two such traps were planted at the locations on the farm. Throughout the year the water level was maintained and collections were made once in five days by dispensing the trapped aphids through the rubber tubing attached to the stem of the funnel. The collections were taken to the laboratory, the number of aphids were counted under binocular microscope, separated and preserved in 75% Alcohol. These aphids were further processed and mounted on slides for identification as per the procedure given by Dr.Raichoudhuri. The details are presented in the flow chart. After identification of the aphids collected at five day intervals during 1980-81, they were grouped as total number of aphids, vectors of plant viruses and vectors of chilli viruses on Hebbal farm. The aphid species which were most prevalent throughout the year and in highest populations were determined. At the same time the metepiological observations i.e. average of five days intervals corresponding to the aphid collection dates were calculated.

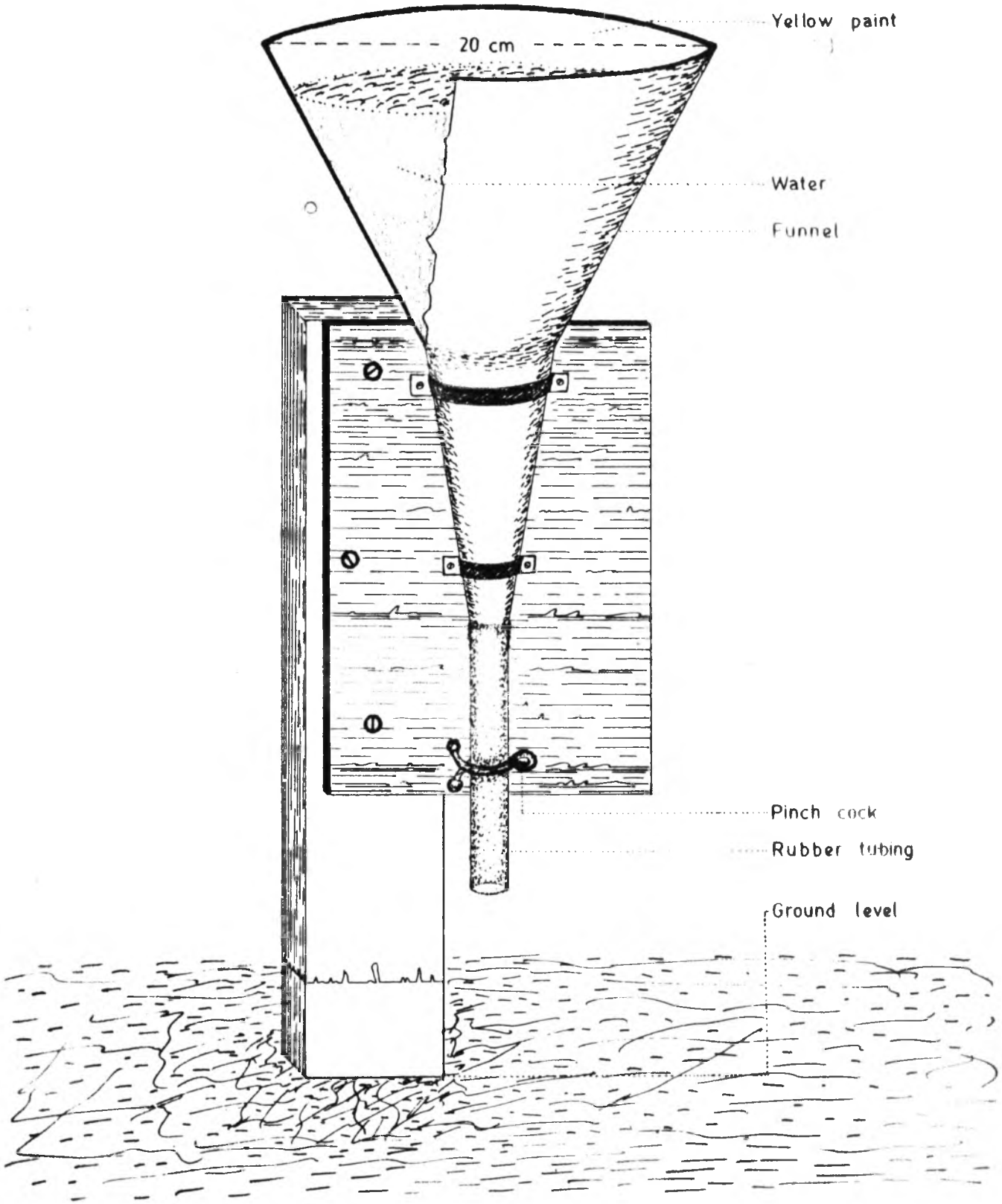


FIG. 4. YELLOW FUNNEL TRAP FOR TRAPPING APHIDS

Fig. No.5. Funnel trap erected in the field

Fig.5

Flow Chart - Procedure for processing and mounting of aphids for identification

Steps		Procedure
I	Aphids stored in 75% alcohol	- Transferred to 85 per cent alcohol, boiled for 5-10 minutes and alcohol decanted.
II		- Added 10 per cent potassium hydroxide solution, boiled till specimens appeared some what transparent and the solution decanted.
III		- Rinsed in 95 per cent Ethyl alcohol.
IV		- Heated in chloral phenol for 2 min.
V		- Placed the aphids on a glass slide in the mounting medium i.e. GUM CHLORAL streched and placed a coverslip.
VI		- Dried the slides in an oven till the peripheral mountant got dried

Note: For boiling the aphids water bath was used.

1 GUM CHLORAL : Chloral hydrate - 20.0 g
Powdered gum arabica - 12.0 g
Glycerine .. - 6.25 g
Distilled water - 20.00 ml

2 Chloral Phenol : Saturated solution of chloral hydrate in distilled liquid phenol.

Correlation between total number of aphids, total number of plant virus vectors and chilli virus vectors and some important aphid vectors individually with different meteorological data was also worked out.

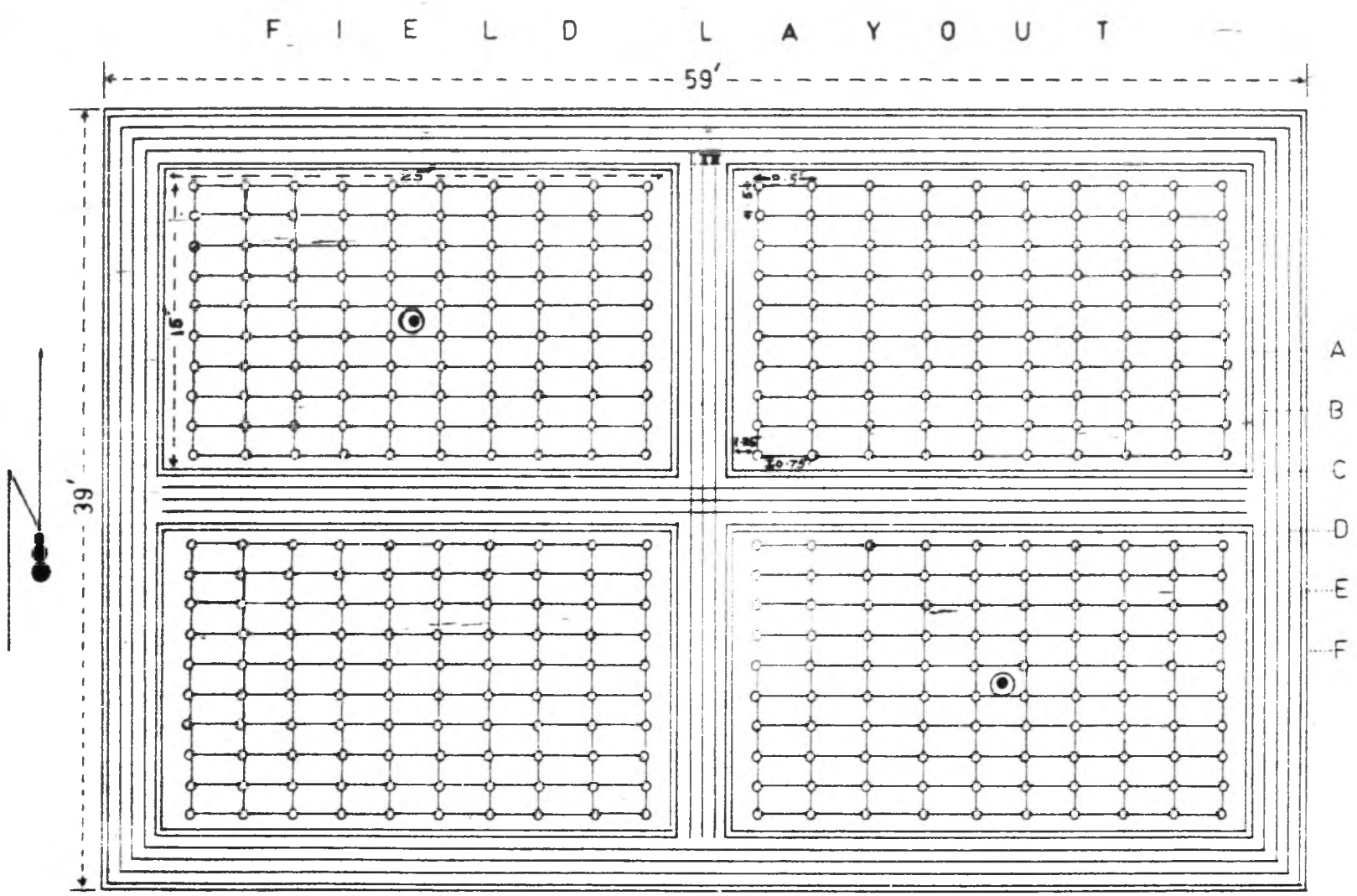
B. Infection pressure of different Capsicum viruses on Herbal farm during 1980-1981

This study was made to know the occurrence of different viruses during different periods of the year. Most susceptible California Wonder plants were used as baits throughout the year. Seedlings raised in the glasshouse were later transplanted in polyethylene bags containing 300 g of soil-manure mixture. Each bag contained only one seedling. A set of hundred plants were exposed for a month in the field away from the known hosts of majority of viruses. These plants were observed for the symptoms once in five days and the ones showing the symptoms were shifted to glass house for identification of the viruses responsible. At the end of each month all the plants irrespective of those showing symptoms or not were taken to the glass house. Before that, seedlings were sprayed with 0.2 per cent, Dimethoate, to kill the insects if present. Plants were manured and irrigated regularly. Final identification of viruses was made based on the reaction of indicator plants and serology.

Further, to find out the relation between aphid population and infection pressure of different viruses, correlation was made with different aphid species. To forecast the incidence of chilli viruses in a locality, the significance of infection pressure compared to population dynamics of aphids was studied.

C. Nature of spread of the most severe Capsicum virus (PVMV) in the field

Healthy seedlings of Byadgi Kaddi, a commercial chilli cultivar, were raised in seed pan in the glass house. When they were one month old they were transplanted in the field in four plots, each having 100 seedlings planted in ten rows. Spacing between the plants in each row maintained was 1.5' and between rows 2.5'. This experiment occupied an area of 59' x 39' with the individual plot size of 15' x 25'. The field was manured at the rate of 25 tonnes of FYM per hectare before planting, in addition to normal fertilizer application. Along the borders of each plot and around the experimental area three rows of Jowar (CSH-5) and three rows of sunhemp were grown as barrier crops to avoid the direct alighting of the alate aphids (Fig.6). This type of lay out reduced the movement of aphids from plot to plot also. The border, barrier, crop was regularly sprayed with an insecticide. In the centre of the



A,E,F Rows of jowar plants (CSH 5), B,C,D Rows of sunhemp plants, I,II,III Rows of sunhemp plants, ooo Chilli plants, ◉ Infector plant.

FIG.6. LAYOUT OF THE FIELD FOR THE STUDY OF NATURE OF SPREAD OF PVMV IN BYADGI CHILLI FIELD ON HEBBAL FARM DURING 1980-81

plot one 30 day old chilli plant inoculated with PVMV showing symptom was planted, with ten apterous aphids of M.persicae. This plant served as infector plant.

The whole experiment was repeated four times in the year by taking four crops of three months duration each during 1980-81 viz., I.from 2-3-1980 to 31-5-1980, II. from 1-6-1980 to 30-8-1980, III. from 1-9-1980 to 27-11-1980 and IV. from 1-12-1980 to 1-3-1981. During each crop period ten alate aphids on the plants collected at random from the plants were identified to know the most prevalent chilli aphids on the farm. Once in five days, starting from five days after the planting of infector plant in the centre of the plot, diseased plants were counted and percentage of diseased plants was calculated. Rate of increase of disease incidence was calculated once in five days by using the formula of van der Plank (1963).

$$r = \frac{230}{t_2 - t_1} \log \frac{u_2 (1-u_1)}{u_1 (1-u_2)}$$

where r being rate of increase of disease per day and u_2 and u_1 are the diseased plants at t_2 and t_1 time respectively.

Diseased plants were marked as soon as they were identified and records were also made of neighbouring plants which were treated as infector plants later. Once in five days the health of every plant along the row was recorded and the method of van der Plank (1946) for estimating the number of random group of adjacent diseased plants was used to indicate whether or not there was spread from plant to plant with in the crop. In order to find out whether the pattern of spread of virus at different intervals was internal or external, van der Plank's formula, $P = \frac{u\ (u-1)}{n}$, where P is the number of pairs to be expected, u is total number of diseased plants examined in a row, and n is total number of plants examined in a row, was used.

i) Effect of PVMV infection, on chilli at different ages of growth

During the spread of PVMV in the field the plants were tagged as soon as the initial symptoms were noticed. Plants, infected when they were 40-45, 70-75 and 90- days old, were selected and tagged. At the end of the experiment, height, girth of the stem, number of leaves, number, size, and green and dry weight of fruits of five plants selected at random in each category were recorded and analysed.

ii) Assessment of losses in ByadgiKaddi cultivar due to development of epidemic of PVMV from a single infector plant

Chilli cultivar, Byadgikaddi seedlings of one month old were planted in four plots having 100 plants each. Two of these plots served as control without the infector plant (Fig.6). This experiment was repeated four times as stated earlier. This was studied to know how much loss would be incurred in a plot of 100 plants with one infector, plant in the centre of the field during three month period. At the end of each crop period total green weight of chilli fruits were recorded and analysed statistically.

Etiology of "Murda" Malady of chilli in Karnataka

Murda is an important disease of chilli in Karnataka. To know the different causal entities and their distribution, a survey and collection of samples were made along with the collection of chilli mosaic isolates. Collection and record of incidence of disease were made as discussed earlier. The isolates collected from the fields in the five districts were sap inoculated to California Wonder plants. Viruses were identified based on reaction of indicator plants, serology and electron microscopy. Each virus group inoculated to one month old seedlings of California Wonder and Byadgikaddi cvrs. The symptoms developed on these plants were compared with the field symptoms with particular reference to Murda syndrome.

There are several reports, stating that mites and thrips also cause murda symptoms. Therefore to produce the syndrome artificially in the glass house, by thrips and mites individually, California Wonder and Byadgikaddi seedlings were raised and were enclosed with thrips, Scirtothrips dorsalis Hood and mites Polyphagotarsonemus latus (Banks) collected from healthy colonies in the cages (Fig.7 & 8). Daily observations were made for the development of 'Murda' symptoms in the glass house on these plants.

Preservation and storage of Capsicum viruses

Many scientists have worked on different methods of preservation and storage of plant viruses. To find out the best method of preservation and storage of chilli viruses, the following four methods were compared. (A) Young infected leaves of California Wonder showing typical symptoms were washed and deep freezed at -20°C; (B) Standard extract in phosphate buffer was deep freezed at -20°C; (C) Standard extract of young infected leaves of California Wonder in phosphate buffer transferred to glass ampules at the rate of 2 ml per each was lyophilized with the help of Edwards Centrifugal freeze drier, EF-6 model; (D) Bits of young infected leaves of California Wonder were dehydrated over Calcium Chloride and packed in gelatin capsules containing calcium chloride crystals and coated with nail polish.

Fig. No.7. Cage used to study damage due to thrips

Fig. No.8. Plastic cage used to study the damage due to mites and also to culture aphids

Fig.7

Fig.8

These capsules were stored in bottles containing Calcium Chloride. The bottles were then kept at freezing temperature throughout the study (Fig.9). Care was taken to avoid contact of leaf tissue with calcium chloride by separating them with the use of cotton wool.

Infectivity of each sample stored by these methods was assayed on 15, 30, 45, 60, 120, 180, 300 and 450 days of storage by inoculating to one month old seedlings of California Wonder. Per cent retention of infectivity over a period of time, of each virus using all the above methods of storage was worked out.

Fig.No.9. A: Glass ampules containing lyophilised sap of chilli leaves affected with viruses

B: Gelatin capsules containing dehydrated tissues of chilli leaves affected with viruses
Central: Opened capsule showing the dehydrated tissue, cotton wool and $CaCl_2$ crystals

Fig.9A

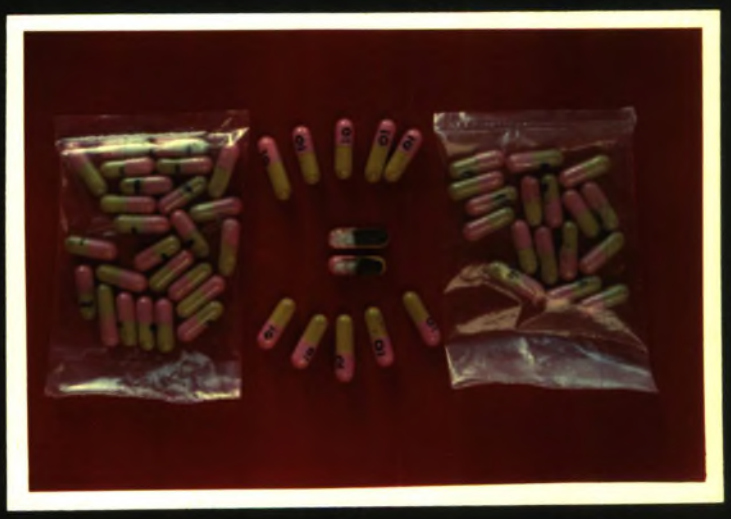


Fig.9B

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

1) Survey, Collection and Establishment of Chilli mosaic virus isolates

The survey was conducted to estimate the distribution of chilli mosaic disease and to collect the chilli mosaic isolates in the districts of Dharwad, Belgaum, Shimoga, Mysore and Gulbarga. A total of 122 fields distributed in 28 villages where chilli is grown extensively were visited and a total of 1300 isolates were collected, of which, 367, 271, 256, 208 and 198 isolates were from Dharwad, Belgaum, Shimoga, Mysore and Gulbarga districts respectively.

The results of the disease incidence is presented in the Table 1. The disease incidence in all the districts surveyed ranged from 11.8 per cent to 94.8 per cent with an average of 53.0 per cent. The average incidence of mosaic in each district when compared, it can be seen that the lowest incidence was 40.62 per cent in Shimoga district followed by 43.43 per cent in Dharwad, 53.77 per cent in Belgaum, 62.24 per cent in Mysore and 64.99 per cent in Gulbarga districts (Fig.10).

At taluk level, the lowest average incidence was 32.4 per cent in Hubli taluk followed by Kundagol (38.52 per cent), Hirekerur (40.76 per cent), Dharwad (43.04 per-

Table 1: Incidence of chilli mosaic in the farmers' fields in different districts in Karnataka

Sl. No.	Name of the District	Total No. of fields surveyed	Per cent incidence	
			Average	Range
1	Dharwad	31	43.43	11.8-73.6
2	Belgaum	26	53.77	34.0-80.8
3	Shimoga	25	40.62	16.4-66.2
4	Mysore	20	62.24	35.0-74.6
5	Gulbarga	20	64.99	31.4-94.8
		122	Average of state :53.0	11.8-94.8

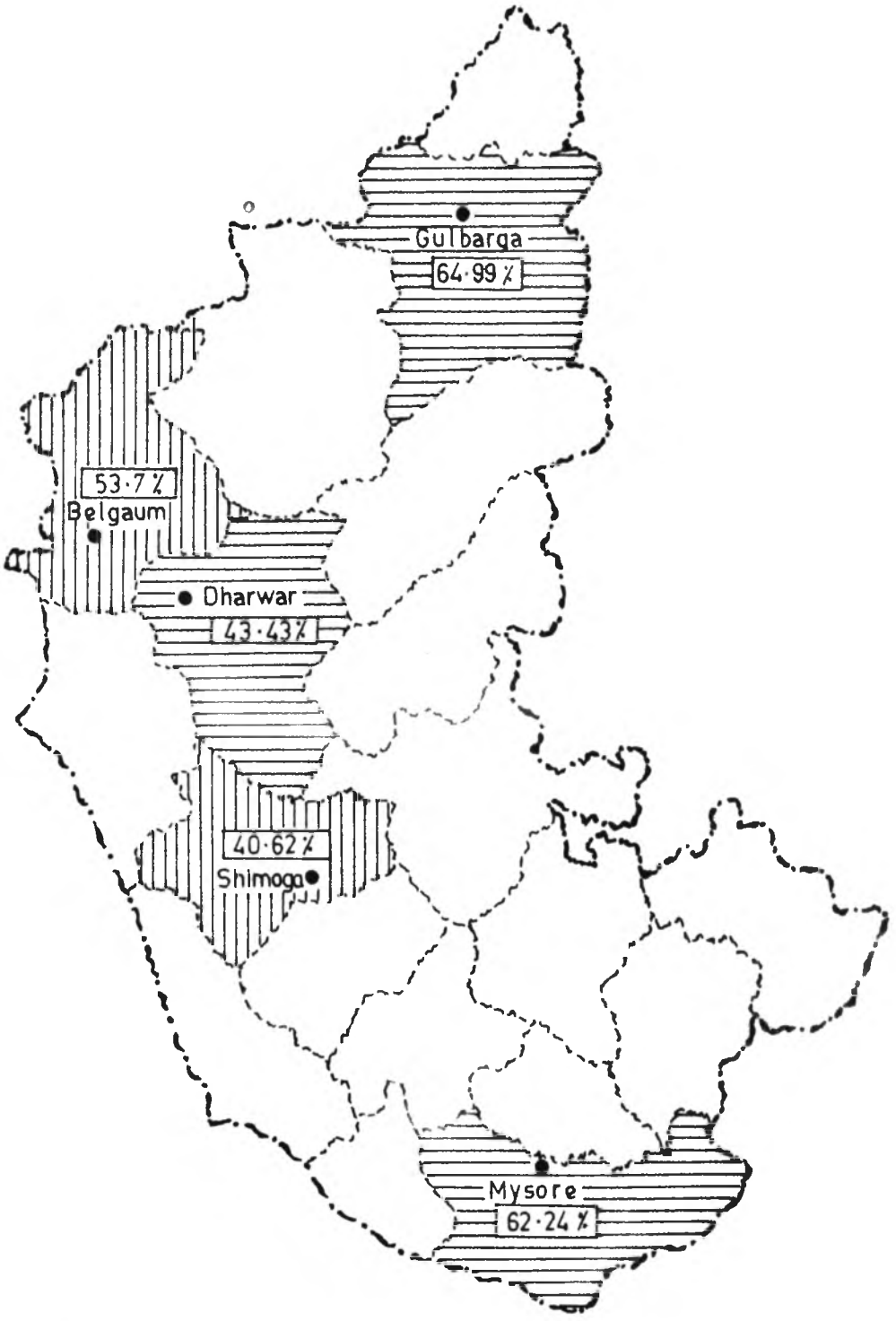


FIG.10. AVERAGE PERCENT INCIDENCE OF CHILLI MOSAIC IN FIVE DISTRICTS OF KARNATAKA

cent), Haveri (53.2 per cent) and Byadgi (54.84 per cent). In district of Belgaum the lowest average incidence was 49.28 per cent in Belgaum taluk followed by Chikkodi (50.43 per cent), Raibag (55.62 per cent), Bailhongal (56.68 per-cent), and Hukkeri (57.44 per cent). In Shimoga district the lowest average incidence was 34.9 per cent in Shikaripur followed by Channagiri (40.08 per cent), Shimoga (40.5 per-cent), Honnalli (41.15 per cent) and Soraba (45.16 per cent). The lowest average incidence in Mysore district was 53.72 per cent in Kollegal taluk followed by Nanjangud (54.88 per-cent), Mysore (61.92 per cent) and Heggadadevanakote (66.0 per cent). Chincholi taluk in Gulbarga district showed the least average incidence of 44.64 per cent followed by Sedam (62.28 per cent), Aland (68.96 per cent), and Chitapur (84.08 per cent (Table 2).

a) Incidence of Mosaic disease in rainfed and irrigated crop

The results are given in Tables 3 and 4. Among all the taluks in the five districts surveyed, the lowest incidence observed to be was 32.4 per cent in Hubli taluk of Dharwad district and highest was 84.08 per cent in Chitapur taluk of Gulbarga district.

In irrigated areas, least incidence was observed to be of 49.6 per cent in Hukkeri taluk of Belgaum district and

Table 2: Incidence of chilli mosaic in the farmers fields of commercial chilli growing areas of Karnataka in different taluks

Sl. No.	Taluks	Total No. of fields surveyed	Per cent incidence	
			Average	Range
	(1) DHARWAD			
1	Byadgi	5	54.84	34.6 - 69.8
2	Dharwad	5	43.04	28.4 - 70.0
3	Haveri	5	53.20	41.4 - 73.6
4	Hirekerur	5	40.76	32.0 - 48.2
5	Hubli	6	32.40	23.0 - 37.4
6	Kundagol	5	38.52	11.8 - 49.8
		31	43.43	11.8 - 73.6
	(2) BELGAUM			
1	Bailhongal	5	56.68	39.0 - 74.4
2	Belgaum	5	49.28	34.0 - 80.8
3	Chikkodi	6	50.43	34.2 - 71.8
4	Hukkeri	5	57.44	51.6 - 77.2
5	Raibag	5	55.62	38.8 - 68.2
		26	53.77	34.0 - 80.8
	(3) SHIMOGA			
1	Channagiri	5	40.08	23.2 - 55.2
2	Honnali	5	41.15	26.2 - 66.2
3	Shikaripur	5	34.90	16.4 - 52.6
4	Shimoga	5	40.50	22.8 - 63.2
5	Soraba	5	45.16	39.0 - 49.0
		25	40.62	16.4 - 66.2
	(4) MYSORE			
1	Heggadadevanakote	5	66.00	62.4 - 72.0
2	Kollegal	5	53.72	35.0 - 68.0
3	Mysore	5	61.92	47.0 - 74.6
4	Nanjangud	5	54.88	44.2 - 73.0
		20	62.24	35.0 - 74.6
	(5) GULBARGA			
1	Aland	5	68.96	56.2 - 78.0
2	Chincholi	5	44.64	31.4 - 50.2
3	Chitapur	5	84.08	59.4 - 94.8
4	Sedam	5	62.28	59.6 - 69.4
	Total	20	64.99	31.4 - 94.8
	Grand total	122	54.18	11.8 - 94.8

Table 3: Incidence of chilli mosaic in rainfed crop

Sl. No.	Name of taluks	Field surveyed	Per cent incidence	
			Average	Range
		(1) DHARWAD		
1	Dharwad	5	43.04	28.4 - 70.0
2	Kundagol	5	38.52	11.8 - 49.8
3	Hirekerur	5	40.76	32.0 - 48.2
4	Byadagi	5	54.84	34.0 - 69.8
5	Haveri	5	53.20	41.4 - 73.6
6	Hubli	6	32.40	23.0 - 37.4
		(2) BELGAUM		
7	Hukkeri	5	57.44	52.6 - 77.2
8	Bailhongal	5	56.68	39.0 - 74.4
		(3) SHIMOGA		
9	Honnali	5	41.15	26.2 - 66.2
10	Shikaripur	5	34.90	16.4 - 52.6
11	Soraba	5	45.16	39.0 - 49.0
12	Channagiri	4	36.30	23.2 - 47.8
13	Shimoga	5	40.50	22.8 - 63.2
		(4) MYSORE		
14	Nanjangud	3	56.20	44.2 - 73.0
15	Mysore	6	63.83	55.0 - 72.0
		(5) GULBARGA		
16	Chitapur	5	84.08	59.4 - 94.8
17	Chincholi	5	44.64	31.4 - 56.2
18	Sedam	5	62.28	59.6 - 69.4
19	Aland	4	66.70	56.2 - 72.6
		93	50.13	11.8 - 94.8

Table 4: Incidence of chilli mosaic in irrigated crops

Sl. No.	Name of taluks	Total No. of fields surveyed	Per cent incidence	
			Average	Range
		(1) BELGAUM		
1	Mukkeri	2	49.60	49.2 - 50.0
2	Raibag	5	55.61	38.8 - 68.2
3	Belgaum	5	49.32	34.0 - 80.8
		(2) SHIMOGA		
4	Channagiri	1	55.20	55.2
		(3) MYSORE		
5	Kollegal	5	53.72	35.0 - 68.0
6	Nanjangud	3	52.90	50.2 - 60.0
7	Mysore	3	63.00	47.0 - 74.6
8	Heggadadevana-kote	1	67.60	67.6
		(4) GULBARGA		
9	Aland	1	78.00	78.0
	Total	26	58.33	34.0 - 80.8

highest of 78.0 per cent in Aland taluk of Gulbarga district. On an average, chilli mosaic incidence was lower in rainfed crop (50.13 per cent) than that in irrigated crop (58.33 per cent).

b) Incidence of mosaic disease in different cultivars

In the course of survey, field selection was randomly made irrespective of varieties cultivated. Thus, the number of fields visited under different varieties varied and represented the extent of cultivated area under each variety. The number of fields, average incidence and range of incidence and general symptoms of chilli mosaic in the fields are presented in Table 5. The survey indicated that Byadgikaddi occupies maximum area under cultivation followed by Sankeshwar, Chincholi, Channagiri, Nyamati and Byadgi Dabbi, occupying comparatively larger areas. Among these, the least average incidence was observed in Nyamati accounting 35.71 per cent and maximum average incidence of 64.36 per cent observed in Chincholi. Among all the varieties irrespective of number of fields surveyed, the least incidence was noticed in the variety Kasigai to the extent of 26.9 per cent.

c) Collection and establishment of virus isolates

In all 1300 isolates showing mosaic and associated symptoms, collected and numbered, were sap inoculated on

Table 5: Incidence of chilli mosaic disease in the local chilli oultivars in the farms field in Karnataka

Sl. No.	Name of the cultivar	Total No. of fields surveyed	Per cent incidence		Symptom in the field
			Average	Range	
1	2	3	4	5	6
1	Byadagikaddi	29	43.24	23.0 - 73.6	MM, IVB, VNt, SST, St, LL, BN
2	Sankeshwar	19	54.60	34.0 - 77.2	MM, RT, BN, LL, St, LC
3	Chincholi	10	64.36	31.0 - 94.8	MM, VB, Rt, CU, SSt, St.
4	Channagiri(Mavinakatte)	10	41.02	22.8 - 63.2	MM, LL, VB, IVB, St
5	Nyamathi	7	35.71	16.4 - 66.2	MM, VNt, LL, St.
6	Byadagi Dabbi	6	50.20	34.6 - 70.0	MM, IVB, SSt, St, LL, DC
7	Neelahalli	5	62.16	59.0 - 69.4	MM, IVB, LL, CU, SSt, Rt
8	Umbragalli	5	66.00	62.4 - 72.0	MM, VNt, SSt, CS, St
9	Yadakota	5	61.92	47.0 - 74.6	MM, SSt, VNt, Rt, St
10	Devanoor	3	46.30	41.2 - 49.8	MM, Rt, CS, St, UC
11	Jwala	3	43.95	35.4 - 80.8	MM, CS, CU, St, Rt, RSt
12	Lodamugli	3	66.86	56.2 - 72.6	MM, IVB, CS, Rt, St, VN
13	Nanjangud (Basavatgi)	3	52.40	50.6 - 55.2	MM, CS, VNt, St, Rt.
14	Gundkai	2	66.80	55.8 - 66.8	MM, CU, SSt, Rt, St.
15	Guntur	2	72.10	66.2 - 78.0	MM, CU, CS, VNt, St.
16	Kasigai	2	26.90	11.8 - 42.0	MM, CU, CS, St
17	Raibag local	2	57.56	53.7 - 61.43	MM, CU, CS, VNt, SSt, LL
18	DH 7-6-6	1	53.00	53.0	MM, IVB, CS, SSt, VNt, St

(contd)

Table 5 - (contd.)

1	2	3	4	5	6
19	Dabbi Office	1	68.0	68.0	MM, CU, SSt, Rt, RSt
20	Kollegal Local	1	35.0	35.0	MM, CS, RSt
21	Konkani	1	36.8	36.8	MM, CS, Rt
22	Gauribidanur	1	58.6	58.6	MM, CU, CS, LL, St.
23	Samba	1	43.0	43.0	MM, IVB, CS, LL, St.
	Total	122			

Note:

BN = Bud necrosis
CS = Chlorotic spot
CU = Cupping of leaves
DC = Downward curling
IVB= Irregular vein Banding
LL = Little leaf
MM = Mosaic mottle
RSt = Rosette
Rt = Rat tailing
SSt = Shoe string leaf
St = Stunted growth
VB = Vein Banding
VN = Veins narrow
VNt = Veins netting
UC = Upward curling

on Capsicum annuum cv. California Wonder. The results are given in the Table 6. Out of these, 80.46 per cent of the isolates were successfully transmitted and 19.54 per cent of the isolates were found not to be sap transmissible to pepper.

Among the sap transmissible isolates, those collected from Dharwad were transmitted to the maximum number (91.0 per cent) followed by Belgaum, Shimoga, Mysore and Gulbarga.

2) Initial grouping of chilli mosaic viruses

Initial groupings of all the isolates transmitted mechanically were made on the basis of symptoms, expressed on California Wonder for a month after inoculation (Table 6). The description of the symptoms produced on pepper is disscussed in detail under each group separately. Out of 1,500 isolates 19.54 per cent of the isolates were not transmitted, 9.61 per cent isolates belonged to group 1, 19.08 per cent to group 2, 12.38 per cent to group 3, 5.46 per cent to group 4, 9.92 per cent to group 5, 13.15 per cent to group 6, 5.38 per cent to group 7, 3.38 per cent to group 8 and 2.08 per cent to group 9.

The established isolates were sap inoculated to a set of differential host plants reported by earlier workers

Table 6: Distribution of chilli mosaic isolates from different chilli growing areas of Karanataka

Sl. No.	District	Total No. of isolates collected	Total Number of isolates under each group in per cent									
			Not transmitted	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	Transmitted
1	Dharwad ..	367	8.99	9.81	20.98	15.53	8.72	11.44	11.17	7.36	4.63	1.36	91.00
2	Belgaum ..	271	14.03	10.33	16.97	13.28	6.27	10.70	13.28	3.32	5.90	5.90	85.95
3	Shimoga ..	256	21.87	12.11	23.05	12.89	3.91	6.64	13.28	4.69	1.17	0.39	78.13
4	Mysore ..	208	24.04	8.65	21.15	7.69	2.40	13.46	11.54	6.25	2.40	2.40	75.95
5	Gulbarga ..	198	38.88	6.06	11.11	9.59	3.54	6.56	18.18	4.55	1.51	0.00	61.10
	..	1300	19.54	9.61	19.08	12.38	5.46	9.92	13.15	5.38	3.38	2.08	80.46

(Prasada Rao, 1976; Villalan, 1975; Zitter, 1972; Sakimura, 1940; and Pirone, 1935), and were grouped based on their reactions as given in Table 7.

A representative isolate from each group was selected and maintained on California Wonder by inoculating at periodical intervals for further studies to confirm the nature of each virus.

3) Symptomatology

The symptoms of representative isolates of each of the eight groups of virus isolates on C.annuum cv. Bell pepper and Byadgikaddi are described below.

Group 1

Seven days after inoculation, faint vein-clearing of the young expanding leaves developed [illegible] followed by mosaic mottling on both the cultivars. Margin of the leaves were slightly bent upwards, new leaves developed with irregular and discontinuous green vein banding symptoms. Some leaves developed dark green raised blisters all over the leaf surface. Veins and veinlets became wavy resulting in upward curling of the leaves. In a few leaves, the tip was drawn into a thread like structure giving a rat tail appearance. Some leaves showed irregular expansion of lamina along with green blisters

Table 7: Reaction of representative virus isolates on different plant species

Sl. No.	Plant species	Reaction on different plants								
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
1	Nicotiana glutinosa ..	+	-	-	ME,+	LL	+	-	LL, +	LL,+
2	Datura stramonium ..	-	-	-	+, FL	LL	+	+	+	LL,+
3	Datura metel ..	+	+	-	+	LL	+	-	LL	LL,+
4	Gomphrena globosa ..	-	-	-	-	LL	-	-	LL	LL
5	Chenopodium amaranticolor	LL	-	-	LL	LL	LL	LL	LL	LL
6	Cucumis sativus ..	-	-	-	-	WNSP	+	+	VB	+
7	Nicandra physaloides ..	+	-	-	+	+	+	-	LL,VB	+
8	Vigna sinensis "Black eye"	-	-	-	-	-	LL	-	LL	LL
99	Phaseolus vulgaris 'Pinto'	-	-	-	-	LL	-	-	+	LL
10	Capsicum annuum CVR California Wonder ..	+	+	+	+	LL,+	+	+	LL,+,CR	LL,+

Note: + = Systemic reaction; - = No reaction;
FL = Filiform leaves ; LL = Local lesion
CR = Concentric rings ; ME = Mild etching
VB = Vein banding ; WNSP = White necrotic specks on cotyledon

(Fig.11). Flowering was reduced and young fruits showed various types of mottling (Fig.21). Plants were stunted.

Group 2

Seven days after inoculation, both the cultivars showed a very faint vein-clearing on young leaves. Later, these leaves developed dark green continuous vein banding, a characteristic symptom of this group and could be noticed upto 25 days after inoculation (Fig.12). The leaves later showed various types of mosaic mottling and in some cases they became thread-like. Internodal length was shortened giving a more stunted appearance. Plants showed poor flowering and bell pepper fruits assumed banana shape.

Group 3

The first symptom was the vein-clearing appeared on young leaves 7-8 days after inoculation followed by mosaic mottling. Later, dark patches developed in an irregular fashion on the leaves, and subsequent leaves showed distortion. Extreme narrowing of the leaf lamina in some cases, leaving only the mid rib a characteristic symptom of this virus group (Fig.13). The lamina developed on both the sides of midrib in a zig-zag manner in case of California Wonder. Lateral buds produced filiform leaves. Internodes were drastically reduced leading to severe stunting. Flower and fruit formation was reduced, fruits in pepper were

Fig. No.11. Capsicum annuum cv. California Wonder leaf showing symptoms of potato virus Y (Group 1)

Fig. No.12. C. annuum cv. California Wonder leaf showing symptoms of pepper vein banding virus(Group 2)

Fig. No.13. C. annuum cv. California Wonder leaves showing symptoms of pepper veinal mottle virus (Group 3)

Fig.11

Fig.12

Fig.13

smaller and round, and in Byadgikaddi they became thin and crinkled.

Group 4

After seven days of inoculation, both the cultivars showed a prominent vein-clearing of the young leaves. This was prolonged for some days and later, these leaves became mild chlorotic, prominent to moderate cupping (Fig.14). After one month, young leaves showed dark green bands along the veins which were conspicuous at the base of the lamina. In some cases, leaves showed marginal waviness. Much flagging of older leaves on infected plants was observed (Fig.15). In hot days, plants showed wilting and stunting. Main branch showed elongation. Fruits were small and showed line patterns. Ripened fruits showed brown coloured areas.

Group 5

Necrotic lesions were developed on inoculated leaves within 3-4 days after inoculation on both the cultivars. The necrosis extended to the stem along the petiole in the form of dark streak resulting in dropping of inoculated leaves. This dark streak further extended along the stem in both directions killing the young plants in some cases. The plants which survived were pale, chlorotic and developed yellowish irregular patches on leaves (Fig.16). Plants were stunted and produced a few flowers and fruits. Fruits

Fig. No.14. Capsicum annuum cv. California Wonder leaves showing symptoms of tobacco etch virus(Group 4)

Fig. No.15. C. annuum cvs. California Wonder and Dyadgi Kaddi plants showing symptoms of tobacco etch virus (Group 4)

Fig.No. 16. C. annuum cv. California Wonder leaf showing symptoms of tobacco mosaic virus (Group 5)

Fig.14

Fig.15

Fig.16

were thick skined, smaller and mottled.

Group 6

Young leaves of the infected plants, in both the cultivars showed vein-clearing from the base of the leaves after 7-8 days of inoculation. The chlorosis spread along the veins followed by characteristic mottling. The internodes were shortened and the length of the petiole was slightly reduced resulting in stunted and bushy growth of the plants. In some leaves, tip was drawn into filiform fashion or rat tailing (Fig.17). Fruits were small and retained normal green colour with dark green warty swellings on the surface in both the cultivars.

Group 7

Both the cultivars showed vein-clearing after 6-7 days of inoculation on young leaves. Later, the whole leaf showed vein-netting symptoms. After ten days, small chlorotic rings limitted by veins developed, which later spread as faint ringlines markedly on pepper leaves (Fig.18). Byadgi cultivars showed faint chlorotic spots followed by mosaic mottling (Fig.19). The leaves became abnormal in shape. Plants were not much stunted and showed too much of flower shedding. Fruits showed mottling on the skin.

Fig. No.17. Capsicum annuum cv. California Wonder leaves showing symptoms of cucumber mosaic virus (Group 6)

Fig. No.18. C. annuum cv. California Wonder leaves showing symptoms of tobacco ring spot virus(Group 7)

Fig. No.19. C. annuum cv. Byadgi Kaddi leaves showing symptoms of tobacco ring spot virus (Group 7)

Fig.17

Fig.18

Fig.19

Group 8

Both the cultivars showed a few scattered pin head necrotic spots after five days of inoculation. After 10-12 days, young leaves showed mosaic mottling with dense small rings and spots. After one month, older leaves showed concentric rings (Fig.20). These concentric rings later became chlorotic and to a lesser extent necrotic. Plants showed clear concentric rings on leaves during March, April and May. The symptoms were not clear during the other periods of the year. Byadgi cultivar showed vein-netting, mosaic mottling and later very small chlorotic spots on the older leaves. Leaves were reduced in size. Plant was not stunted. Fruits of both the cultivars showed large ring-spots on fruits resembling those on leaves. Plants showed a few flowers and fruits. After one month of inoculation, growth of California Wonder plants was reduced and became compact.

Group 9

Small necrotic spots were formed on inoculated leaves after three days and within seven days, leaves showed vein-clearing on young leaves. Plants were stunted and compact. Leaves became smaller and yellowish in colour. Flowers were aborted and fruits were hard and remained green for longer time and later became whitish. Based on the differential symptoms on *L.metal* and *C.sativus*, this group was found to

contain a mixture of groups 5 and 6. This was confirmed by serological reaction to the antisera of these two viruses.

The effect of all the eight virus groups on the fruits of bell pepper and Byadgikaddi is presented in Fig.21.

4) Transmission studies

a) Insect transmission

Five species of aphids viz., M.persicae, A.gossypii, A.craccivora, R.maidis and H.setariae were tested for the transmission of different representative isolates of virus groups, and the thrips viz., T.tabaci and S.dorsalis for transmission of virus group 8 on bell pepper seedlings were used. The results are presented in Table 8.

It is clear from the Table that M.persicae and A.gossypii were able to transmit the isolates belonging to groups 1, 2, 3, 4 and 6 with 40 to 80 per cent efficiency than A.craccivora and H.setariae H.setariae transmitted only the virus isolates belonging to groups 1 and 3 with 20 percent efficiency. Other virus groups viz. 5, 7 and 8 were not transmitted by any of the species of aphids tried. Among the thrips, only the nymphs of T.tabaci from onion transmitted the virus group 8 with 20 per cent efficiency but not others.

Fig. No.20. Capsicum annuum cv. California Wonder leaf showing tomato spotted wilt virus (Group 8)

Fig. No.21. C. annuum cvs California Wonder and Byadgi Kaddi fruits respectively showing symptoms produced by eight viruses
(From left to right)

1 = Healthy fruits
2 = PVBV infected fruits
3 = PVY ,, ,,
4 = PVMV ,, ,,
5 = TEV ,, ,,
6 = TMV infected fruits
7 = CMV ,, ,,
8 = TRSV ,, ,,
9 = TSWV ,, ,,

Fig. 20

Fig. 21

Table 8: Insect transmission of representative isolates of 8 groups of chilli mosaic viruses in Karnataka

Sl. No.	Insect species	Per cent plants infected							
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
APHIDS									
1	Myzus persicae	40	60	80	40	-	40	0	0
2	Aphis gossypii	60	80	40	40	0	20	0	0
3	Aphis craccivora	60	20	40	20	0	30	0	0
4	Rhopalosiphum maidis	0	0	0	0	0	0	0	0
5	Hysteroneura setariae	20	0	20	0	0	0	0	0
THRIPS									
6	Thrips tabaci - Adults	-	-	-	-	-	-	-	0
	(Tobacco source) - Nymphs	-	-	-	-	-	-	-	0
7	Thrips tabaci - Adults	-	-	-	-	-	-	-	0
	(Onion source) - Nymphs	-	-	-	-	-	-	-	20
8	Scirtothrips dorsalis - Adults	-	-	-	-	-	-	-	0
	(Chilli source) - Nymphs	-	-	-	-	-	-	-	0

b) Seed transmission

None of the seedlings raised from the seeds collected from the infected California Wonder with each of the virus group were found to exhibit symptoms or to carry the virus latently as observed by inoculating to indicator plants.

5) Host range studies

Fifty plant species belonging to nine families viz. Amaranthaceae, Asteraceae, Boraginaceae, Brassicaceae, Chenopodiaceae, Cucurbitaceae, Fabaceae, Malvaceae and Solanaceae were tested. In each, five plants were inoculated with the representative isolate of each virus group. The reaction of host plants to the eight virus groups is presented in the Table 9.

Group 1

This group produced numerous minute local lesions on inoculated leaves of C.amaranticolour (Fig.22). C.quinoa and C.album within six days after inoculation. On detached leaves of 'A-6' potato, (S.demisum x S.tuberosum), star shaped black necrotic lesions were observed after 3 days of inoculation (Fig.23).

Young inoculated leaves of D.metel developed vein-clearing followed by chlorotic mottling, blistering and

Table 9: Reaction of host plants to representative isolates each of 8 chilli virus groups

Sl. No.	Host families and species	Virus groups							
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
1	2	3	4	5	6	7	8	9	10
	I. AMARANTHACEAE								
1	Amaranthus caudatus L.	-	-	-	-	MM	-	-	-
2	Celosia urgentea L.	FCS	-	-	FCS	-	-	-	-
3	Gomphrena globosa L.	-	-	-	-	NLL	-	CS,NS	NS
	II. ASTERACEAE								
4	Helianthus annuus L.	-	-	-	-	-	-	-	-
5	Zinnia elegans Jacq Zinnia	-	-	-	-	-	-	MM	CS,NS
6	Emilia sonchifolia D.C.	-	-	-	-	-	-	-	NS,LP
	III. BORAGINACEAE								
7	Trichodesma zeylanicum R.Br.	-	-	-	-	-	-	-	CR
	V. BRASSICACEAE								
8	Brassica pekinensis	-	-	-	-	-	-	-	-
9	B.oleraceae L.var. botrytis	-	-	-	-	-	-	-	-
10	Raphanus sativus L.	-	-	-	-	-	-	-	-

Table 9 - (Contd.)

1	2	3	4	5	6	7	8	9	10
	V. CHENOPODIACEAE								
11	Beta vulgaris L. ..	-	-	-	-	-	-	-	-
12	Chenopodium album L. ..	NLL	-	-	-	NLL	CLL	-	CLL
13	C.amaranticolor Coste & Reyn	NLL	-	-	NLL	CLL	NLL	NLL	CLL
14	C.quinoa willd ..	NLL	-	-	NLL	NLL	NLL	CLL	NS
	VI. CUCURBITACEAE								
15	Cucumis sativus L. ..	-	-	-	-	WCSC	CS,MM	CS,MM	-
16	C.melo L. ..	-	-	-	-	-	-	CS,MM	-
17	Cucurbita maxima Duch ..	-	-	-	-	-	-	MM	-
	VII. FABACEAE								
18	Arachis hypogaea L. ..	-	-	-	-	-	-	-	NS,ST
19	Cajanus cajan (L.)Millsp ..	-	-	-	-	-	-	-	-
20	Crotalaria juncea (L.) ..	-	-	-	-	-	-	-	NLL
21	Cyamopsis tetragonoloba (L.)Taub	-	-	-	-	-	-	-	-
22	Glycine max (L.) Merr ..	-	-	-	-	-	-	-	MM
23	Phaseolus vulgaris L. Pinto	-	-	-	-	NLL	-	-	MM, St
24	Pisum sativum L. var. Bonneville	-	-	-	-	-	-	-	CS
25	Vigna unguiculata (L.)Walp CV(-152)	-	-	-	-	-	NLL	-	NLL
26	V.unguiculuta cv. Black eye	-	-	-	-	-	NLL	NLL	NLL
	VIII. MALVACEAE								
27	Abelmoscus esculentus (L.)Moench	-	-	-	-	-	-	-	-

Table 9 - (Contd.)

1	2	3	4	5	6	7	8	9	10
	IX. SOLANACEAE								
28	Capsicum annuum L. var. grossum CV California Wonder	VC,IVB, ,MM,LD	MM,VB LL	VC,MM,LD SSL,St	VC,MM CUPL	NLL,MM BNSPS YPK	VC,MM, LD, Rt	VC,MM, CRS	CS,CR LP
29	C.annuum var. Gauribidanur	VC,IVB, MM	MM, IVB	MM,LD	VC,MM	MM,LD	VC,MM, LD	FCS	CS,MM
30	C.annuum var Byadagikaddi	VC,IVB, LL,St	VC,MM, VB,Rt	VC,MM, IVB,SSL LD	VC,LL MM	NLL,MM, LF,BNSPS YPK	VC,MM, LL, Rt	CS,St	CS,LL, CRS,LP
31	C.microcarpum	VC,MM, LD	VC,MM	MM	MM,St	NLL	PVC,MM	MM	-
32	Capsicum pendulum	VC,MM	VC,MM, LL	VC,MM	VC,MM CVPL	NLL	VC,MM, LL	CS	-
33	Capsicum frutescence L. Tabasco	VC,MM	VC,MM	MM	TN	NLL	MM	VC	-
34	Datura metel L.	MM,LD	VC,MM, LD,SSL	-	VC,MM	NLL BNSPS	MM,LD	-	-
35	D.stramonium L.	-	-	-	MM,Rt, St,DFB, SF	NWLL	CS	CRS,MM	MM,LD
36	Lycopersicon esculentum Mill var. Pusa Ruby	MM	-	-	mMM	MM,LD	MM	MM	BL,NS,LD
37	Nicandra physaloides Gaertn	NLL,MM	-	-	mMM	MM	MM,LD,FA SSL	-	CS
38	Nicotiana tabacum L. var. Xanthi	MM,VC,VN	-	-	MM,NE	MM,LD	CS	MM	CS,St

Table 9 - (Contd.)

1	2	3	4	5	6	7	8	9	10
39	N.tabacum cv.White Burley K-1	VC,MM	MM	-	MM,NE	MM,LD	MM	CS,MM	NS
40	N.glutinosa L.	CS,MM, RLS,St	-	-	MM,ME	NLL	MM,LD,FA	-	NS,LD
41	N.rustica L.	VN,MM,St	-	-	CS,MM, ME	TN, NWLL	MM	CS	NS
42	Petunia hybrida Vilm	MM	MM	MM	MM	-	-	CS,MM	NS
43	Physalis floridana Rydb	NLL,MM	-	-	mMM,RLS	MM,RLS, St	MM	MM	CS
44	P.peruviana L.	MM	MM	VB,MM, LD	-	mMM	-	MM	VB
45	Solanum demissum x S.tuberosum 'A6'hybrid	NSLL	-	-	-	-	-	-	-
46	S.melongena L.	-	-	-	mMM	mMM	-	MM	NLL
47	S.nigrum L.	MM	MM	MM	MM	mMM	MM	-	-
48	S.tuberosum L.	MM	-	-	MM	-	-	-	-
49	Commelina nudiflora	-	-	-	-	-	NLL	-	-
50	(Chikkori) Cichorium intybus	-	-	-	-	-	-	-	CS,LP

Note:
BL = Bronze leaves
BNSPS = Brown necrotic streaks on petioles and stems
CLL = Chlorotic local lesions
CR = Concentric chlorotic rings
CRS = Chlorotic ring spot
CS = Chlorotic spots
CVPL = Cupping leaves
DFB = Death of flower bud
FA = Flower abortion
FCS = Faint chlorotic spot
LD = Leaf distortion
LF = Leaf fall
LL = Little leaves
LP = Line pattern
ME = Mild etching
mMM = Mild mosaic
MM = Mosiac mottle
NE = Necrotic etching
NS = Necrotic spots
NSLL = Necrotic star shaped local lesions
YPK = Young plants killed
NWLL = Necrotic white local lesions
PVC = Prominent vein clearing
RT = Rat tailing
SF = Spineless fruit
SSL = Shoe string leaves
St = Stunting
TN = Top necrosis
VB = Vein banding
VC = Vein clearing
VN = Veinal necrosis
WCSC = White chlorotic spots on cotyledons

puckering of leaves (Fig.24). Systemic chlorotic mottle was observed on Petunia hybrida, Physalis floridana (Fig.25), P.peruviana, S.nigrum, S.tuberosum, N.tabacum var. 'Xanthi' and 'Samsun', N.glutinosa (Fig.26) and N.rustica. Systemic necrosis of veins and leaves was observed on N.tabacum var. 'White Burley' (Fig.27). Nicandra physaloides produced faint necrotic spots on inoculated leaves and later systemic mottles (Fig.28).

Group 2

This virus group showed reaction only in solanaceous plants. Young seedlings of D.metel produced vein-clearing on young leaves within 6 days after inoculation, followed by crinkling, blistering, puckering and other deformations. After 20 days, plants showed filiform leaves (Fig.29). This virus produced mosaic mottling on P.peruviana, P.hybrida, S.nigrum, N.tabacum var. 'White Burley', C.microcarpum and C.pendulum within 10-12 days after inoculation. N.rustica showed systemic necrotic spots followed by leaf necrosis.

Group 3

This virus group had an extremely limited host range and was not transmissible to the plants of any other family tested except a few species in Solanaceae. This virus produced mosaic mottle on C.frutescence, C.microcarpum, C.pendulum, P.hybrida, P.peruviana and S.nigrum showed vein banding, mosaic mottling and leaf distortion.

Fig. No.22. Chenopodium amaranticolar leaves showing chlorotic to necrotic local lesions on inoculation with potato virus Y

Fig. No.23. A-6 Potato leaves showing dark brown star shaped necrotic local lesions on inoculation with potato virus Y

Fig. No.24. Dodura metel plant showing dark green blisters and mosaic mottling on inoculation with potato virus Y

Fig. 22

Fig. 23

Fig. 24

Fig. No.25. *Physalis floridana* plant showing mosaic mottling on inoculation with potato virus Y
Left = Inoculated Right = Healthy

Fig. No.26. *Nicotiana glutinosa* plant showing mosaic mottling on inoculation with potato virus Y

Fig. No.27. *N. tabacum* cv White Burley leaves showing vein clearing on inoculation with potato virus Y

Fig. 25

Fig. 26

Fig. 27

Fig. No.28. Nicandra physaloides plant showing mosaic mottling on inoculation with potato virus Y

Fig. No.29. Datura metel plant showing mosaic mottling and filiform leaves on inoculation with pepper vein banding virus.

Central = Healthy Left and Right=Inoculated

Fig. 28

Fig. 29

Group 4

This virus produced faint chlorotic spots on Celosia argentia. Necrotic local lesions were produced on C.amaranticolor and C.quinoa within 4 days after inoculation. Apart from Amaranthaceae and Chenopodiaceae the virus was restricted to solanaceae. Datura stramonium showed mosaic mottling and rat tailing and filiform leaves (Fig.30) and fruits produced were spineless, plants were stunted and sometimes flower buds were killed. D.metel, C.pendulum, L.esculentum, N.physaloides, S.nigrum, S.tuberosum, P.hybrida, P.floridana developed mosaic mottling symptoms. Whereas N.tabacum var. 'Samsun' and 'Xanthi' and N.rustica showed mild to necrotic etching symptoms in addition to mosaic mottling (Fig.31). Capsicum microcarpum showed stunted growth and C.frutescence showed top necrosis and wilting of young plants.

Group 5

The virus group produced chlorotic to necrotic lesions on inoculated leaves of Gomphrena globosa, C.amaranticolor, C.quinoa, C.album, D.metel, D.stramonium, N.glutinosa, N.rustica (Fig.32) and Phaseolus vulgaris var. 'Pinto' within 3-5 days after inoculation while it produced necrotic local lesions in addition to systemic symptoms in N.tabacum var. 'Xanthi' whereas systemic symptoms on P.floridana, P.peruviana, L.esculentum (Fig.33), N.physaloides, N.tabacum var. 'White Burley' (Fig.34) and Amaranthus caudatus.

Fig. No.30. *Datura stramonium* leaves showing mosaic, mottling, puckering and filiformity on inoculation with tobacco etch virus.

Fig. No.31. *Nicotiana rustica* leaf showing superficial round mild etching on inoculation with tobacco etch virus.

Fig. No.32. Leaves of *Gomphrena globosa*, *Nicotiana glutinosa*, *Datura stramonium*, *D. metel* *Chenopodium amaranticolar*, and *Capsicum microcarpum* showing chlorotic to necrotic local lesions on inoculation with tobacco mosaic virus.

Fig. 30

Fig. 31

Fig. 32

Fig. No.33. Lycopersicon esculentum leaves showing symptoms on inoculation with tobacco mosaic virus and cucumber mosaic virus together.

Fig. No.33 a. Nicotiana tabacum cv 'Xanthi' showed elongated styles on inoculation with TMV and CMV together.

Left = Healthy Right = Inoculated

Fig.33

Fig.33a

Group 6

The virus produced necrotic local lesions with red margin on inoculated leaves of C.amaranticolor (Fig.35) and C.quinoa and numerous chlorotic local lesions on C.album within 4-5 days after inoculation. Vigna sinensis var. 'Black Eye' and V.unguiculata var. C.152 showed reddish brown necrotic lesions. In Cucumis sativus young leaves showed small greenish yellow areas within 5-6 days after inoculation followed by yellow mosaic mottling on subsequent leaves (Fig.36). Nicandra physaloides developed mosaic mottling followed by crinkling, distortion with filiform leaves within 15 days after inoculation (Fig.37). Systemic symptoms were observed on P.floridana, S.nigrum, L.esculentum, N.tabacum var. 'White Burley' (Fig.38), and also distorted leaves in N.glutinosa (Fig.39). D.stramonium showed mild chlorotic spots and later followed by systemic mosaic. C.microcarpum, C.pendulum and C.frutescence developed mosaic mottling and leaf distortion within 10-15 days after inoculation.

Group 7

Gomphrena globosa produced chlorotic spots on inoculated leaves which later turned necrotic within five days after inoculation. C.amaranticolor (Fig.40) and C.quinoa developed necrotic and chlorotic local lesions respectively

Fig. No.34. Nictoiana tabacum cv White Burley leaves showing mosaic mottling on inoculation with tobacco mosaic virus.

Fig. No.35. Chenopodium amaranticolar leaf showing brown necrotic spots on inoculation with cucumber mosaic virus.

Fig.No.36. Cucumis sativus leaves showing mosaic mottling on inoculation with cucumber mosaic virus

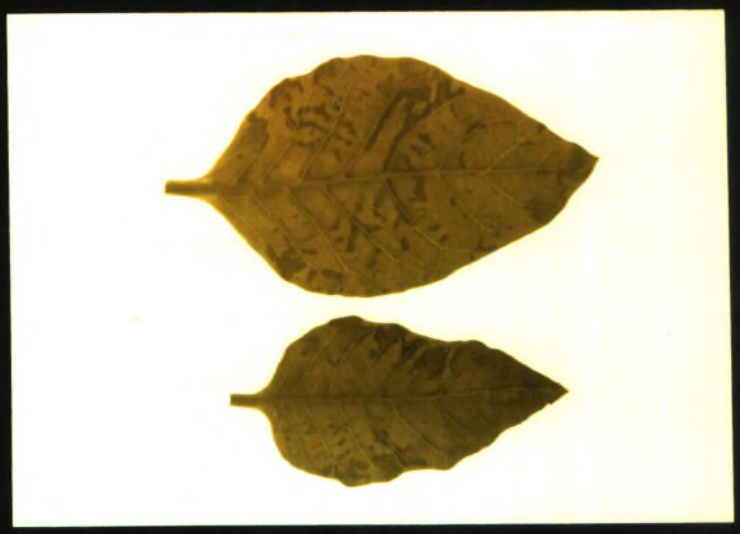


Fig. 34

Fig. 35

Fig. 36

Fig. No.37. Nicandra physaloides leaves showing mosaic mottling and leaf distortion on inoculation with cucumber mosaic virus.

Fig. No.38. Nicotiana tabacum cv White Burley leaf showing mosaic mottling on inoculation with cucumber mosaic virus.

Fig. No.39. N. glutinosa leaves showing mosaic mottling and leaf distortion and flowers showing elongation of styles on inoculation with cucumber mosaic virus.
Flowers: Left = Healthy
Right = (Inoculated) elongated styles

Fig.37

Fig.38

Fig.39

on inoculated leaves within five days after inoculation. Vigna sinensis var. 'Black Eye' developed reddish brown lesions on the inoculated primary leaves within three days. Cucumis sativus and C.melo reacted with systemic chlorotic spots 7-10 days after inoculation followed by systemic mottling (Fig.41). Zinnia elegance, Cucurbita maxima, P.floridana, P.peruviana, S.melongena, L.esculentum and N.tabacum var.'Xanthi' and N.rustica showed mosaic mottling, whereas, D.stramonium and N.tabacum var. 'White Burley' produced chlorotic spots within 10 days after inoculation (Fig. 42).

Group 8

The virus produced chlorotic to necrotic lesions on G.globosa and Z.elegans within 8-10 days after inoculation. First a few big necrotic lesions were produced on Dahlia, Emilia sonchiifolia D.C. and Chikkori (Cichorium intybus) within six days after inoculation and later the plant developed systemic line pattern symptoms (Fig. 43). Chenopodium album and C.amaranticolar showed chlorotic local lesions and C.quinoa produced necrotic spots. Trichodesma zeylanicum R.Br. produced systemic chlorotic rings on the leaves 15 days after inoculation(Fig.44). C.sativus did not show any symptoms. Physalis peruviana did not show any symptoms immediately but after fifteen days, matured leaves showed dark green vein-banding symptoms. Arachis hypogea reacted by developing

Fig. No.40. *Chenopodium amaranticolar* leaves showing necrotic local lesions on inoculation with tobacco ring spot virus.

Fig. No.41. *Cucumis sativus* leaf showing mosaic mottling on inoculation with tobacco ring spot virus.

Fig. No.42. *Nicotiana tabacum* cv White Burley leaf showing chlorotic rings and mosaic mottling on inoculation with tobacco ring spot virus.

Fig.40

Fig.41

Fig.42

Fig. No.43. *Emilia sonchifolia* leaf showing necrotic local lesions on inoculation with tomato spotted wilt virus.

Fig. No.44. *Trichoderma sevlenicum* leaf showing systemic chlorotic rings on inoculation with tomato spotted wilt virus.

Fig. No.45. *Lycopersicon esculentum* leaves showing big necrotic brown spots on inoculation with tomato spotted wilt virus.

Fig.43

Fig.44

Fig.45

first necrotic brown spots and later plants became stunted in growth. P.vulgaris 'Pinto' and Glycine max showed systemic mosaic mottling symptoms 20 days after inoculation. Pisum sativum showed chlorotic spots on the inoculated leaves after seven days of inoculation. Vigna unguiculata C-152 and V.sinensis 'Black Eye' reacted by producing small necrotic lesions. Capsicum annuum cv. California Wonder produced small necrotic specks after six days of inoculation and later the plants showed systemic chlorotic spotting on young leaves followed by concentric chlorotic rings after 25-30 days of inoculation. Cultivar Byadgikaddi also showed small necrotic spots and later small yellow chlorotic ring spots. Datura stramonium showed systemic symptoms like mosaic mottling and leaf distortion. Lycopersicon esculentum var. Pusa Ruby first showed necrotic irregular big brown spots (Fig.45) and later the plant produced bronze coloured leaves after 20 days of inoculation. Fruits of L.esculantum were round with chlorotic concentric rings (Fig.46). Nicotiana tabacum 'Xanthi' produced small chlorotic spots on the inoculated leaves after eight to ten days of inoculation. N.tabacum 'White Burley K-1', N.glutinosa, N.rustica, S.melongena and Petunia hybrida showed big isolated necrotic spots on the inoculated leaves after eight to ten days of inoculation. N.glutinosa showed isolated big necrotic brownish lesions with concentric rings which was used as a good indicator host. But later the plant showed systemic symptoms like abnormal

chlorotic leaves (Fig.47). Physalis floridana also showed only a few chlorotic yellow spots on the inoculated leaves after seven days of inoculation (Fig.48).

All the virus groups became systemic on C.annuum var. California Wonder, Gowribidanur and Byadagikaddi. C.microcarpum, C.pendulum and C.frutesoence produced necrotic lesions to the virus group 5 and not to group 8. Group 4 caused top necrosis of C.frutescence Tabasco. Groups 5 & 8 produced necrotic local lesions on inoculated leaves followed by systemic symptoms on C.annuum cv. California Wonder, Byadagikaddi and Gowribidanur.

b) Physical properties

The physical properties of each virus group was studied by using each of the representative isolate maintained on California Wonder seedlings.

a) Dilution end point

The results are presented in the Table 10. The dilution end point of virus group 1 and 4 was found to be 1:1000 to 1:5000, groups 2, 3 and 7 had 1:5000 to 1:10,000, group 5 had 1:2,50,000 to 1:5,00,000, group 6 had 1:10,000 to 1:50,000, and group 8 had 1:500 to 1:1000.

Fig. No.46. *Lycopersicon esculentum* fruit showing chlorotic concentric rings on inoculation with tomato spotted wilt virus.

Fig. No.47. *Nicotiana glutinosa* leaf showing big necrotic spots with concentric markings on inoculation with tomato spotted wilt virus.

Fig. No.48. *Physalis floridana* leaf showing big chlorotic yellow spots on inoculation with tomato spotted wilt virus.

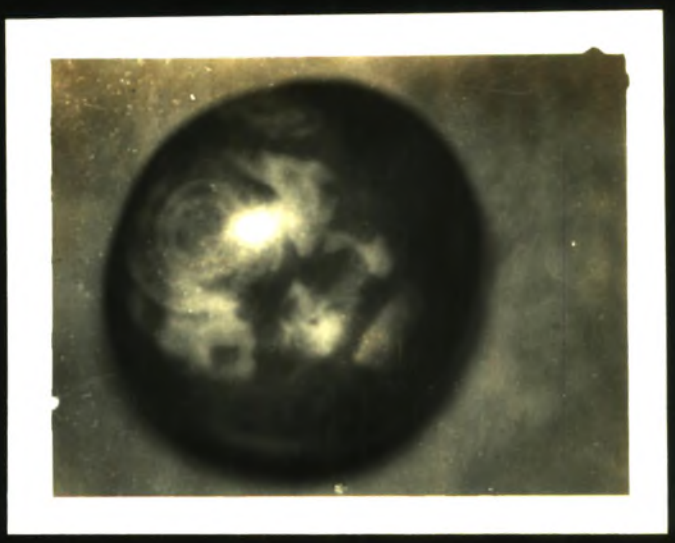


Fig.46

Fig.47

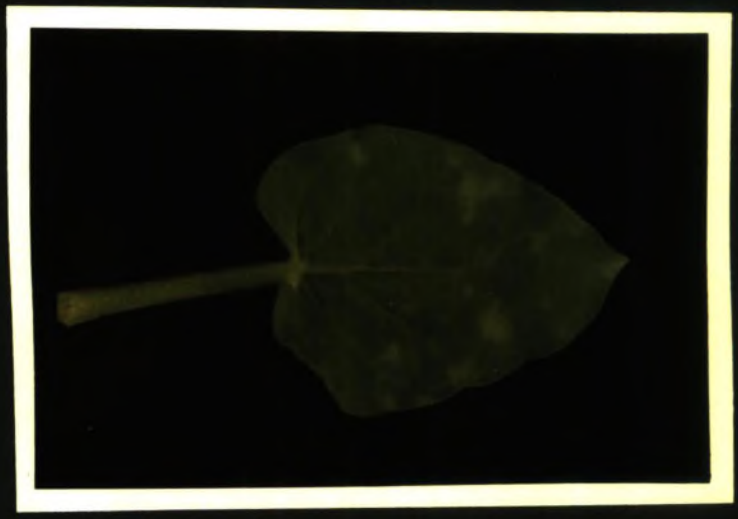


Fig.48

Table 10: Dilution end point (DEP) of representative isolates of 8 groups of chilli mosaic viruses

Sl. No.	Dilution	Number of plants infected out of 10 inoculated virus groups							
		G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8
1	Control (1:1) ..	7	9	6	8	10	9	6	4
2	1:10 ..	6	7	6	6	8	7	6	4
3	1:50 ..	4	5	4	6	7	6	4	2
4	1:100 ..	4	4	4	3	6	6	4	1
5	1:500 ..	2	4	3	2	6	5	3	1
6	1:1000 ..	1	2	2	2	6	3	1	0
7	1:5000 ..	0	2	1	0	5	2	1	0
8	1:10000 ..	0	0	0	0	4	2	0	0
9	1:50000 ..	0	0	0	0	4	0	0	0
10	1:100000 ..	0	0	0	0	3	0	0	0
11	1:250000 ..	0	0	0	0	2	0	0	0
12	1:500000 ..	0	0	0	0	0	0	0	0

b) Thermal inactivation point

The thermal inactivation point of the viruses in the crude sap from systemically infected chilli leaves lies between 60 and 65°C for representative isolate of virus groups1, 3 and 7, 55 and 60°C for group 2, 65 and 70°C for groups 4 and 6, 95 and 100°C for group 5 and 45 and 50°C for group 8 (Table 11).

c) Longevity in vitro

The results are presented in the Table 12. The results on longevity in vitro revealed that the representative isolates of virus groups 1, 2 and 7 had 24 hours, groups 3, 4 and 6 had 48 hours, and group 8 had 2 hours. However, the representative isolate group 5 was found to be active upto the 11th week in storage.

The summarised results of the physical properties of 8 groups of viruses are presented in Table 13.

7) Analytical Key to differentiate the eight Capsicum viruses

When the Capsicum virus isolates were tested on the differential host plants, they produced typical reaction. Therefore, a Key prepared for identification of the virus groups based on the reactions of the differential hosts is given below:

Table 11: Thermal inactivation point (TIP) of representative isolates of 8 groups of chilli mosaic viruses

Sl. No.	10 minutes exposure to temperature (°C)	Number of plants infected out of 10 inoculated virus groups							
		G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8
1	Control (Room Temp.)	6	6	6	7	9	7	8	4
2	40	6	6	6	6	7	7	6	3
3	45	6	4	4	4	6	4	6	1
4	50	4	4	4	4	6	4	4	0
5	55	4	4	4	4	4	3	3	0
6	60	2	0	2	4	3	2	2	0
7	65	0	0	0	2	3	2	0	0
8	70	0	0	0	0	3	0	0	0
9	75	0	0	0	0	2	0	0	0
10	80	0	0	0	0	2	0	0	0
11	85	0	0	0	0	2	0	0	0
12	90	0	0	0	0	1	0	0	0
13	95	0	0	0	0	1	0	0	0
14	100	0	0	0	0	0	0	0	0

Table 12: Longevity *in vitro* (LIV) of representative isolates of 7 groups of chilli mosaic viruses

Sl. No.	Period of storage at room temperature (20 - 28°C)	Number of plants infected out of 10 inoculated virus groups						
		G_1	G_2	G_3	G_4	G_6	G_7	G_8
1	0 hrs	8	7	6	9	8	9	4
2	½ hrs	8	7	6	8	8	9	2
3	2 hrs	7	6	5	6	7	5	1
4	4 hrs	7	6	4	5	5	3	0
5	8 hrs	5	4	4	3	3	2	0
6	16 hrs	5	2	3	2	3	2	0
7	24 hrs	2	1	2	2	2	1	0
8	48 hrs	0	0	2	1	2	0	0
9	72 hrs	0	0	0	0	0	0	0
10	4 days	0	0	0	0	0	0	0

Table 13: Physical properties of 8 chilli mosaic virus groups

Sl. No.	Virus groups	Dilution end point (DEP)	Thermal inactivation points (TIP)	Longevity in vitro (LIV) at room temp. (21-26°C)
1	G_1 (PVY)	1:1000 - 1:5000	60 - 65°C	24 hours
2	G_2 (PVBV)	1:5000 - 1:10000	55 - 60°C	24 hours
3	G_3 (PVMV)	1:5000 - 1:10000	60 - 65°C	48 hours
4	G_4 (TEV)	1:1000 - 1:5000	65 - 70°C	48 hours
5	G_5 (TMV)	1:250000 - 1:500000	95 - 100°C	11 weeks
6	G_6 (CMV)	1:10000 - 1:50000	65 - 70°C	48 hours
7	G_7 (TRSV)	1:5000 - 1:10000	60 - 65°C	24 hours
8	G_8 (TSWV)	1:500 - 1:1000	40 - 50°C	2 hours

A. Chlorotic/Necrotic local lesion on:

Chenopodium amaranticolar .. .. (B)

B. Systemic mosaic mottling on Cucumis sativus .. (C)

C. Systemic mottle coupled with crinkling/puckering and filiform leaves on Nicandra physaloides .. CMV (1)

CC. No reaction on N. physaloides .. TRSV (2)

BB. No systemic mosaic mottling on C. sativus .. (D)

D. Systemic mosaic with puckering, blistering and deformation of leaves on Nicotiana glutinosa .. PVY (3)

DD. Necrotic local lesions on N. glutinosa. (E)

E. Concentric yellow rings on both leaves and fruits of California Wonder.. TSWV(4)

EE. Bright yellowish patches on young leaves of California Wonder .. .. TMV (5)

DDD. Systemic mosaic mottling with filiform leaves on Datura stramonium .. .. TEV (6)

AA. No reaction on Chenopodium amaranticolor .. (F)

F. Vein-clearing followed by mosaic mottling and filiform leaves on Datura metel. .PVBV(7)

FF. No reaction on D. metel. .. PVMV (8)

8) Purification

A schematic outline for purification of virus by Polyethylene glycol precipitation method and the results of infectivity test with the fractions collected at each step in the process of purification for each virus group, made on California Wonder for the presence of viruses are presented in Table 14 and 15 respectively.

Table 14: Purification of chilli viruses by polyethylene glycol precipitation method

Discard	Steps	Proceed
	Infected leaves	
	1 ———	Homogenise in equal volume of 0.5 M phosphate buffer pH 7.2. containing 0.2% mercaptoethanol. Squeeze through two layers of cheese cloth.
Pulp ———	2 ———	Sap Add n-butanol to 8.5 per cent of the final volume of sap. Then keep this mixture overnight at 4°C. centrifuge for 40 min. at 3000 rpm.
Pellet ———	3 ———	Supernatant Add polyethylene glycol (6000 Mol.Wt.) to 4-8 per cent of the final volume and 4 per-cent sodium chloride slowly while constantly stirring for 30-40 min. at 5°C. centrifuge for 40 min at 15,000 rpm.
Supernatant ——	4 ———	Pellet Resuspend in 2 ml of 0.1 M phosphate buffer pH 7.0 containing 0.5 per cent sodium sulphite, centrifuge for 15 min. at 5000 rpm.
Pellet ———	5 ———	Supernatant Final virus suspension

Table 15: Infectivity tests of representative isolate of each of the eight groups at different steps of purification by polyethylene glycol precipitation method

Sl. No.	Step Nos.	Fraction used for infectivity	Number of plants infected out of 10 inoculated virus groups							
			G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8
1	2	Squeezed sap	8	9	10	8	10	10	9	2
2	3	Supernatant	7	6	8	6	10	4	8	0
		Pellet	2	2	3	2	3	1	1	0
3	4	Supernatant	1	2	1	3	2	0	1	0
		Pellet	8	6	7	6	8	7	7	0
4	5	Supernatant	6	5	5	5	8	8	6	0
		Pellet	0	0	0	0	0	0	0	0

9) Electron microscopy

The electron microscopy of the purified preparations of the diseased plant samples after shadow casting revealed the presence of flexuous rods measuring 681 x 12.5 nm(Fig.49), 677 x 13 nm (Fig.50), 656 x 12.5 nm (Fig.51) and 623 x 12 nm (Fig.52) in case of group 1, 2, 3 and 4 respectively, and rigid rods measuring 278 x 15 nm (Fig.53) in group 5 and spherical particles measuring 30 nm (Fig.54) and 27-28 nm (Fig.55) in case of group 6 and 7 respectively. However, the present method of purification failed to get the virus particles in pure form in case of virus group 8 (Table 16).

10) Serology

The serological relationship of viruses of 8 groups were tested against the standard antisera of Potato Virus Y^{VN}, Pepper vein banding virus, Pepper veinal mottle virus, tobacco mosaic virus, cucumber mosaic virus, tobacco ring spot virus, Potato virus S, X; raspberry ring spot virus, alfalfa mosaic virus, tomato strain of tobacco mosaic virus. The results are presented in Table 17. In agar gel double diffusion tests in Petri dishes, precipitation bands were observed after 48 hours of incubation, between the antigens of groups 1, 2, 3, 5, 6 and 7 with the antisera of PVY^{VN} (Fig.56), PVBV (Fig.57), PVMV (Fig.58), TMV (Fig.59), CMV (Fig.60) and TRSV (Fig.61) respectively. Precipitation bands were not observed with the

Fig. No.49. Electron micrograph of potato virus Y

Fig. No.50. Electron micrograph of pepper vein banding virus

Fig.49

Fig.50

Fig. No.51. Electron micrograph of pepper veinal mottle virus.

Fig. No.52. Electron micrograph of tobacco etch virus.

Fig.51

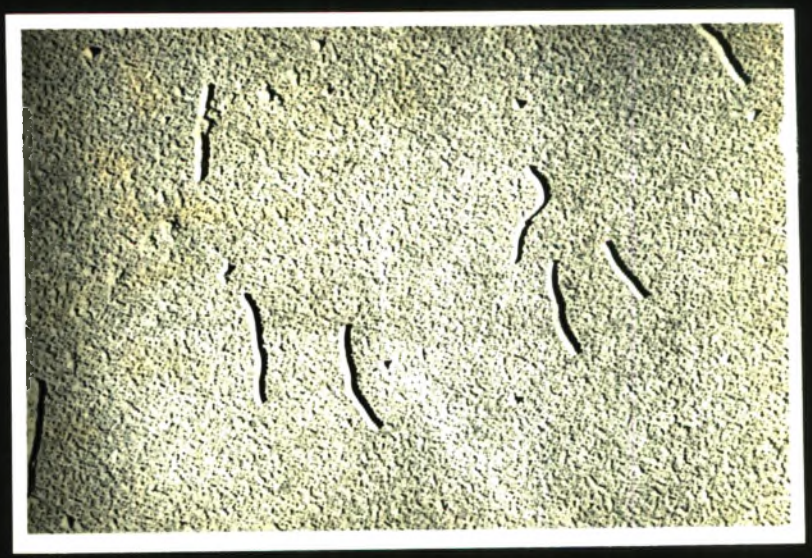


Fig.52

Fig. No.53. Electron micrograph of tobacco mosaic virus.

Fig. No.54. Electron micrograph of cucumber mosaic virus.

Fig. No.55. Electron micrograph of tobacco ring spot virus.

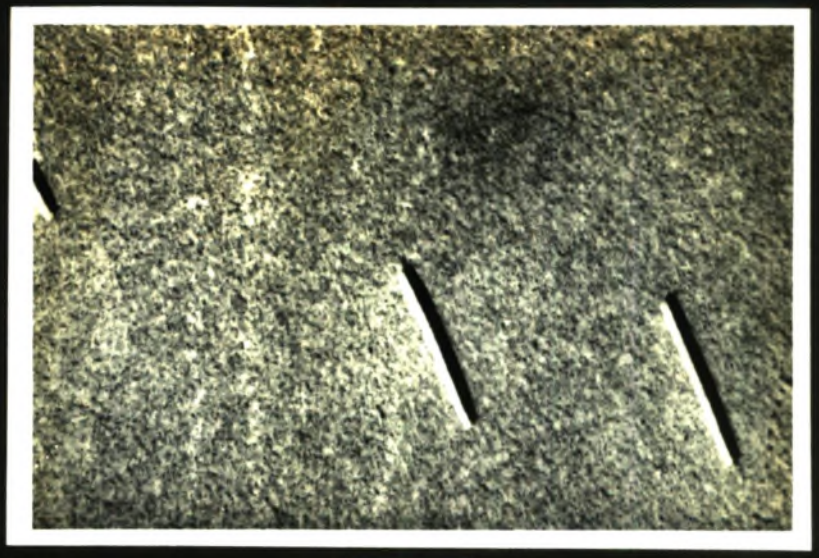


Fig.53

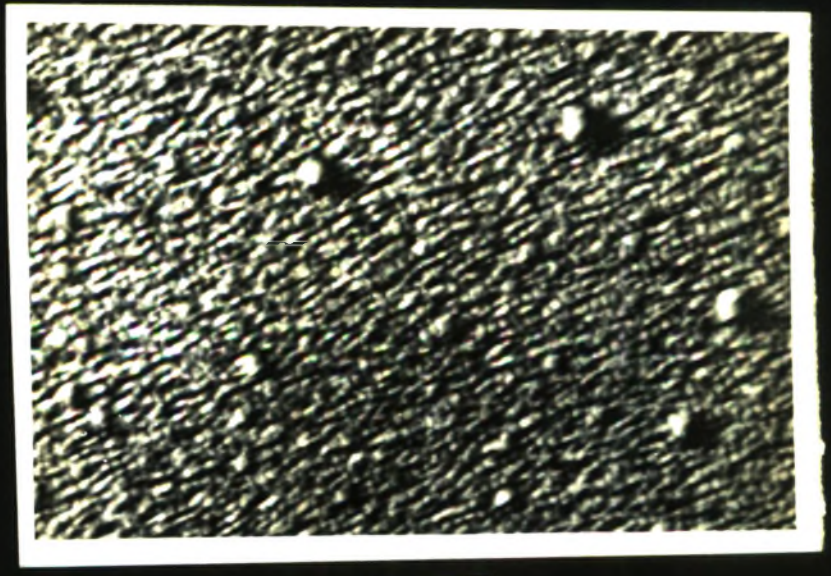


Fig.54

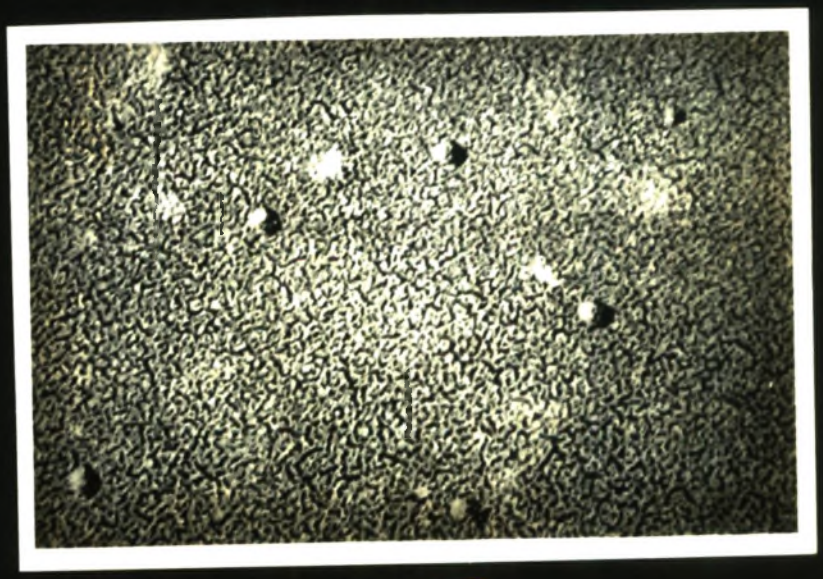


Fig.55

Table 16: Particle shape, size and name of eight groups of chilli mosaic viruses in Karnataka

Sl. No.	Group No.	Shape	Size	Name of virus
1	G_1	Flexuous rod	681 x 12.5 nm	PVY
2	G_2	Flexuous rod	677 x 13.0 nm	PVBV
3	G_3	Flexuous rod	656 x 12.5 nm	PVMV
4	G_4	Flexuous rod	623 x 12.0 nm	TEV
5	G_5	Rigid rod	278 x 15.0 nm	TMV
6	G_6	Isometric	30 nm	CMV
7	G_7	Isometric	27 - 28 nm	TRSV
8	G_8	Isometric	-	TSWV

Table 17: Serological reaction of eight groups of chilli mosaic viruses against standard antisera

Sl. No.	Virus group	Antisera										
		VN PVY	PVBV	PVMV	TMV	CMV	TRSV	PVS	PVX	RR SPV	AMV	TMV TS
1	G_1(PVY)	+	-	-	-	-	-	-	-	-	-	-
2	G_2(PVBV)	-	+	-	-	-	-	-	-	-	-	-
3	G_3(PVMV)	-	-	+	-	-	-	-	-	-	-	-
4	G_4(TEV)	-	-	-	-	-	-	-	-	-	-	-
5	G_5(TMV)	-	-	-	+	-	-	-	-	-	-	-
6	G_6(CMV)	-	-	-	-	+	-	-	-	-	-	-
7	G_7(TRSV)	-	-	-	-	-	+	-	-	-	-	-
8	G_8(TSWV)	-	-	-	-	-	-	-	-	-	-	-
9	G_9(TMV+CMV)	-	-	-	+	+	-	-	-	-	-	-

Note: + = Positive reaction; - = No reaction

PVY = Potato virus Y
PVBV = Pepper vein banding virus
PVMV = Pepper veinal mottle virus
TMV = Tobacco mosaic virus
CMV = Cucumber mosaic virus
TRSV = Tobacco ring spot virus
PVS = Potato virus S
PVX = Potato virus-X
RRSPV = Raspberry ring spot virus
AMV = Alfalfa mosaic virus
TMVTS = Tobacco mosaic virus Tomato strain
TEV = Tobacco etch virus
TSWV = Tomato spotted wilt virus

Fig. No.56. Potato virus Y from chilli showing precipitin band with standard PVY antiserum

Fig. No.57. Pepper vein banding virus from chilli showing precipitin band with standard PVBV antiserum

Fig. No.58. Pepper veinal mottle virus from chilli showing precipitin band with standard PVMV antiserum

1 = PVY antiserum
2 = PVBV antiserum
3 = PVMV antiserum
4 = TMV antiserum
5 = CMV antiserum
6 = TRSV antiserum
G1 = Potato virus Y
G2 = Pepper vein banding virus
G3 = Pepper veinal mottle virus
G5 = Tobacco mosaic virus
G6 = Cucumber mosaic virus
G7 = Tobacco ring spot virus
G9 = Mixed culture, TMV + CMV

Fig.56

Fig.57

Fig.58

Fig. No.59. Tobacco mosaic virus from chilli showing precipitin band with standard TMV antiserum

Fig. No.60. Cucumber mosaic virus from chilli showing precipitin band with standard CMV antiserum

Fig. No.61. Tobacco ring spot virus from chilli showing precipitin band with standard TRSV antiserum

Fig. No.62. Mixed culture, tobacco mosaic and cucumber mosaic viruses showing precipitin band with standard TMV and CMV antisera.

Fig. 59

Fig.60

Fig.61

Fig.62

other standard antisera and antigens tested. Group 9 showed positive reaction against both antisera of TMV and CMV (Fig.62).

11, Distribution of Chilli viruses

The results of the detailed studies with the representative isolates from each group confirmed that groups 1, 2, 3, 4, 5, 6, 7 and 8 as PVY, PVBV, PVMV, TMV, TMV, CMV, TRSV, TSWV respectively and the group 9 as the mixture of TMV + CMV.

The analysis of the data on the distribution of these viruses in the surveyed areas presented in the Table 18 revealed that PVBV to be most prevalent followed by CMV, PVMV, TMV, PVY, TMV, TRSV, TSWV and the mixture TMV + CMV.

When the incidence of most prevalent virus in each district is considered it is found that PVBV to be the most prevalent in the districts of Dharwad, Belgaum, Shimoga and Mysore. However CMV was most prevalent in Gulbarga (Fig.63).

A comparison of prevalence of different viruses among different taluks in each district is presented in the Table 18. In each district the percentage of most prevalent virus at each taluk level is underlined. The taluk which recorded highest total percentage of incidence of all viruses is marked with an asterisk(*).

Table 18: Distribution of different chilli viruses in different areas of Karnataka, during 1979

Sl. No.	Taluks	Total No.of isolates collectedin fields	Distribution percentage of different viruses									
			Not transmitted	IVY G_1	PVBV G_2	PVMV G_3	TEV G_4	TMV G_5	CMV G_6	TRSV G_7	TSWV G_8	TMV + CMV G_9	Transmitted
1	2	3	4	5	6	7	8	9	10	11	12	13	14
					I. DHARWAD								
1	Dharwad	63	11.11	6.35	23.81	9.52	4.76	22.22	11.11	9.52	1.58	0.00	88.89
2	Kundagol	57	12.28	7.02	17.54	12.28	15.79	8.77	12.28	5.26	8.77	0.00	87.72
3	Hirekerur	61	8.20	11.47	29.51	16.39	8.20	9.84	6.56	4.92	4.92	0.00	91.80
4	Byadagi	61	4.92	11.47	24.59	19.67	6.56	6.56	13.11	9.84	1.64	1.64	95.08
5	Haveri	58	3.45	10.34	17.24	15.52	8.62	13.79	12.07	8.62	5.17	5.17	96.55*
6	Hubli	67	13.42	11.94	13.42	19.40	8.95	7.46	11.94	5.97	5.97	1.49	86.57
	Total ..	367	8.89	9.81	20.98	15.53	8.72	11.44	11.17	7.36	4.63	1.36	91.01
					II. BELGAUM								
1	Hukkeri	57	12.28	15.79	17.54	19.30	5.26	7.02	10.53	1.75	5.26	5.26	87.72*
2	Chikkodi	61	13.11	6.56	13.11	13.11	9.84	13.11	14.75	3.28	4.92	8.20	86.90*
3	Raibag	49	14.28	4.08	16.33	14.28	8.16	12.24	10.20	4.08	8.16	8.16	85.71
4	Bailhongal	54	14.81	12.96	18.20	5.55	1.85	5.55	20.37	5.55	11.11	3.70	85.18
5	Belgaum	50	16.00	12.00	20.00	14.00	6.00	16.00	10.00	2.00	0.00	4.00	84.00
	Total ..	271	14.02	10.33	16.97	13.28	6.27	10.71	13.28	3.32	5.90	5.90	85.98

Table 18 - (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
						III. SHIMOGA							
1	Honnali	51	11.76	19.61	25.50	21.60	3.92	3.92	5.90	7.84	0.00	0.00	88.23*
2	Shikaripur	51	11.76	11.76	35.29	13.73	3.92	3.92	13.73	3.92	0.00	1.96	88.23*
3	Sorab	50	26.00	2.00	14.00	14.00	8.00	10.00	20.00	4.00	2.00	0.00	74.00
4	Channagiri	53	28.30	15.09	24.53	5.66	3.77	7.55	13.21	1.89	0.00	0.00	71.70
5	Shimoga	51	31.37	11.76	15.69	9.80	0.00	7.84	13.73	5.90	3.92	0.00	68.63
		256	21.88	12.11	23.05	12.89	3.91	6.64	13.28	4.69	1.17	0.39	78.13
						IV. MYSORE							
1	Kollegal	51	29.41	3.92	11.76	13.73	1.96	17.65	13.73	3.92	1.96	1.96	70.59
2	Nanjangud	53	35.85	9.43	15.09	5.66	0.00	11.32	13.21	3.77	5.66	0.00	64.15
3	Mysore	53	13.21	5.66	43.40	5.66	3.77	11.32	5.66	5.66	1.89	3.77	86.79*
4	H.D. Kote	51	17.65	15.69	13.73	5.88	3.92	13.73	13.73	11.76	0.00	3.92	82.35
		208	24.04	8.65	21.15	7.69	2.40	13.46	11.54	6.25	2.40	2.40	75.96
						V. GULBARGA							
1	Chitapur	50	38.00	4.00	12.00	16.00	0.00	8.00	16.00	6.00	0.00	0.00	62.0
2	Chincholi	48	33.33	6.25	4.17	10.42	8.33	14.58	14.58	6.25	2.08	0.00	66.67*
3	Sedam	50	42.00	8.00	14.00	8.00	0.00	4.00	22.00	4.00	0.00	0.00	58.00
4	Aland	50	42.00	8.00	14.00	4.00	6.00	0.00	20.00	2.00	4.00	0.00	58.00
		198	38.89	6.06	11.11	9.59	3.53	6.56	18.18	4.54	1.51	0.00	61.11
		1300	19.54	9.61	19.08	12.38	5.46	9.92	13.15	5.38	3.38	2.08	80.46

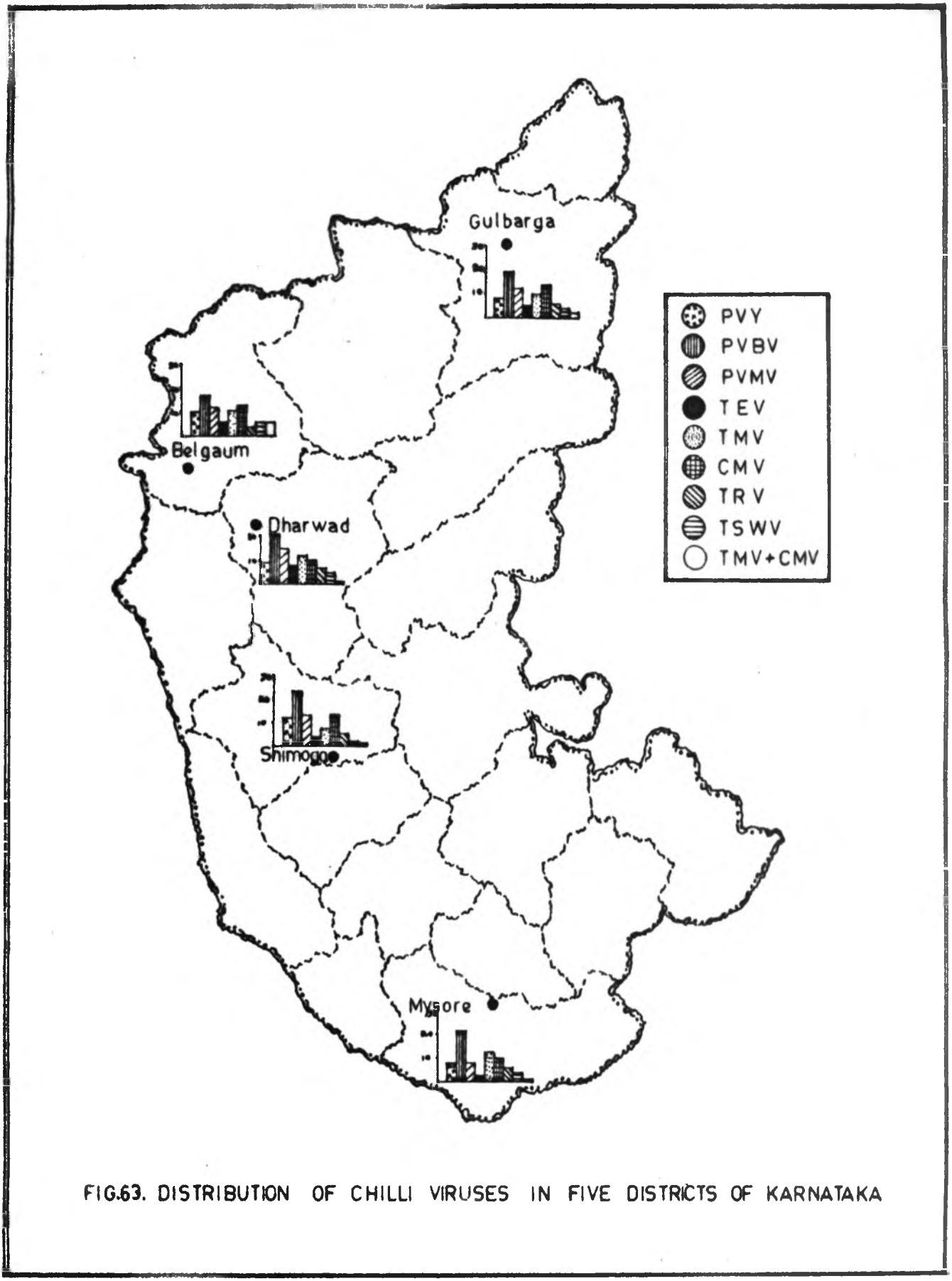


FIG.63. DISTRIBUTION OF CHILLI VIRUSES IN FIVE DISTRICTS OF KARNATAKA

Dharwad district

Among the six taluks, Haveri recorded the highest total percentage of incidence. Among the viruses recorded in different taluks in Dharwad district, PVBV was more prevalent in five taluks, Hirekerur recording the highest incidence followed by Byadgi, Dharwad, Kundgol and Haveri, whereas CMV was maximum in Hubli taluk.

Belgaum district

Among the five taluks, Hukkeri recorded the highest total percentage of incidence. Among the viruses recorded in different taluks in Belgaum district PVBV was more prevalent in Belgaum and Raibag taluks. Whereas, CMV was more prevalent in Bailhongal and Chikkodi taluks. Hukkeri taluk recorded the highest incidence of PVMV followed by PVBV.

Shimoga district

Among the five taluks, Honnali and Shikaripur taluks recoroed the highest total percentage of incidence. Among the viruses recorded in different taluks in Shimoga district, PVBV was more prevalent in four taluks, Shikaripur recording the highest incidence followed by Honnali, Channagiri and Shimoga. Whereas CMV was maximum in Sorab taluk.

Mysore district

Among the four taluks, Mysore recorded the highest total percentage of incidence. Among the viruses recorded in different taluks in Mysore district, IVBV was more prevalent in Mysore and Nanjangud taluks whereas PVY and TMV were more prevalent in Heggadadevanakote and Kollegal taluks respectively.

Gulbarga district

Among the four taluks,Chincholi recorded the highest total percentage of incidence. Among the viruses recorded in different taluks in Gulbarga district CMV was more prevalent in three taluks, Sedam recorded the highest incidence followed by Aland, Chitapur and Chincholi. In Chincholi taluk both CMV and TMV were equally maximum.

The data obtained on the distribution of different virus isolates in each of the popular commercial varieties of chilli is presented in the Table 19. The incidence of each virus on each variety is presented as the percentage of total number of isolates collected on any variety.

Looking at the Table, it is clear that all the eight viruses were recorded on only five out of 23 varieties viz., Byadgikaddi, Byadgi Dabbi, Sankeshwar, Yedakota local and Chincholi at varied percentage. However, in another six

Table 19: Distribution of different chilli viruses in different commercial chilli cultivars during 1979

Sl. No.	Cultivars	Total No.of isolates collected from fields	Per cent of isolates occurring in different chilli varieties										
			Non-transmitted	PVY G_1	PVBV G_2	PVMV G_3	TEV G_4	TMV G_5	CMV G_6	TRSV G_7	TSWV G_8	TMV + CMV	Total transmitted
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Byadgikaddi	391	16.37	9.46	19.18	14.83	6.39	10.23	12.79	5.88	3.58	1.28	83.63
2	Byadgi Dabbi	64	7.81	9.37	26.56	14.06	0.77	14.06	10.93	9.37	1.56	1.56	92.18
3	Kasigai	24	16.67	16.67	12.50	12.50	20.83	4.17	12.50	0.00	4.17	0.00	83.33
4	Devanoor	33	9.09	0.00	21.21	12.12	12.12	12.12	12.12	9.09	12.12	0.00	90.91
5	Sankeshwar	195	12.82	9.74	14.87	12.31	7.18	9.23	15.38	4.61	7.18	6.67	87.17
6	DH 7-6-6	16	6.25	18.75	25.00	31.25	0.00	12.50	6.25	0.00	0.00	0.00	93.75
7	Jwala	30	23.33	6.67	16.67	16.67	6.67	16.67	10.00	0.00	0.00	3.33	76.67
8	Raibag local	20	25.00	0.00	20.00	10.00	5.00	15.00	10.00	0.00	10.00	5.00	75.00
9	Konkani	10	0.00	40.00	40.00	0.00	0.00	10.00	0.00	0.00	0.00	10.00	100.00
10	Nyamathi	91	10.98	17.58	30.77	17.58	3.29	4.39	8.79	6.59	0.00	0.00	89.01
11	Channagiri (Mavinakatti)	20	15.00	20.00	30.00	0.00	10.00	5.00	15.00	5.00	0.00	0.00	85.00
12	Nanjangud (Basawatgi)	53	35.85	9.43	15.09	5.66	0.00	11.32	13.20	3.77	5.66	0.00	61.15
13	Yedakota local	53	13.21	5.66	43.39	5.66	3.77	11.32	5.66	5.66	1.88	3.77	86.79
14	Umbragalli	51	17.65	15.68	13.72	5.88	3.92	13.72	13.72	11.76	0.00	3.92	82.35

Table 19 - (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
15	Gundakai	10	30.00	10.00	0.00	20.00	0.00	20.00	20.00	0.00	0.00	0.00	70.00
16	Gouribida-nur	10	20.00	10.00	20.00	20.00	0.00	10.00	10.00	10.00	0.00	0.00	80.00
17	Samba	11	36.36	0.00	27.27	9.09	0.00	9.09	9.00	0.00	9.09	0.00	63.63
18	Dabbi Office	10	40.00	0.00	0.00	20.00	0.00	20.00	20.00	0.00	0.00	0.00	60.00
19	Kollegal	10	20.00	0.00	10.00	0.00	10.00	30.00	10.00	10.00	0.00	10.00	80.00
	Local												
20	Chincholi	98	35.71	3.10	8.16	13.26	4.08	11.22	15.31	6.12	1.02	0.00	64.28
21	Neelhalli	50	42.00	6.00	14.00	8.00	0.00	4.00	22.00	4.00	0.00	0.00	58.00
22	Lodamugli	30	46.66	13.33	10.00	3.33	6.66	0.00	16.66	3.33	0.00	0.00	53.33
23	Guntur	20	35.00	0.00	20.00	5.00	5.00	0.00	25.00	0.00	10.00	0.00	65.00
	Total	1300											

varieties, seven viruses were present. Least number, i.e. only three viruses were observed in Konkani variety.

Distribution of each virus in different varieties revealed that maximum incidence of PVBV was noticed in twelve varieties (Table 19) whereas PVY was maximum in Konkani, PVMV in DH7-6-6, Jwala, Gundakai, Gouribidanur and Dabbi office, TEV in Kasigai only, TMV was found to be highest in Jwala, Umbragalli, Gundakai, Dabbi office and Kollegal local and CMV in Sankeshwar, Umbragalli, Gundakai, Dabbi office, Chincholi, Neelhalli, Lodamugali and Gunter.

The mixed infection of TMV + CMV was observed only in eight varieties out of 23 but not to a maximum extent.

12) Effect of a severe isolate of PVBV on Capsicum genotypes

Among the six isolates of PVBV representing different areas, an isolate which showed severe symptoms on the popular cv. Byadgikaddi was selected for assessing the reactions of fortysix genotypes of Capsicum.

Symptoms and other observations were made on 5, 10, 15, 30, 45, 75 and 90th day. Percentage disease index was worked out for each genotype and presented in the Table 20.

Table 20: Reaction of different genotypes of chilli to severe isolate of PVBV at different intervals after inoculated

Genotypes	Interval in days						
	5	10	15	30	45	75	PDI on 90th day
1	2	3	4	5	6	7	8
1 Byadgi (Dabbi)	VC	VC	VB, LD, RT	IVB, LL, SSL, WM	IVB, RT, WM	LL, VB, SSL	VS (65.45)
2 Byadgi (Kundagol)	Nil	FVC	MM, CL	LD, CL, IVB	IVB, LD, Rt	St, LL	VS (71.41)
3 Capsicum chinense	Nil	Nil	VC	VB, MM, LL, St	VB, LL	IVB, LL, St	VS (79.03)
4 Chincholi	VC	VC	VB, LD	VB, IVB	IVB, SSL, WM	LL, VB, SSL, St	VS (65.83)
5 Cluster chilli	VC	VC, MM CL	VC, MM, IVB, LD	IVB, LD, Rt, RLS, MM	VB, IVB, Rt, St	Rt, LL, Bushy plant	S (59.00)
6 CA 960	FVC	FVC	VC	IVB	IVB, Rt, WM, St, LL	VB, IVB, Rt, LL, St	S (57.20)
7 CA 1068	Nil	Nil	VB, LD	VB, IVB	VB, IVB, WM	VB, St	S (52.00)
8 DH 7-6-6	Nil	VC	VC	IVB, LL	VB, St	LL, Rt	S (59.24)
9 EC 119981	VC	VC	VB, Rt, St	VB, IVB, Rt, WM, St	IVB, Rt, St	LL, WM, St	S (52.33)
10 EC 127967	FVC	CL	CL	VC, IVB	VB, IVB, WM, LL	WM, VB	VS (61.41)
11 EC 127968	FVC	VC, WM	CL, WM	WM, CL, MM, IVB, LL, St, SSL	VB, Rt, Bushy plant	More axillary branches, St	VS (66.43)
12 EC 127970	Nil	VC	VC, IVB, CL	IVB, RT, SSL, St	IVB, RT, St	SSL, LL, St, Axillary branches	VS (69.90)
13 EC 127972	Nil	Nil	VC	IVB, LL	VB, IVB, LL, St	St, Bushy plant	VS (69.22)
14 EC 127975	Nil	Nil	Nil	VC, VB, CL, RT, St	VB, IVB, LD, St, Axillary branches	SSL, St, Bushy plant	VS (61.00)
15 EC 127977	Nil	VC	VC, CL	-	-	-	-
16 EC 137971	FVC	VC	VC, St	IVB, RT, LL, St, SSL	VB, IVB, SSL	VB, RT, SSL, St	VS (63.69)
17 G-3	Nil	VC	LD	VB, IVB, LL, RT, SSL	VB, IVB, LL, RT, SSL	RT, LL, St	VS (62.36)
18 G-4	FVC	Nil	VC, VB, MM, RT	VB, IVB	VB, IVB, LD, RT	VB, LL, WM, LD	VS (61.12)
19 G-5	FVC	VC	VC, MM, RT	VB, IVB, LL	VB, IVB, RT, LD, LL	VB, LL, RT	S (59.51)
20 Gouribidanur	Nil	FVC	IVB	VB, IVB, LL, St	VB, LL, LD, WM	WM, LL	S (56.00)
21 Gulbarga local	VC	VC	VB, MM, RT	VB, IVB, RT, St, SSL	VB, IVB, RT, SSL, Axillary branches	VB, RT, Bushy plant	S (58.81)
22 IC 13256	FVC	VC	MM, RT	VB, IVB, SSL	VB, IVB	IVB, LL	S (49.31)
23 LEC 27	Nil	FVC	VB, CL	VB, IVB, LL	VB, IVB	VB, LL	S (48.33)
24 LEC 28	Nil	VC	VC, VB	VB, IVB, WM	VB, IVB, WM	IVB, LD	S (60.52)
25 Line 5 Green Sel-1	FVC	VC	VB, CVPL	VB, IVB, RT, WM	VB, IVB, Rt	RT, VB	S (60.23

Table 20 - (Contd.)

1		2	3	4	5	6	7	8	
26	Line 6 Green Sel-2	FVC	VC	IVB,LD	VB,LL	VB,Bushy plant	VB,LL,Bushy plant	S	(49.70)
27	Line 7 Green Sel-2	FVC	VC,MM, CL	VC,MM,RT	VB,IVB,RT,SSL,CUPL	VB,IVB	IVB,LI,NL	S	(56.71)
28	Line 8 Green Sel-3	FVC	VC,CL	IVB,RT	IVB,WM,RT	IVB,RT, SSL	St, RT,SSL,CUPL	S	(50.42)
29	Line 9 Green Sel-4	FVC	FVC	VC,IVB,RT	VB,IVB,RT,SSL	VB,IVB,RT,WM	VB,RT,CUPL	S	(53.31)
30	Line 11 Green Sel-6	VC	VC,CL	IVB,MM	IVB,RT,SSL	IVB,RT	IVB,RT,SSL	S	(59.30)
31	Line 13 Green Sel-2	VC	VC	VB,RT	VB,RT	VB,IVB,Bushy plant	IVB,RT,LI,Bushy plant.	S	(56.75)
32	Line 15 Green Sel-4	VC	VC	VB,MM,CL	IVB,RT,SSL,LL	IVB,RT,LL	St IVB,RT,LL	S	(59.44)
33	Ludhiana	FVC	VC	VC,MM,VB	IVB,LL	VB,IVB,RT	IVB,RT,LD	VS	(62.41)
34	NP 46-A	FVC	VC	IVB	IVB,MM,RT	IVB,RT,SSL	RT,SSL,IVB	S	(50.00)
35	Nyamati	Nil	VC	IVB,LD	IVB,LL,RT	IVB	VB,CL,RT,LL	S	(60.69)
36	Mysore selection	Nil	St	Nil	Twice inoculated No symptoms	VC,Dark leaves	Only VC	T	(3.73)
37	Pentha C-1 (Top)	FVC	VC	VB	VB,CL	VB,IVB	VB,LL	M	(40.93)
38	Perennial conical	Nil	Nil	Nil	St	St,MM	IVB,St	S	(50.61)
39	Pusa Jwala	Nil	FVC	VC,MM	VB,RT,CUPL,IVB	IVB,RT	IVB,RT	S	(58.41)
40	Puri red	VC	VC	IVB,RT	IVB,RT,WM	IVB,RT	LL,IVB,RT	S	(50.00)
41	Sankeshwar	FVC	VC	IVB	IVB,LD,St	VB,IVB,WM	RT,LL,St	VS	(61.38)
42	X 196	FVC	VC	IVB,CL	IVB,LL,RT,SSL	VB,IVB,RT,SSL	VB,LL,CL	VS	(64.40)
43	X 197	VC	VC	VB,RT	IVB,RT,SSL	IVB,RT,SSL	VB,RT	VS	(61.13)
44	X 200	FVC	VC,CL	VC,CL,LD,RT	IVB,RT,SSL,St	VB,IVB,RT,LD,St	LL,SSL,St	S	(55.12)
45	X 206	FVC	VC	IVB	IVB,LD,St	VB,IVB,WM,St,RT	LL,RT,St	VS	(61.51)
46	X 210	VC	VC,CL	VB,RT,WM	VB,IVB,RT,SSL	IVB,RT	VB,RT,LI	S	(57.91)

Note: CL = Chlorotic leaves
LD = Leaf disfortion
LL = Little leaves
MM = Mosaic mottle
mM = mild Mosaic
NL = Narrow leaves

RT(Rt) = Rat tailing of leaves
St = Stunted growth
VB = Vein banding
VC = Vein clearing
FVC = Faint vein clearing
IVB = Irregular vein banding

RLS = Reduction in leaf size
SSL = Shoe string leaves
CUPL = Cupping of leaves

PDI = Per cent disease index -
T = Tolerant = 1-20
M = Moderately susceptible = 21-40
S = Susceptible = 41-60
VS = Very susceptible = above 60

The results show that upto 30 days after inoculation in most of the genotypes symptoms were mild, and 30 days onwards upto 75 days, plants showed abnormal growth with distortion of leaves in some genotypes.

Genotype, Mysore selection showed faint vein-clearing even after second inoculation showing high tolerance. Genotypes viz., CA 1068, EC 27, EC 28 and Pentha C-1 showed consistently typical vein-banding symptoms till 90 days.

The genotypes, Byadgi Dabbi, CA 960, EC 127968, EC 127970, EC 137971, C-3, IC 13256, Line 7 Green Sel-2, Line 9 Green Sel-4, Line 11-Green Sel-6, Line 14 Green Sel-3, Line 15 Green Sel-4, X 196, X 197 and X 200 showed more filiform leaves and rat tailing after 30 days.

Line 5 Green Sel-1, Line 8 Green Sel-3, and Line 9 Green Sel-4 showed cupping of older leaves in addition to other symptoms.

Genotypes, Gulbarga local, EC 127968, EC 127970 and EC 127975 were stimulated to produce more axillary branches and appeared bushy.

Based on the leaf area the per cent disease index for each genotype was worked out. Based on the disease

index the varieties are classified into Tolerant, Moderately susceptible, susceptible and very susceptible, having the PDI 1-20, 21-40, 41-60 and 60 and above respectively. Genotype Pentha C-1 (Top), was found to be moderately susceptible and remaining were very susceptible and Mysore selection was found to be tolerant.

Effect on different growth parameters

This experiment was conducted to know the effect of infection by severe isolate of PVBV on different growth parameters like flowering time, height of plants, growth of stem, number of leaves green and dry weight of leaves, number of branches, number of fruits, length, green and dry weight of fruits, length, fresh and dry weight of roots.

The measurements of each parameters were made and presented as percentage variation in relation to appropriate healthy checks in each genotype (Table 22)(Fig.64).

i) Effect on flowering

Inoculated plants of different genotypes were observed upto flowering of the plants and data are presented in the Table 21.

From the Table, it is clear that in most of the genotypes there was delay in flowering of inoculated plants.

Table 21: Effect of seven isolates of PVBV on flowering of chilli genotypes after inoculation of one month old seedlings

Sl. No.	Genotypes	Delay or early over healthy plant (in days)	Sl. No.	Genotypes	Delay or early over healthy plant (in days)
1	Byadgi(Dabbi)	+ 6	25	LEC 28	+ 16
2	Byadgi(Kundagol)	+ 5	26	Line 5 Green Sel-1	+ 5
3	Capsicum chinense	+11	27	Line 6 Green Sel-2	+ 10
4	Chincholi	+13	28	Line 7 Green Sel-2	+ 9
5	Cluster chilli	+ 5	29	Line 8 Green Sel-3	+ 11
6	CA 960	+12	30	Line 9 Green Sel-4	+ 3
7	CA 1068	+ 3	31	Line11 Green Sel-6	+ 4
8	DH 7-6-6	+ 6	32	Line13 Green Sel-2	+ 2
9	EC 119981	+ 7	33	Line 15 Green Sel-4	+ 8
10	EC 127967	+ 8	34	NP 46-A	+ 6
11	EC 127968	+15	35	Nyamathi	+ 5
12	EC 127969	+ 5	36	Mysore selection	+ 3
13	EC 127970	+ 6	37	Pentha C-1 (Top)	+ 9
14	EC 127972	+ 2	38	Perennial conical	+ 13
15	EC 127974	0	39	Pusa Jwala	+ 3
16	EC 127975	+ 3	40	Sankeshwar	+ 7
17	EC 127977	+ 7	41	X 196	- 1
18	EC 137971	+ 4	42	X 197	+ 10
19	G - 3	+ 5	43	X 200	- 2
20	G -4	+ 1	44	X 206	+ 15
21	G -5	+ 4	45	X 210	+ 5
22	Gauribidanur	- 3		Average delay in flowering ..	6.74 Range = 1
23	Gulbarga local	+ 1			
24	LEC 27	+ 4		Average earliness in flowering .	2.00

Delay = +

Early = -

Table 22: Effect of severe isolate of PVBV on growth parameters of different Capsicum genotypes

Genotypes	Height		Girth		Number of leaves		Green weight of leaves		Dry weight of leaves		Number of branches		Number of fruits	
	D (cm)	O	D (cm)	O	D	O	D (g)	O	D (g)	O	D	O	D	O
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Byadgi (Dabbi)	57.40	40.82	2.24	37.08	162.2	66.03	9.66	80.00	2.48	66.03	11.20	50.90	2.00	93.46
2 Byadgi (Kundagol)	65.80	32.86	2.56	26.86	169.2	68.40	13.08	76.10	2.42	74.41	12.00	42.86	2.20	92.50
3 Capsicum Chinense	36.00	53.96	2.04	37.80	123.0	70.97	11.52	65.80	2.12	62.68	14.60	18.00	0.00	100.00
4 Chinchola	56.10	26.00	2.90	20.76	201.6	58.54	16.30	65.56	5.10	48.01	12.02	43.30	10.30	58.80
5 Cluster chilli	69.40	28.45	2.36	36.56	174.6	34.85	20.60	66.70	2.68	71.61	18.00	12.62	3.40	80.00
6 CA 960	69.80	39.93	2.82	26.56	426.2	41.13	33.78	48.21	4.04	65.23	23.40	5.64	3.20	89.94
7 CA 1068	78.00	19.75	2.40	21.57	264.6	49.70	30.80	34.60	4.72	40.70	26.20	16.96+	1.60	92.31
8 DH 7-6-6	45.60	34.50	2.20	36.78	129.6	71.34	8.94	79.50	1.60	77.14	9.60	43.52	0.00	100.00
9 EC 119981	66.00	29.50	2.58	25.00	196.6	59.51	14.74	69.00	2.86	68.22	12.00	52.00	0.20	98.94
10 EC 127967	84.00	20.60	3.02	13.71	378.4	18.41	26.96	33.80	3.98	43.63	23.20	43.21+	2.40	88.00
11 EC 127968	58.40	40.65	2.18	42.33	272.2	42.40	16.26	66.30	2.50	73.10	22.80	14.30	2.00	91.15
12 EC 127969	53.20	52.84	3.14	12.30	-	-	17.18	63.20	2.32	52.65	24.80	13.76+	4.80	76.23
13 EC 127970	52.00	53.15	2.32	43.00	295.6	39.30	10.10	83.50	2.16	71.87	20.00	3.85	2.00	91.80
14 EC 127972	49.20	32.42	2.68	14.10	198.4	33.00	14.64	66.87	2.52	63.37	16.60	31.96	2.60	87.62
15 EC 127974	45.80	50.54	3.04	11.11	-	-	-	-	-	-	17.40	35.10	3.40	83.33
16 EC 127975	52.80	52.52	2.44	28.65	146.4	59.60	11.96	65.13	2.10	66.23	16.80	37.31	0.60	97.30
17 EC 137971	45.60	52.90	2.26	33.13	156.8	52.80	6.82	80.93	1.38	74.06	17.20	16.21+	0.00	100.00
18 G-3	72.40	23.30	2.30	28.60	287.0	44.72	12.60	77.97	2.52	69.42	30.00	23.96+	2.60	87.96
19 G-4	84.60	27.32	2.86	17.34	331.8	37.00	18.12	64.87	3.26	46.20	23.40	0.90+	2.00	90.74
20 G-5	79.80	19.40	2.54	27.01	417.0	29.23	19.38	65.60	3.40	50.87	24.00	6.20+	5.00	76.63
21 Gouribidanur	51.80	33.07	2.62	18.63	312.4	35.80	16.44	60.60	2.68	59.88	17.20	11.68+	4.80	83.22
22 Gulbarga local	97.60	8.61	2.80	11.40	363.6	26.87	23.30	55.00	3.30	56.00	20.80	14.75	3.60	85.83
23 LLC 27	77.40	23.82	3.26	15.54	224.2	74.07	19.06	73.40	3.98	65.63	19.80	33.11	0.60	97.22
24 LLC 28	92.80	17.60	2.30	13.53	373.0	22.50	27.54	42.62	5.30	16.70	22.00	13.54+	1.00	94.44
25 Line 5 Green Bel-1	89.40	8.60	2.60	17.20	282.0	37.33	18.42	59.81	2.82	47.39	17.40	25.00	4.80	79.66

Table 22-(Contd.)

	Genotypes	Green weight of fruits		Dry weight of fruits		Average length of fruits		Root length		Fresh root weight		Dry weight of roots	
		D (g)	O	D (g)	O	D (g)	O	D (g)	O	D (g)	O	D (g)	O
	1	16	17	18	19	20	21	22	23	24	25	26	27
1	Byadgi (Dabbi)	3.08	90.78	0.90	87.33	8.50	42.69	26.40	20.00	8.44	71.92	2.06	57.30
2	Byadgi (Kundagol)	2.50	94.74	0.10	98.33	8.60	43.90	28.00	30.00	12.10	45.25	1.54	77.70
3	Capsicum (Chinese)	0.00	100.00	0.00	0.00	0.00	0.00	22.20	33.13	6.06	73.54	1.28	69.81
4	Chinchola	6.37	86.24	2.33	71.92	5.60	63.50	23.00	28.79	10.98	43.26	3.40	40.70
5	Cluster Chilli	4.18	73.93	0.56	89.23	9.60	27.55	26.40	20.00	6.74	77.38	1.32	76.92
6	CA 960	2.74	89.22	0.40	93.81	8.60	18.10	32.20	22.97	9.52	73.80	5.84	46.91
7	CA 1068	1.82	89.86	0.22	91.97	8.50	14.60	27.60	23.76	7.06	71.14	2.28	43.56
8	DH 7-6-6	0.00	100.00	0.00	100.00	0.00	100.00	23.60	29.76	9.00	59.60	1.02	79.92
9	EC 119981	0.20	99.15	0.04	99.20	7.30	21.10	23.00	33.30	7.52	74.06	1.98	69.72
10	EC 127967	3.50	82.50	0.60	87.60	6.00	57.14	26.20	30.70	10.58	62.35	2.52	30.77
11	EC 127968	4.20	85.66	0.64	86.90	5.30	18.46	25.46	29.83	5.18	82.07	1.50	74.22
12	EC 127969	0.00	100.00	0.00	0.00	0.00	0.00	25.00	25.60	13.40	59.44	2.12	40.11
13	EC 127970	0.98	98.40	0.20	99.20	7.30	23.80	21.80	36.26	6.08	82.91	1.08	84.34
14	EC 127972	0.00	100.00	0.00	0.00	0.00	100.00	24.00	32.96	6.80	75.10	1.70	46.54
15	EC 127974	0.00	100.00	0.00	0.00	-	-	34.00	18.70	20.82	42.17	3.24	61.06
16	EC 127975	0.30	99.44	0.10	99.00	6.00	38.46	24.80	41.51	6.24	76.45	1.00	81.75
17	EC 137971	0.00	100.00	0.00	0.00	0.00	100.00	23.20	26.11	4.96	84.57	1.16	67.04
18	G - 3	2.30	88.51	0.30	89.30	10.60	27.65	26.40	18.52	7.30	72.50	1.46	63.32
19	G - 4	2.42	87.50	0.44	88.60	8.10	36.62	28.20	22.53	8.56	76.65	2.42	47.60
20	G - 5	5.98	81.68	0.86	90.13	5.70	26.00	29.60	17.32	8.22	73.22	2.02	48.73
21	Gouribidanur	3.86	92.04	0.58	90.96	6.60	25.84	25.00	30.93	8.44	66.24	2.22	60.10
22	Gulbarga local	8.10	79.03	1.02	82.04	8.70	36.17	28.80	20.44	10.02	74.97	3.12	35.54
23	LEC 27	0.42	98.23	0.00	98.63	6.50	30.70	26.60	21.76	14.74	48.10	3.48	29.55
24	LEC 28	1.20	94.26	0.24	93.41	7.50	41.86	33.40	18.14	6.84	74.19	1.62	50.31
25	Line 5 Green Sel-1	6.54	72.17	1.22	75.90	14.90	9.70	26.80	21.64	8.36	78.99	2.46	72.04

Table 22 - (Contd.)

	1	16	17	18	19	20	21	22	23	24	25	26	27
26	Line 6 Green Sel-2	7.56	76.55	1.50	77.54	10.90	1.11+	27.40	19.41	12.22	64.30	2.66	66.91
27	Line 7 Green Sel-2	3.55	88.67	0.68	90.53	3.30	30.33	29.00	11.04	12.32	73.67	1.48	80.80
28	Line 8 Green Sel-3	5.62	86.63	0.86	78.40	11.20	15.18	25.00	22.36	4.82	87.60	0.84	84.21
29	Line 9 Green Sel-4	6.82	64.55	1.06	75.60	13.30	10.44	28.60	15.40	9.18	78.11	2.86	47.00
30	Line 11 Green Sel-6	7.72	64.70	1.26	57.72	10.70	21.21	29.40	22.22	12.68	66.65	2.58	49.21
31	Line 13 Green Sel-2	6.50	70.90	1.30	65.05	12.00	3.85	23.00	36.11	5.00	82.91	1.38	63.30
32	Line 14 Green Sel-3	9.58	75.14	-	-	10.00	19.55	26.00	30.11	12.54	72.80	-	-
33	Line 15 Green Sel-4	4.08	78.75	1.70	61.36	12.00	22.23	25.60	23.35	10.40	73.40	0.80	69.70
34	NP 46-A	6.80	71.30	3.97	31.70	8.10	11.00	29.00	11.31	19.80	20.50	3.20	55.55
35	Nyamathi	1.62	93.00	2.18	39.44	3.30	46.30	29.40	16.95	13.12	51.26	0.36	88.43
36	Mysore selection	50.52	14.10	6.16	21.02	3.80	28.34	34.80	17.92	26.56	58.52	9.40	32.66
37	Pentha C-1 (Top)	29.20	70.63	3.24	31.35	13.00	16.02	29.60	30.20	19.48	42.70	4.18	77.81
38	Perennial conical	3.40	81.66	5.84	6.45	4.00	61.90	31.60	22.17	18.66	57.00	0.40	84.85
39	Pusa Jwala	8.30	76.30	2.30	46.51	7.70	48.01	25.53	31.55	15.67	38.06	2.60	16.13
40	Sankeshwar	5.23	89.82	2.12	70.90	5.30	70.00	26.50	30.81	11.68	37.97	1.78	75.62
41	X 196	7.70	81.10	2.70	38.10	9.80	22.10	33.40	25.11	15.44	61.97	1.56	79.94
42	X 197	3.50	81.00	3.44	10.00	10.10	10.85	28.20	15.06	13.66	66.37	0.54	83.02
43	X 200	7.10	72.31	1.46	61.60	11.10	5.53	26.60	23.56	10.18	71.88	1.04	66.23
44	X 206	2.79	92.36	1.30	78.90	9.00	15.33	24.60	28.07	6.44	78.46	0.34	94.09
45	X 210	3.80	84.96	2.12	50.70	9.50	27.65	25.00	34.90	8.86	66.56	0.56	88.30
46	GM	5.67		2.27		..		27.08		10.25		0.96	
47	Genotypes	**		**		**		**		**		**	
48	SEM	5.40		0.74		0.52		2.54		3.69		0.88	
49	C.D. at 5%	10.59		1.45		1.02		4.98		7.24		1.73	
50	C.D. at 1%	13.92		1.91		1.34		6.55		9.52		2.28	

Table 22 - (Contd.)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
26	Line 6 Green Sel-2	79.60	30.66	2.76	19.77	224.2	65.70	18.66	71.50	3.66	65.92	16.20	39.10	7.60	67.52
27	Line 7 Green Sel-2	75.20	15.51	2.60	31.60	428.6	4.45	31.50	41.32	5.12	44.60	24.40	52.50^{+}	3.80	74.70
28	Line 8 Green Sel-3	73.80	28.21	2.34	33.52	272.2	49.70	19.46	71.25	2.76	73.51	23.20	20.00	4.60	82.60
29	Line 9 Green Sel-4	87.40	9.71	2.94	19.67	513.2	26.90	24.50	58.41	4.08	49.25	22.60	11.90^{+}	3.80	81.55
30	Line 11 Green Sel-6	74.60	23.72	2.68	11.26	339.8	30.73	17.18	66.30	3.92	41.84	21.00	6.06^{+}	6.40	73.33
31	Line 13 Green Sel-2	59.20	44.15	2.76	21.14	231.2	25.32	13.96	63.32	2.36	65.60	15.40	5.00	5.80	73.63
32	Line 14 Green Sel-3	76.40	28.60	2.95	13.24	413.0	21.60	30.14	48.90	-	-	18.60	28.50	6.20	81.76
33	Line 15 Green Sel-4	68.00	37.15	2.48	20.52	341.4	31.30	22.90	51.52	3.58	30.10	33.80	30.00^{+}	3.80	81.90
34	NP 45-A	56.30	6.50	3.10	0.00	312.3	39.00	26.87	38.60	5.40	43.75	20.60	1.50^{+}	16.00	37.50
35	Nyamati	78.40	5.08	2.76	17.86	191.8	54.65	16.42	60.99	2.74	55.81	23.8	3.25	2.00	90.70
36	Mysore selection	101.80	8.00	3.26	17.67	334.0	37.75	45.32	52.50	7.16	57.12	16.0	20.80	51.60	15.41
37	Pentha C-1 (Top)	98.00	3.54	2.66	19.88	194.8	52.00	21.78	46.80	3.38	57.54	18.20	12.50	17.20	68.03
38	Perennial conical	76.20	28.40	3.06	5.55	175.4	63.88	17.48	58.73	4.04	38.78	9.60	44.82	3.80	85.71
39	Pusa Jwala	75.90	11.02	3.10	18.42	231.8	52.98	20.37	57.80	3.30	49.23	25.30	18.80^{+}	12.00	62.85
40	Sankeshwar	63.31	20.86	3.10	16.90	157.8	72.96	14.02	74.70	3.69	64.17	10.00	56.51	6.00	81.82
41	X 196	62.00	41.30	2.40	24.05	162.6	52.82	14.34	71.40	2.20	71.72	12.60	38.25	3.20	85.84
42	X 197	89.00	15.10	2.86	16.86	426.2	34.21	21.24	62.10	3.64	56.70	41.20	71.66^{+}	3.00	85.85
43	X 200	81.80	21.95	2.41	28.00	343.6	37.75	28.46	51.15	4.24	58.27	23.20	0	8.20	71.91
44	X 206	54.40	44.38	2.20	32.93	513.4	45.30	16.82	81.34	2.58	79.36	24.80	2.36	3.40	84.95
45	X 210	78.80	29.64	2.52	35.05	273.6	47.54	30.50	46.90	4.26	60.92	24.80	12.72^{+}	3.40	84.26
46	GM	70.56		2.62		285.7		20.23	-	3.34		20.24	-	4.61	-
47	Genotypes	**		**		**		**		**		**		**	
48	SEM	11.21		0.23		93.57		6.26		1.07		4.31		3.32	
49	CD at 5%	21.98		0.46		183.41		12.27		2.10		8.45		6.52	
50	CD at 1%	28.89		0.61		241.05		16.13		2.73		11.11		8.56	

Note: ** = 1 per cent level significant

NS = Non-significant
D = Inoculated actuals
O = Per cent reduction over healthy
+ = Increase over healthy

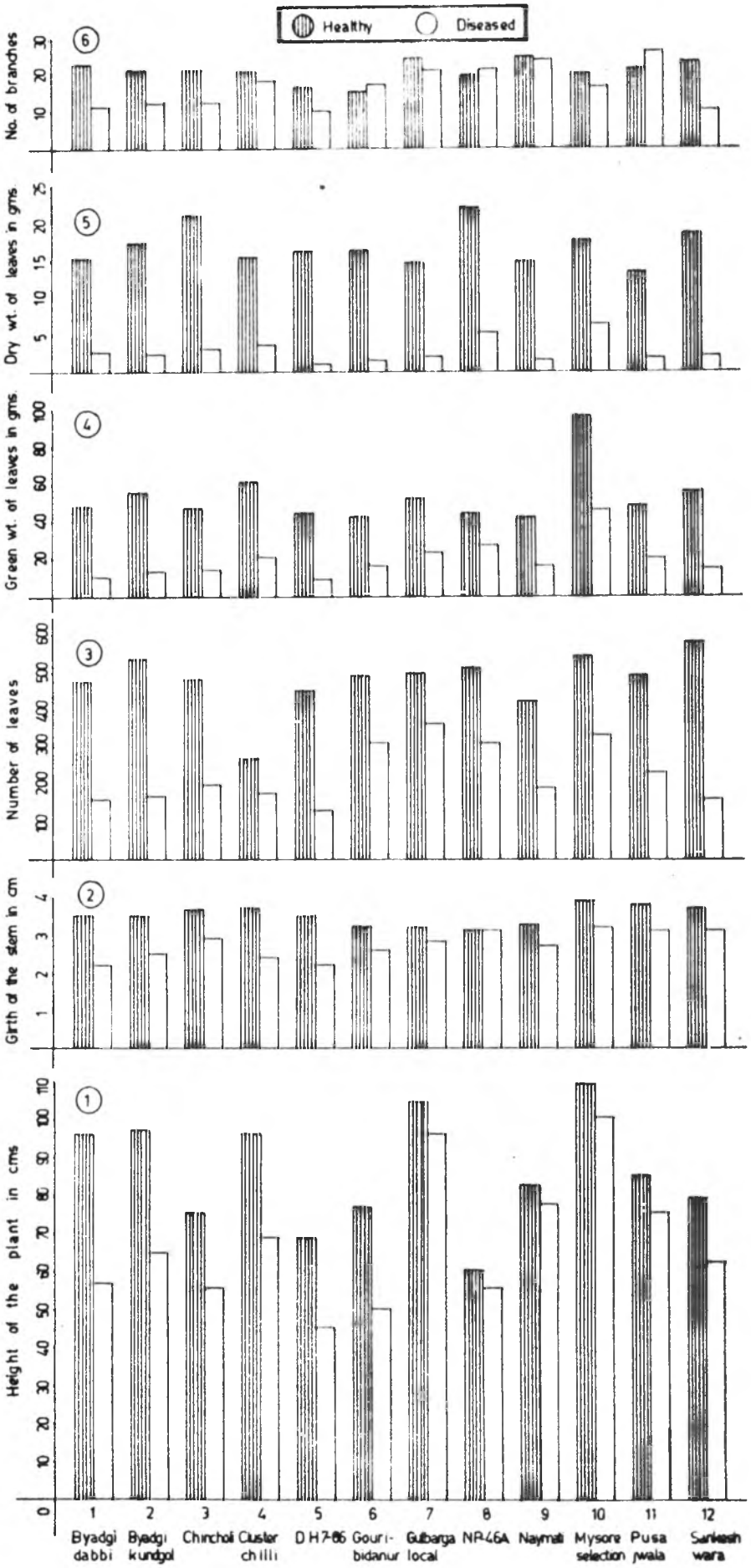


FIG. 64. EFFECT OF SEVERE STRAIN OF PVBV ON GROWTH PARAMETERS PER PLANT ON 12 CULTIVARS

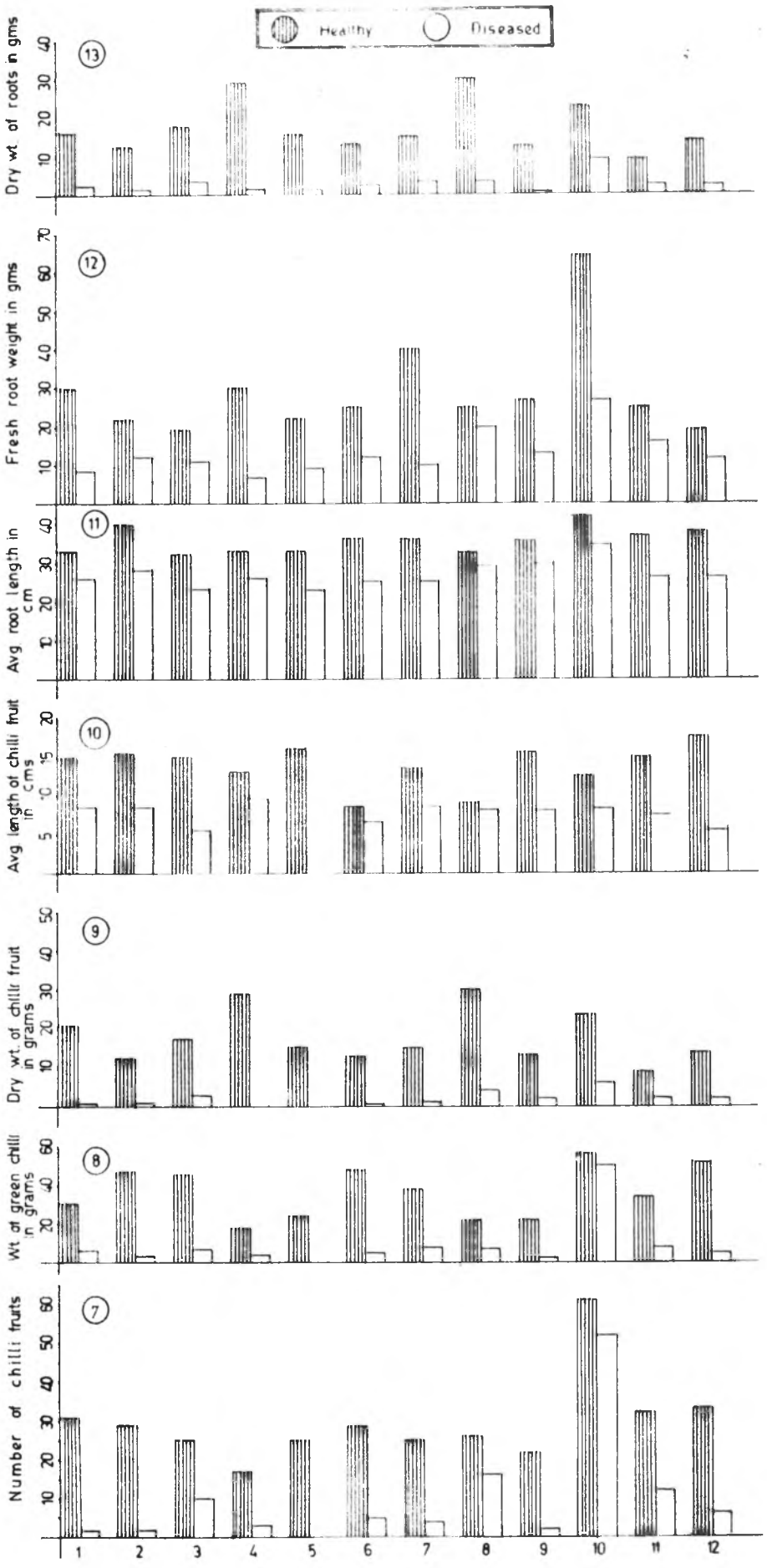


FIG 64. (Continued)

Delay in flowering was from 1-16 days. On an average 6.74 days delay in flowering was observed in most of the genotypes.

Genotypes, CA 960, Chincholi, EC 127968, LEC 28, Line 6 Green Sel-2, Line 8 Green Sel-3, Perennial Conical and X 206 the flowering was delayed by 10-16 days. However, in Gouribidanur, X 196 and X 200 there was 1-3 days earliness in flowering was noticed.

2) Effect on height of the plants

The height of the inoculated genotypes was measured after 90 days of inoculation. An per cent reduction over healthy was calculated and presented in the Table 22. All the cultivars varied significantly in most of the characters. The statistical analysis showed that the genotype, EC 127970 showed the highest (53.13 per cent) reduction in height. The least reduction of 3.54 per cent was observed in Pentha C-1 (Top), Mysore selection, NP 46A and Nyamati. The genotypes, Byadgi Dabbi, Capsicum chinense, EC 127968, EC 127969, EC 127970, EC 127974, EC 127975 and EC 137971 showed more than 50 per cent reduction in their height due to infection (Fig.65).

3) Effect on girth of stem

Table 22 shows that all the genotypes varied significantly. Genotype EC 127968 showed maximum reduction

(42.33 per cent) in its girth differing significantly from the others. The least reduction was in perennial conical (5.5 per cent). Genotypes viz., Byadgi Dabbi, EC 127968, EC 127970, EC 127971, DH 7-6-6, Line 7 Green Sel-2, Line 8 Green Sel-3, X 206 and X 210 showed more than 30 per cent reduction in their stem girth differing significantly from others.

4) Effect on number of leaves

Here also all the genotypes differed significantly in the production of number of leaves due to infection. Genotype, LEC 27 showed maximum reduction (74.07 per cent) in number of leaves. Line 7 Green Sel-2 showed least reduction of 4.4 per-cent only.

5) Effect on green weight of leaves

The statistical analysis showed significant reduction in the green weight of leaves in most of the genotypes. EC 127970 showed maximum reduction (83.5 per cent) in its green weight of leaves significantly differing from the others. EC 127967 showed least reduction (33.0 per cent) in its green weight of leaves. In most of the genotypes, severe isolate of PVBV significantly reduced the green weight by more than 50 per cent.

6) Effect on dry weight of leaves

Statistical analysis of the data showed that genotype LBC 28 showed 16.7 per cent reduction which is least affected than other genotypes. Maximum reduction in dry weight was in X 206 (79.36 per cent) followed by DH 7-6-6 (77.14 per cent) which differ significantly from the others. However, there was more than 60 per cent reduction in dry weight of leaves in most of the genotypes.

7) Effect on number of branches

The severe isolate of PVBV significantly reduced, the number of branches in most of the genotypes. Sankeshwar showed significantly greater reduction (56.44 per cent) in the number of branches than the others. There was no reduction in the number of branches in X 200.

In some genotypes there was stimulation to produce more number of branches. Genotype X 197, showed maximum increase (71.66 per cent) in number of branches. G-4 showed only 0.9 per cent increase in the number of branches.

8) Effect on number of fruits

The severe isolate completely inhibited the production of fruits in DH 7-6-6 and EC 119981. Mysore selection showed least reduction of 15.41 per cent in the number of fruits.

In most of the genotypes the reduction in number of fruits was significantly more than fifty per cent.

9) Effect on green weight of fruits

It can be seen from data that in all the genotype there was significant reduction in green weight of fruits and the genotypes differed significantly from each other. Genotype, EC 127975 (99.44 per cent) showed maximum reduction in its green weight of fruits and least reduction was found in Mysore selection (14.1 per cent). Generally the severe isolate reduced the green weight of fruits by more than 70-80 per cent.

10) Effect on dry weight of fruits

There was maximum reduction of dry weight of fruits in the genotypes EC 119981 (99.2 per cent), EC 127970 (99.2 per cent), EC 127975 (99.0 per cent), LEC 27 (98.63 per cent), LEC 28 (93.41 per cent), and Line 7 Green Sel-2 (90.53 per cent).

Least reduction in dry weight, was noticed in Pusa Jwala (16.13 per cent) and Mysore selection (32.66 per cent). By seeing the Table,it is clear that there was generally 60-70 per cent reduction in dry weight of fruits in most of the inoculated genotypes compared to their healthy controls.

11) Effect on length of fruits

Here also there was significant reduction in the length of fruit in most of the genotypes. Sankeshwar showed maximum reduction of 70 per cent in length of the fruits significantly differing from the other genotypes. The genotype Line 13 Green Sel-2 showed least reduction of 3.85 per cent in fruit length followed by Nyamathi, Mysore selection, Perennial Conical and Pentha C-1 (Top).

12) Effect on root length

The genotype, EC 127975 showed significant reduction of 41.5 per cent in its root length. Line 7 Green Sel-2 showed least reduction of 11.04 per cent (Fig.66).

13) Effect on fresh weight of root

All the genotypes differed significantly in their reaction to the severe isolate in fresh weight. There was maximum reduction in fresh weight of root in genotype, Line 8 Green Sel-3 (87.6 per cent) significantly more than in others. NI 46-A showed least reduction in its fresh root weight, of 20.50 per cent. In general, in all the genotypes, this isolate significantly reduced the fresh root weight by more than 60 per cent over the control.

Fig. No. 65. Five *Capsicum annuum* cultivars showing mosaic mottling and stunting on inoculation with severe strain of PVBV

Cultivars from left to right

1. EC 137971
2. Byadgi Dabbi
3. X 196
4. Pentha C-1(Top)
5. Mysore Selection

Fig. No. 66. Five *C. annuum* cultivars showing roots stunting on inoculation with severe strain of PVBV compared with healthy ones

Cultivars from left to right

1. EC 137971
2. Byadgi Dabbi
3. X 196
4. Penth C-1(Top)
5. Mysore Selection

Fig.65

Fig.66

14) Effect on dry weight of roots

Table 22 shows that all genotypes varied significantly. Among these, the virus had least effect on Perennial Conical (6.45 per cent) and differed significantly from the others. Genotypes, Mysore selection (21.02 per cent) and NP 46-A (31.7 per cent) showed least reduction in dry weight of roots. Generally there was more than 40 per cent reduction in dry weight of roots in most of the genotypes.

13) EPIDEMIOLOGY

A) Population dynamics of different aphid species and aphid vectors on Hebbal Farm

Since most of the viruses studied are known to be transmitted by aphids, in order to know the prevalence of different aphid species and aphid vectors on Hebbal farm, aphids were trapped daily and collected once in five days from 17th March, 1980 to 12th March 1981. A modified funnel trap (Fig.4 and 5) was used to trap the aphids. Different aphids were identified and counted, population of individual species are presented in Table 23 (Fig.67).

In the period of collection, thirty two different aphid species were encountered on the farm. Population of Aphis craccivora was maximum followed by A.gossypii, Aphis spp.,

Table 23: Population dynamics of different aphids on Hebbal farm during 1980-81

Sl. No.	Name of the aphids	17-3-80	22-3-80	27-3-80	1-4-80	6-4-80	11-4-80	16-4-80	21-4-80	26-4-80	1-5-80	6-5-80	11-5-80	16-5-80	21-5-80	26-5-80	31-5-80	5-6-80	10-6-80	15-6-80	20-6-80	25-6-80	30-6-80	5-7-80	10-7-80	15-7-80	20-7-80	25-7-80	30-7-80	5-8-80	10-8-80	15-8-80	19-8-80	24-8-80	29-8-80	3-9-80	8-9-80	13-9-80	18-9-80	23-9-80	28-9-80
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32	32	33	34	35	36	37	38	39	40	41	42
1	Aphis craccivora Koch	0	0	0	0	0	2	3	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	4	1	1	4
2	Aphis gossypii Complex	4	1	0	0	5	1	0	0	0	0	3	3	0	2	0	0	0	1	2	3	2	1	0	1	0	0	1	3	0	1	1	1	0	0	1	1	2	3	2	0
3	Aphis spp.(unidentified	0	0	0	2	10	0	13	6	2	2	0	0	0	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	0	2	0	0	0	2	3	1	1
4	Aphis fabae Complex	0	1	2	2	0	0	2	0	0	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	2	3	2
5	Myzus persicae (Sulzer)	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
6	Aphis spiraecola Patch	0	0	0	7	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Myzocallis polychaetus David	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Rhopalosiphum maidis (Fitch)	0	0	0	0	4	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Rhopalosiphum padi (L.)	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
10	Aphis kurosuwai Takahashi	4	1	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
11	Tetraneura nigriabdominalis(Sasaki)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	2	1	0	0
12	Hydaphis coriandri Das	0	1	1	0	1	1	4	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Rhopalosiphum rufiabdominalis(Sasaki)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Melanaphis sacchari(Zehntner)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
15	Hysteroneura setariae(Thomas)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Rhopalosiphoma ampullata bengalensis Basu	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Aphis nerii B.d.F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Myzus spp.(unidentified)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	Brevicoryne brassicae(L.)	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	Thereaphis trifolii(Monell)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Tinocallis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Contd

Table 23 (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
22	Toxoptera citricidus (Kirkaldy)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Toxopteru aurantii B.d.F.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Rhopalosiphum spp.(Unidentified)	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Aphis nasturtii Kaltenbach	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	Rhopalo siphum nymphaeae (L.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	Neomyzus circumflexus(Buckton)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
28	Hyalopterus pruni Geoffroy	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	Greenidea (Greenidea) artocarpi (Westwood)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
30	Dactynotus (Uromelan) compositae Theobald)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	Hormaphidinae (Unidentified)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	Unidentified aphids	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
33	Total collections	8	5	5	16	29	7	25	9	2	14	7	3	0	2	0	0	0	6	2	4	3	2	2	1	0	0	1	4	0	1	4	1	2	4	2	11	12	12	11	7

Table 23 - (Contd.)

1	2	3-10-80	8-10-80	13-10-80	18-10-80	23-10-80	28-10-80	2-11-80	7-11-80	14-11-80	17-11-80	22-11-80	27-11-80	1-12-80	6-12-80	11-12-80	16-12-80	21-12-80	26-12-80	31-12-80	5-1-81	10-1-81	15-1-81	21-1-81	25-1-81	30-1-81	5-2-81	10-2-81	15-2-81	20-2-81	25-2-81	2-3-81	7-3-81	12-3-81	TOTAL
		43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
1	Aphis gracoivora Koch	0	0	0	0	3	0	1	8	0	12	15	20	3	0	1	1	0	2	1	0	0	2	0	8	0	2	0	3	0	0	2	5	0	116
2	Aphis gossypii Complex	2	0	0	0	0	0	0	0	2	7	7	7	0	3	0	1	0	2	1	0	0	1	1	6	0	0	1	6	3	0	0	0	0	95
3	Aphis spp. (Unidentified)	0	0	0	0	0	0	0	1	0	1	3	1	1	0	0	0	0	0	1	0	0	1	2	0	0	1	0	0	0	1	0	0	3	64
4	Aphis fabae Complex	0	1	0	0	0	0	0	3	2	5	7	1	0	0	2	0	0	5	0	0	0	0	0	1	0	2	2	0	0	0	0	0	0	58
5	Myzus persicae (Sulzer)	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	6	12	2	0	31
6	Aphis spiraecola Patch	0	0	0	0	0	0	0	0	0	6	4	0	0	1	0	0	0	5	1	0	0	0	2	0	0	0	1	0	0	0	0	0	0	30
7	Myzocallis polychaetus David	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	4	10	2	0	0	0	0	20
8	Rhopalosiphum maidis (Fitch)	0	0	2	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	17
9	Rhopalosiphum padi (L.)	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	15
10	Aphis kurosawai Takahashi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
11	Tetraneura nigriabdominalis (Sasaki)	0	0	2	0	1	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
12	Hydaphis coriandri Das	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
13	Rhopalosiphum rutiabdominalis (Sasaki)	0	0	0	0	0	0	0	0	0	0	0	1	2	3	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	10
14	Melanaphis sacchari (Zehntner)	0	0	0	0	0	0	0	0	0	5	0	1	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	9
15	Hysteroneura setariae (Thomas)	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	2	7
16	Amphorophora ampullata bengalensis Basu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5
17	Aphis nerii B.d.F.	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	5
18	Myzus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4
19	Brevicoryne brassicae (L.)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
20	Thereoaphis trifolii (Monell)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	3
21	Tinocallis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3

Table 23 - (Contd.)

1	2	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
22	Toxoptera citricidus (Kirkaldy)	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
23	Toxoptera aurantii B.d.F.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
24	Rhopalosiphum spp.(Unidentified)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
25	Aphis nasturtii Kaltenbach	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
26	Rhopalosiphum nymphaeae (L.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
27	Neomyzus circumflexus (Buckton)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
28	Hyalopterus pruni (Geoffroy)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
29	Greenidea (Greenidea)artocarpi(Westwood)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
30	Dactynotus (Uromelan)compositae(Theobald)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
31	Hormaphidinae (Unidentified)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
32	Unidentified aphids	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
33	Total collections	2	1	4	9	7	0	2	12	5	41	44	36	12	14	4	5	0	16	5	2	3	6	5	19	0	6	9	20	5	7	18	7	8	550

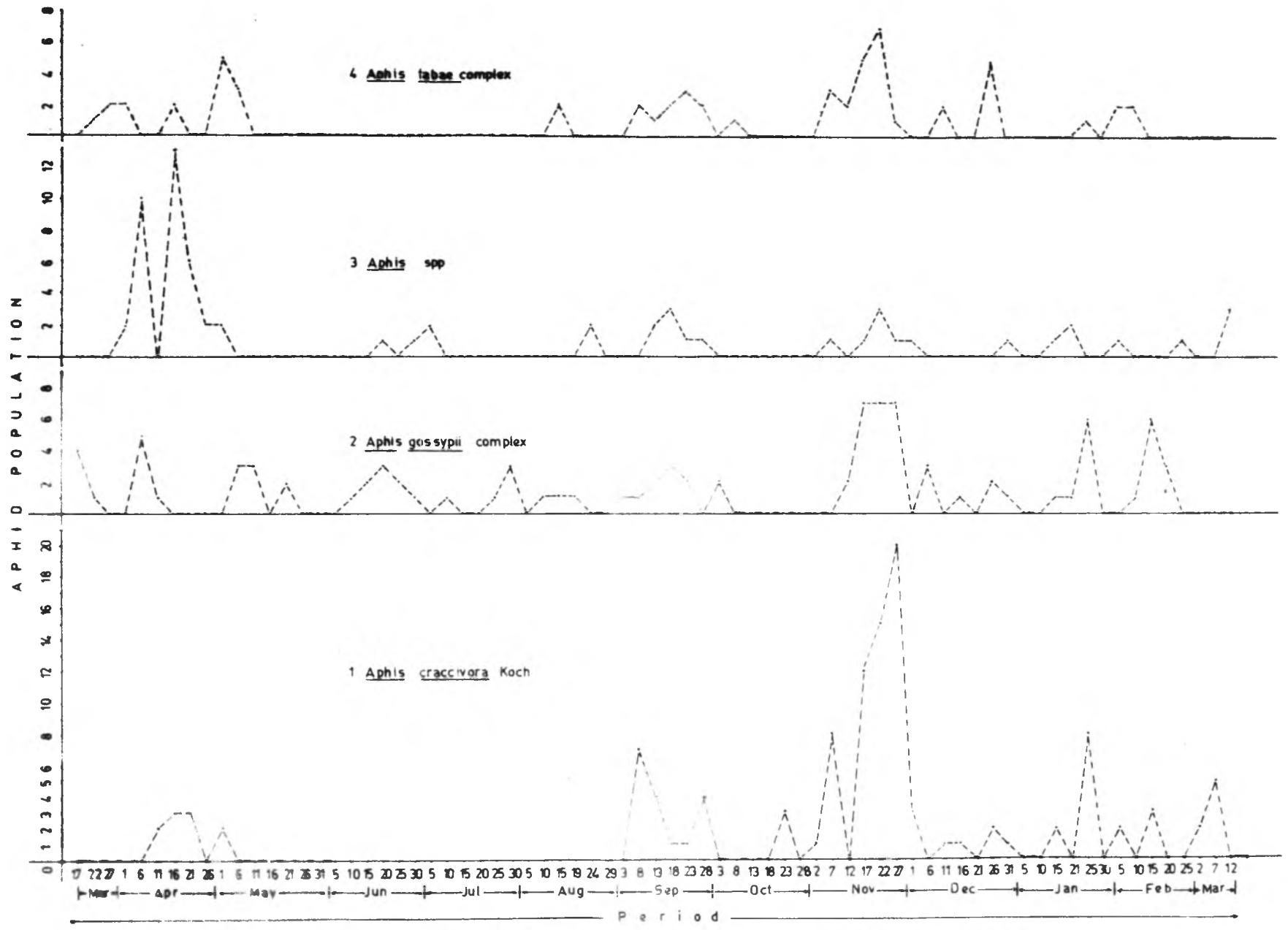


FIG. 67 POPULATION DYNAMICS OF DIFFERENT APHID SPECIES ON HEBBAL FARM DURING 1980 – 81

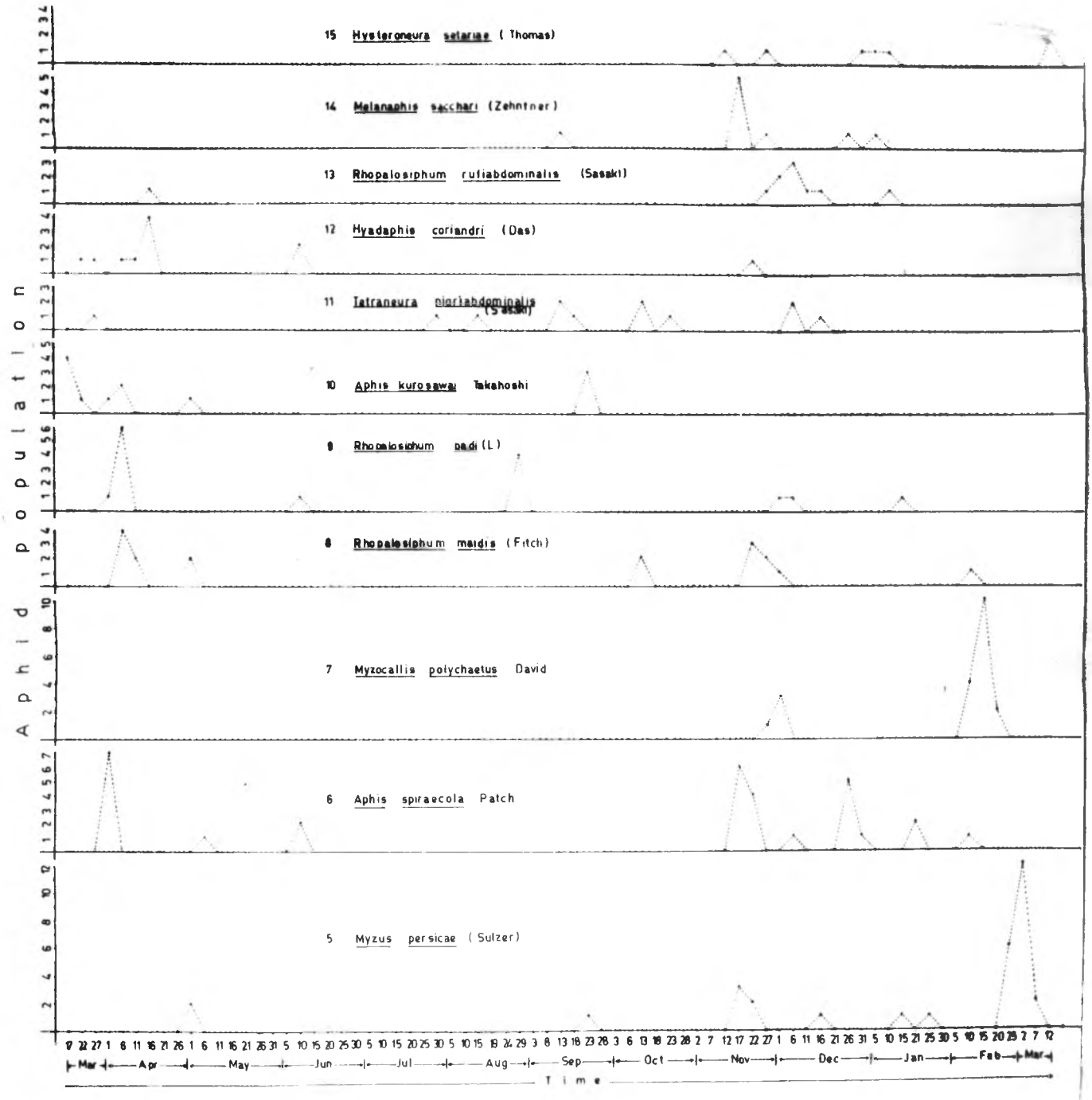


FIG. 67 (Continued)

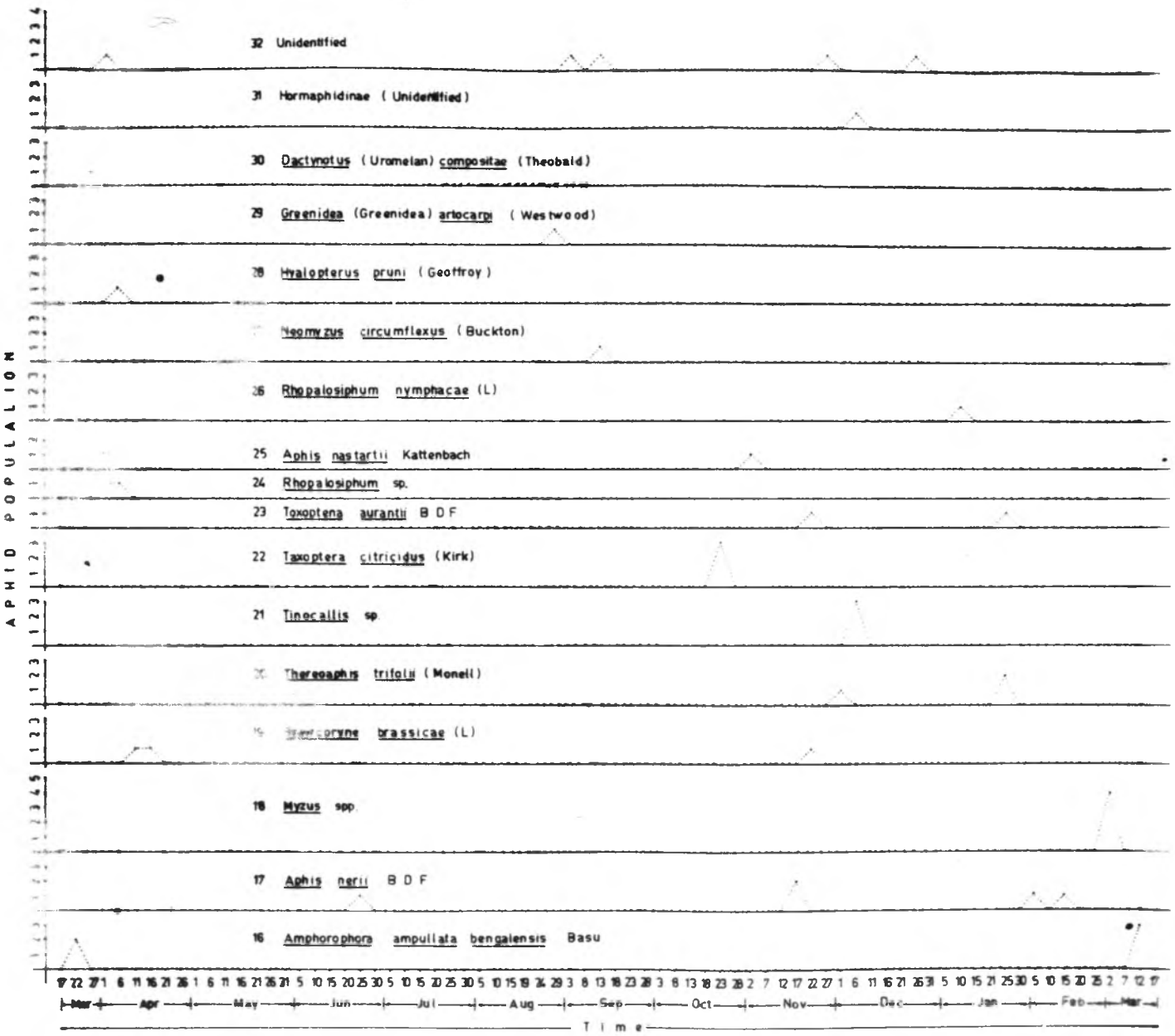


FIG. 67 (Continued)

A.fabae, Myzus persicae, A.spiraecola and Myzocallis polychaetus and others as presented in the Table 23.

Aphids viz., Rhopalosiphum nymphaeae, Neomyzus circumflexus, Hyalopterus pruni, unidentified Hormaphidinae, Greenidea (Greenidea) artocarpi (West Wood), and Lactynotus (Uromelan) compositae Theobald were trapped one individual each in a year.

From the Table, it is clear that the flight of A.craccivora could be seen from 8th September to 1st May. Its flight was absent during May to August 1980. Its maximum flight was during November 1980. Population of A.gossypii was uniform through out the year and showed maximum population during November to March. Aphis fabae was observed through out the year but it was absent between 11th May and 10th August.

Population of Myzus persicae was completely absent from 1st May to 23rd September 1980. Otherwise its flight was observed throughout the period though irregular. In most of the aphids, peak period of flight was during the months of November, March and April of 1980.

From the collected aphid species aphid vectors of plant viruses were separated based on latest references

made by Carter (1973), Mandahar (1978) and Maramorosch (1969). The data presented in the Table 24, depicts that seventeen aphid species out of the collections, are known to be the vectors of plant viruses.

Among the vectors, maximum population was that of A.craccivora followed by A.gossypii, A.fabae, M.persicae, A.spiraecola, Rhopalosiphum maidis, R.padi, Hydaphis coriandri, Hysteroneura setariae, A.nerii, Brevicoryne brassicae, Toxoptera citricidus, T.aurantii, A.nasturtii, R.nymphaeae, Neomyzus circumflexus and Hyalopterus pruni.

Among these vectors, M.persicae has been reported to be the first in transmitting maximum number of plant viruses followed by A.fabae, N.circumflexus, A.gossypii, B.brassicae, A.craccivora, A.nasturtii, R.maidis, A.spiraecola and others (Table 24). On Hebbal farm, CMV, PVMV, PVY, TEV and PVBV were found on Capsicum cultivars.

The collected aphids at five day interval were again classified in to total number of aphids, aphid vectors of plant viruses, and vectors of chilli viruses and important individual aphid vectors reported so far, are presented in Table 25.

Weather data regarding rainfall, minimum and maximum temperature, relative humidity at 07.20 hr and 14.20 hr,

Table 24: Aphid vectors of different plant viruses on Hebbal farm during 1980-81
(Arranged in decreasing order of aphid population trapped)

Sl. No.	Aphid	Plant viruses transmitted
1	2	3
1	Aphis cracoivora Koch	Chilli mosaic, citrus tristeza, Cucumber mosaic, groundnut mosaic, groundnut rosettae, maize dwarf mosaic, Pepper veinal mottle virus, potato virus-Y, soyabean mosaic.
2	Aphis gossypii Complex	Bean mosaic, chilli mosaic, corn mosaic, cucumber mosaic, cauli flower mosaic, groundnut rosettae, lily rosette, maize dwarf mosaic, onion yellow dwarf, passiflora chlorotic spot, pepper vein banding, pepper veinal mottle, potato virus-Y, sweet potato mosaic, tobacco etch.
3	Aphis fabae Scop	Bean common mosaic, bean yellow mosaic, beet mosaic, beet yellow, broad bean mottle, cabbage black ring spot, cauliflower mosaic, celery mosaic, cowpea mosaic, cucumber mosaic, lucern mosaic, onion yellow dwarf, potato virus-Y, soybean mosaic, Tobacco etch, tulip breaking, turnip mosaic.
4	Myzus persicae (Sulzer)	Bean common mosaic, bean yellow mosaic, beet mosaic, beet yellows, broad bean mottle, cabbage black ring spot, cauliflower mosaic, cowpea mosaic, cucumber mosaic, Dahlia mosaic, hanbane mosaic, lettuce mosaic, lucern mosaic, maize dwarf mosaic, maize mosaic, pea enation mosaic, pea mosaic, pea-mottle, pepper vein banding, potato acuba mosaic, potato leaf roll, potato virus-A, Potato virus-Y, radish mosaic, soybean mosaic, sugarcane mosaic, tomato aspermy virus, tobacco etch, tulip breaking, turnip yellow mosaic, turnip mosaic, water-melon mosaic.

Table 24 - (Cont.)

1	2	3
5	Aphis spiraecola Patch	Bean common mosaic, papw mosaic, peanut stunt, pepper veinal mottle, potato virus-Y, tobacco etch.
6	Rhopalosiphum maidis (Fitch)	Barley yellow dwarf, bean yellow mosaic, maize dwarf mosaic, maize mosaic, onion yellow dwarf, pepper veinal mottle, sugarcane mosaic.
7	Rhopalosiphum padi (L.)	Barley yellow dwarf, maize dwarf mosaic, potato virus-Y
8	Hydophis coriandri (Das.)	Beet mosaic, cauliflower mosaic
9	Hysteroneura setariae (Thomas)	Onion yellow dwarf, pepper veinal mottle, sugarcane mosaic
10	Aphis nerii B.D.F.	Chilli mosaic, potato virus-Y, sugarcane mosaic
11	Brevicoryne brassieae (L.)	Bean common mosaic, bean yellow mosaic, beet mosaic, cabbage black ring spot, cabbage virus-B, cauliflower mosaic, cucumber mosaic, maize dwarf mosaic, onion yellow dwarf, potato virus-Y, radish mosaic, turnip mosaic.
12	Toxoptera citricidus 'Kirk'	Abaca mosaic, citrus tristeza, pepper veinal mottle
13	Toxoptera aurantii B.D.F.	Citrus mottling, citrus tristeza
14	Aphis nastartii Kaltenback	Cucumber mosaic, peanut mottle virus, potato acuba mosaic, potato leaf roll, potato virus-A, potato virus-Y, soybean mosaic, tobacco etch.
15	Rhopalosiphum nymphaeae L.	Cucumber mosaic virus, turnip mosaic
16	Neomyzus circumflexus (Buckt)	Barley yellow dwarf, beet mosaic, beet yellow, cabbage black ring spot virus, cauliflower mosaic, celery mosaic, cucumber mosaic, dahlia mosaic, henbane mosaic, onion yellow dwarf, potato virus-A, potato virus-Y, Radish mosaic, soybean mosaic, tobacco etch, tulip breaking, turnip yellow mosaic.
17	Hyalopterus pruni (Geoffr)	Celery mosaic, cucumber mosaic, onion yellow dwarf

Note: The viruses underlined are found to occur on chilli at Hebbal Farm.

Table 25: Population of aphids and different aphid vectors on Hebbal farm during 1980-81 (Average of 5 days)

Date	Total number aphid species	Total Number of aphid vectors of plant viruses	Total Number of aphid vectors of chilli viruses	Aphis craccivora	Aphis gossypii	Aphis fabae	Aphis spinaecola	Aphis nerii	Aphis nastartii	Total number of Aphis spp.	Myzus persicae	Rhopalosiphum maidis	Rhopalosiphum padi	Hydaphis coriandri	Hysteroneura setariae	Brevicoryne brassicae	Toxoptera citricidus
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
17-3-1980	8	4	4	0	4	0	0	0	0	8	0	0	0	0	0	0	0
22-3-1980	5	3	1	0	1	1	0	0	0	3	0	0	0	1	0	0	0
27-3-1980	5	3	0	0	0	1	0	0	0	2	0	0	0	1	0	0	0
1-4-1980	16	11	8	0	0	2	7	0	1	12	0	0	1	0	0	0	0
6-4-1980	29	16	9	0	5	0	0	0	0	17	0	4	6	1	0	0	0
11-4-1980	7	7	5	2	1	0	0	0	0	3	0	2	0	1	0	1	0
16-4-1980	25	11	3	3	0	2	0	0	0	18	0	0	0	4	0	1	0
21-4-1980	9	3	3	3	0	0	0	0	0	9	0	0	0	0	0	0	0
26-4-1980	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
1-5-1980	14	11	6	2	0	5	0	0	0	11	2	2	0	0	0	0	0
6-5-1980	7	7	4	0	3	3	1	0	0	7	0	0	0	0	0	0	0
11-5-1980	3	3	3	0	3	0	0	0	0	3	0	0	0	0	0	0	0
16-5-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-5-1980	2	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0
26-5-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 25 - (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
31-5-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-6-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-6-1980	6	6	3	0	1	0	2	0	0	3	0	0	1	2	0	0	0
15-6-1980	2	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0
20-6-1980	4	3	3	0	3	0	0	0	0	4	0	0	0	0	0	0	0
25-6-1980	3	3	3	0	2	0	0	1	0	3	0	0	0	0	0	0	0
30-6-1980	2	1	1	0	1	0	0	0	0	2	0	0	0	0	0	0	0
5-7-1980	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
10-7-1980	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
15-7-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-7-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-7-1980	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
30-7-1980	4	3	3	0	3	0	0	0	0	3	0	0	0	0	0	0	0
5-8-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-8-1980	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
15-8-1980	4	3	1	0	1	2	0	0	0	3	0	0	0	0	0	0	0
19-8-1980	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
24-8-1980	2	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0
29-8-1980	4	4	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
3-9-1980	2	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0
8-9-1980	11	10	8	7	1	2	0	0	0	10	0	0	0	0	0	0	0
13-9-1980	12	7	6	4	2	1	0	0	0	9	0	0	0	0	0	0	0
18-9-1980	12	7	4	1	3	2	0	0	0	9	0	0	0	0	0	0	0

Table 25 - (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
23-9-1980	11	7	4	1	2	3	0	0	0	8	1	0	0	0	0	0	0
28-9-1980	7	6	4	4	0	2	0	0	0	7	0	0	0	0	0	0	0
3-10-1980	2	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0
8-10-1980	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
13-10-1980	4	2	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0
18-10-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-10-1980	7	7	6	3	0	0	0	0	0	3	0	0	0	0	0	0	3
28-10-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-11-1980	2	2	2	1	0	0	0	0	1	2	0	0	0	0	0	0	0
7-11-1980	12	11	8	8	0	3	0	0	0	12	0	0	0	0	0	0	0
12-11-1980	5	5	3	0	2	2	0	0	0	4	0	0	0	0	1	0	0
17-11-1980	41	35	30	12	7	5	6	2	0	33	3	0	0	0	0	0	0
22-11-1980	44	41	31	15	7	7	4	0	0	36	2	3	0	1	0	1	0
27-11-1980	36	31	30	20	7	1	0	0	0	28	0	2	0	0	1	0	0
1-12-1980	12	5	4	3	0	0	0	0	0	4	0	1	1	0	0	0	0
6-12-1980	14	5	4	0	3	0	1	0	0	5	0	0	1	0	0	0	0
11-12-1980	4	3	1	1	0	2	0	0	0	3	0	0	0	0	0	0	0
16-12-1980	5	3	3	1	0	0	0	0	0	2	1	0	0	0	0	0	0
21-12-1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-12-1980	16	14	9	2	2	5	5	0	0	14	0	0	0	0	0	0	0
31-12-1980	5	4	4	1	1	0	1	0	0	5	0	0	0	0	1	0	0

Table 25 - (Contd.)

1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
5-1-1981	..	2	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
10-1-1981	..	3	2	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
15-1-1981	..	6	5	4	2	1	0	0	0	0	4	1	0	1	0	0	0	0
20-1-1981	..	5	3	3	0	1	0	2	0	0	25	0	0	0	0	0	0	0
25-1-1981	..	19	17	15	8	6	1	0	0	0	15	1	0	0	0	0	0	0
30-1-1981	..	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-2-1981	..	6	5	3	2	0	2	0	1	0	6	0	0	0	0	0	0	0
10-2-1981	..	9	5	3	0	1	2	1	0	0	5	0	1	0	0	0	0	0
15-2-1981	..	20	10	10	3	6	0	0	1	0	10	0	0	0	0	0	0	0
20-2-1981	..	5	3	3	0	3	0	0	0	0	3	0	0	0	0	0	0	0
25-2-1981	..	7	6	6	0	0	0	0	0	0	1	6	0	0	0	0	0	0
2-3-1981	..	18	14	14	2	0	0	0	0	0	2	12	0	0	0	0	0	0
7-3-1981	..	7	7	7	5	0	0	0	0	0	5	2	0	0	0	0	0	0
12-3-1981	..	8	2	2	0	0	0	0	0	0	3	0	0	0	0	2	0	0
Total	..	502	401	305	116	96	59	30	5	2	361	31	17	15	11	7	3	3
Average	..	6.88	5.50	4.2	1.59	1.32	0.81	0.41	0.07	0.03	5.0	0.42	0.23	0.20	0.15	0.09	0.04	0.04

wind speed, sunshine and evaporation during 1980-81 was collected from meteorological observatory at Main Research Station, Hebbal, and average for every five days was calculated and presented in Table 26. Correlation coefficient between weather conditions and total population of aphid species, aphid vectors of plant viruses and individual important vectors was statistically analysed and the results are presented in Table 27 (Fig.68).

a) Total population of aphid species

The results indicate that there was a positive correlation between total aphid population and maximum and minimum temperature, relative humidity at 07.20 and 14.20 hrs, sunshine and evaporation at one per cent level. Rainfall was positively correlated with the total aphid population but was not significant. Wind speed had a highly significant negative correlation with the total aphid population.

b) Total population aphid vectors of plant viruses

There was positive correlation between total population of aphid vectors of plant viruses and relative humidity at 07.20 and 14.20 hrs, but was significant only with minimum temperature. Rainfall, maximum temperature, wind speed, sunshine, and evaporation showed negative correlation with

Table 26: Weather data of Hebbal farm from 17-3-1980 to 17-3-1981 (Average of five days)

Date	Rain-fall (mm)	Max. temp. °C	Min. Temp. °C	R.H.at 07-20 hours %	R.H.at 14-20 hours %	Wind speed kmph	Hrs.of bright sun-shine	Evapo-ration mm
1	2	3	4	5	6	7	8	9
17-3-80	1.56	30.88	17.60	83.00	28.00	7.52	8.92	7.76
22-3-80	0.00	32.66	14.80	73.00	17.20	5.78	10.34	9.38
27-3-80	0.00	33.46	17.30	70.00	23.20	5.90	10.30	8.80
1-4-80	12.04	31.94	19.56	77.60	41.80	6.36	8.66	7.82
6-4-80	2.90	31.84	18.72	79.80	40.80	5.06	8.94	6.38
11-4-80	0.00	31.98	20.90	85.80	35.80	5.82	8.30	6.30
16-4-80	0.00	35.36	21.50	66.60	26.20	5.34	10.80	8.16
21-4-80	5.00	32.60	21.64	72.00	43.20	7.10	8.20	7.52
26-4-80	0.00	33.98	22.12	85.20	36.20	6.36	9.66	6.00
1-5-80	0.12	34.18	21.96	81.60	37.20	6.50	8.78	5.90
6-5-80	1.22	32.80	21.46	92.40	45.20	7.08	8.72	6.22
11-5-80	6.26	33.40	21.84	83.60	44.60	6.08	9.04	6.50
16-5-80	7.06	33.20	21.40	85.20	46.00	5.84	9.16	5.40
21-5-80	10.50	33.72	21.44	89.40	49.20	8.34	10.00	6.18
26-5-80	0.00	35.56	21.98	82.60	30.00	11.06	10.98	9.10
31-5-80	14.00	33.16	21.12	88.00	47.00	10.04	7.16	6.90
5-6-80	3.00	28.18	20.30	94.60	70.00	11.38	3.20	3.48
10-6-80	0.20	29.22	20.34	92.40	66.80	17.20	6.26	5.48
15-6-80	0.80	28.86	20.30	90.80	64.00	12.46	3.06	5.24
20-6-80	0.76	29.08	20.52	91.80	59.20	14.90	2.20	4.14
25-6-80	0.00	29.06	19.64	92.80	58.80	18.52	5.58	6.60
30-6-80	0.80	29.20	20.10	91.80	57.00	16.60	3.84	5.82
5-7-80	1.32	27.98	19.76	92.80	69.60	17.98	3.18	4.08
10-7-80	0.00	29.70	20.86	98.00	63.00	17.78	5.74	6.02
15-7-80	0.98	29.86	19.60	95.20	68.20	14.50	7.14	5.14
20-7-80	6.10	30.00	20.14	92.80	63.40	13.18	7.54	4.94
25-7-80	6.20	28.00	19.94	94.40	68.40	14.08	4.16	4.06

Table 26 - (Contd.)

1	2	3	4	5	6	7	8	9
30-7-80	2.74	28.53	19.52	93.00	65.80	14.20	5.18	4.12
5-8-80	1.34	27.53	19.20	96.70	64.80	14.50	3.30	4.08
10-8-80	0.00	29.26	18.94	95.20	52.60	12.80	6.74	5.68
15-8-80	6.78	28.58	19.58	94.00	63.80	12.60	5.40	4.76
19-8-80	3.03	28.15	19.93	95.50	59.00	13.73	6.25	5.03
24-8-80	0.58	27.36	19.20	94.40	61.60	15.40	5.26	4.14
29-8-80	4.84	28.78	19.10	94.60	60.40	12.16	7.69	5.16
3-9-80	1.10	28.22	19.26	90.80	56.20	12.32	6.30	5.26
8-9-80	1.62	28.50	19.56	90.00	65.60	9.18	5.38	4.78
13-9-80	0.00	29.24	18.98	90.20	50.60	9.10	5.96	5.30
18-9-80	0.00	30.36	18.44	83.00	47.40	10.36	8.34	6.48
23-9-80	25.86	30.18	19.94	92.60	54.80	6.62	6.40	4.93
28-9-80	3.52	29.10	19.68	93.40	57.40	5.04	7.98	4.32
3-10-80	2.26	28.96	19.52	95.80	62.20	4.80	6.50	3.40
8-10-80	0.00	29.70	17.72	84.40	48.00	3.78	9.70	4.38
13-10-80	0.00	29.40	20.26	94.40	57.80	5.96	8.12	4.06
18-10-80	0.00	27.72	18.92	86.00	53.80	4.76	3.98	3.82
23-10-80	5.84	29.96	19.74	94.80	54.60	6.68	6.10	3.82
28-10-80	0.00	27.72	18.50	89.60	50.20	3.92	8.62	3.42
2-11-80	0.00	28.72	15.50	86.40	34.40	5.10	10.44	5.10
7-11-80	0.00	29.28	17.24	86.60	42.00	5.38	9.44	5.10
12-11-80	1.94	27.88	16.92	90.20	58.60	6.84	7.94	4.10
17-11-80	5.34	24.54	19.18	98.40	79.60	8.42	1.98	1.70
22-11-80	0.56	25.46	18.32	96.40	61.00	5.92	5.80	2.46
27-11-80	0.00	27.36	16.66	99.00	46.80	5.34	9.70	4.40
1-12-80	0.00	27.25	15.38	87.00	38.50	5.53	9.18	5.00
6-12-80	0.00	25.22	15.86	89.80	57.00	6.42	7.70	3.78
11-12-80	0.00	28.58	14.38	85.00	34.20	3.64	9.66	4.50
16-12-80	0.00	28.06	14.70	95.20	39.60	5.28	9.98	4.80
21-12-80	0.00	27.34	13.36	94.20	48.20	5.80	9.96	4.96
26-12-80	0.00	27.52	15.80	88.00	49.60	5.14	7.14	3.82
31-12-80	0.00	27.10	16.92	86.20	43.20	7.16	7.32	4.14

Table 26 - (Contd.)

1	2	3	4	5	6	7	8	9
5-1-81	0.00	27.55	15.22	92.20	41.80	6.46	9.74	5.04
10-1-81	0.24	29.42	13.54	88.80	34.40	4.30	10.24	4.52
15-1-81	0.00	26.42	16.52	94.00	54.80	4.26	8.00	4.14
21-1-81	0.00	26.26	16.46	96.60	55.80	6.28	7.02	4.10
25-1-81	0.00	28.78	16.26	95.20	46.60	5.28	9.38	4.52
30-1-81	0.00	27.98	15.62	98.00	46.60	7.26	9.82	5.08
5-2-81	0.00	30.28	13.81	95.00	42.66	5.57	10.35	5.55
10-2-81	0.00	30.24	16.66	94.60	49.80	5.96	10.14	5.52
15-2-81	0.00	31.42	18.20	89.40	37.60	4.38	9.78	5.50
20-2-81	0.00	29.50	11.24	74.20	22.20	5.94	11.04	7.46
25-2-81	0.00	30.72	12.56	86.00	33.40	7.20	11.10	8.10
2-3-81	0.00	33.02	14.26	66.00	26.40	7.18	10.74	9.12
7-3-81	0.00	32.30	15.76	78.60	22.20	7.90	10.40	9.14
12-3-81	3.36	32.54	19.22	79.00	43.00	7.26	9.78	7.60
Total :	151.27	2168.47	1338.38	6481.80	3576.56	662.97	566.14	395.45
Average	2.07	29.70	18.34	88.78	48.99	9.08	7.75	5.42

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Table 27: Correlation of population dynamics of total population of aphids species and some aphid vectors of chilli viruses with meteorological factors during one year period of 1980-81 on Hebbal farm

Sl. No.	Meteorological factors	Correlation during 1980-81 (One year)
1	2	3
	1. Total population of aphid species	
1	Rainfall ..	+ 0.03^{NS}
2	Maximum Temperature	+ 0.76**
3	Minimum temperature	+ 0.41**
4	Relative humidity at 07.20 hours	+ 0.69**
5	Relative humidity at 14.20 hours	+ 0.47**
6	Wind speed km ph ..	- 0.47**
7	Hours of bright sun shine	+ 0.26*
8	Evaporation ..	+ 0.13^{NS}
	2. Total population of aphid vectors of plant viruses	
1	Rainfall ..	- 0.013^{NS}
2	Maximum Temperature..	- 0.25*
3	Minimum Temperature..	+ 0.98**
4	Relative Humidity at 07.20 hours	+ 0.012^{NS}
5	Relative humidity at 14.20 hours	+ 0.02^{NS}
6	Wind speed km ph	- 0.68**
7	Hours of bright sunshine	- 0.04^{NS}
8	Evaporation ..	- 0.18^{NS}

Table 27 - (Contd.)

1	2		3
	3. Total population of aphid vectors of chilli viruses		
1	Rainfall ..	-	0.03^{NS}
2	Maximum Temperature..	-	0.27*
3	Minimum Temperature..	-	0.13^{NS}
4	Relative humidity at 07.20 hours	+	0.10^{NS}
5	Relative humidity at 14.20 hours	+	0.28*
6	Wind speed km ph ..	-	0.61**
7	Hours of bright sunshine	-	0.003^{NS}
8	Evaporation ..	-	0.66**
	4. Population of Aphis craccivora		
1	Rainfall ..	-	0.08^{NS}
2	Maximum Temperature..	-	0.26*
3	Minimum Temperature..	-	0.08^{NS}
4	Relative humidity at 07.20 hours	+	0.16^{NS}
5	Relative humidity at 14.20 hours	+	0.05^{NS}
6	Wind speed km ph ..	-	0.55**
7	Hours of bright sunshine	-	0.013^{NS}
8	Evaporation ..	-	0.23*
	5. Population of Aphis gossypii		
1	Rainfall ..	-	0.01^{NS}
2	Maximum Temperature..	-	0.44**
3	Minimum Temperature..	-	0.12^{NS}
4	Relative humidity at 07.20 hours	+	0.04^{NS}
5	Relative humidity at 14.20 hours	+	0.08^{NS}
6	Wind speed km ph ..	-	0.43**
7	Hours of bright sunshine	-	0.19^{NS}
8	Evaporation ..	-	0.28*

Table 27 - (Contd.)

1	2	3	
	6. Population of Aphis fabae		
1	Rainfall ..	+	0.11^{NS}
2	Maximum Temperature..	+	0.08^{NS}
3	Minimum Temperature..	+	0.37**
4	Relative humidity at 07.20 hours	+	0.11^{NS}
5	Relative humidity at 14.20 hours	+	0.13^{NS}
6	Wind speed km phq ..	-	0.48**
7	Hours of bright sunshine	-	0.05^{NS}
8	Evaporation ..	-	0.14^{NS}
	7. Population of Aphis spiraecola		
1	Rainfal ..	+	0.15^{NS}
2	Maximum Temperature..	-	0.25*
3	Minimum Temperature..	-	0.01^{NS}
4	Relative humidity at 07.20 hours	+	0.05^{NS}
5	Relative humidity at 14.20 hours	+	0.18^{NS}
6	Wind speed km ph ..	-	0.25*
7	Hours of bright sunshine	-	0.18^{NS}
8	Evaporation ..	-	0.19^{NS}
	8. Population of Aphis spp.(Total)		
1	Rainfall ..	+	0.04^{NS}
2	Maximum Temperature..	+	0.75**
3	Minimum Temperature..	+	0.51**
4	Relative humidity at 07.20 hours	+	0.90**
5	Relative humidity at 14.20 hours	+	0.32**
6	Wind speed km ph ..	-	0.35**
7	Hours of bright sunshine	+	0.18^{NS}
8	Evaporation ..	+	0.055^{NS}

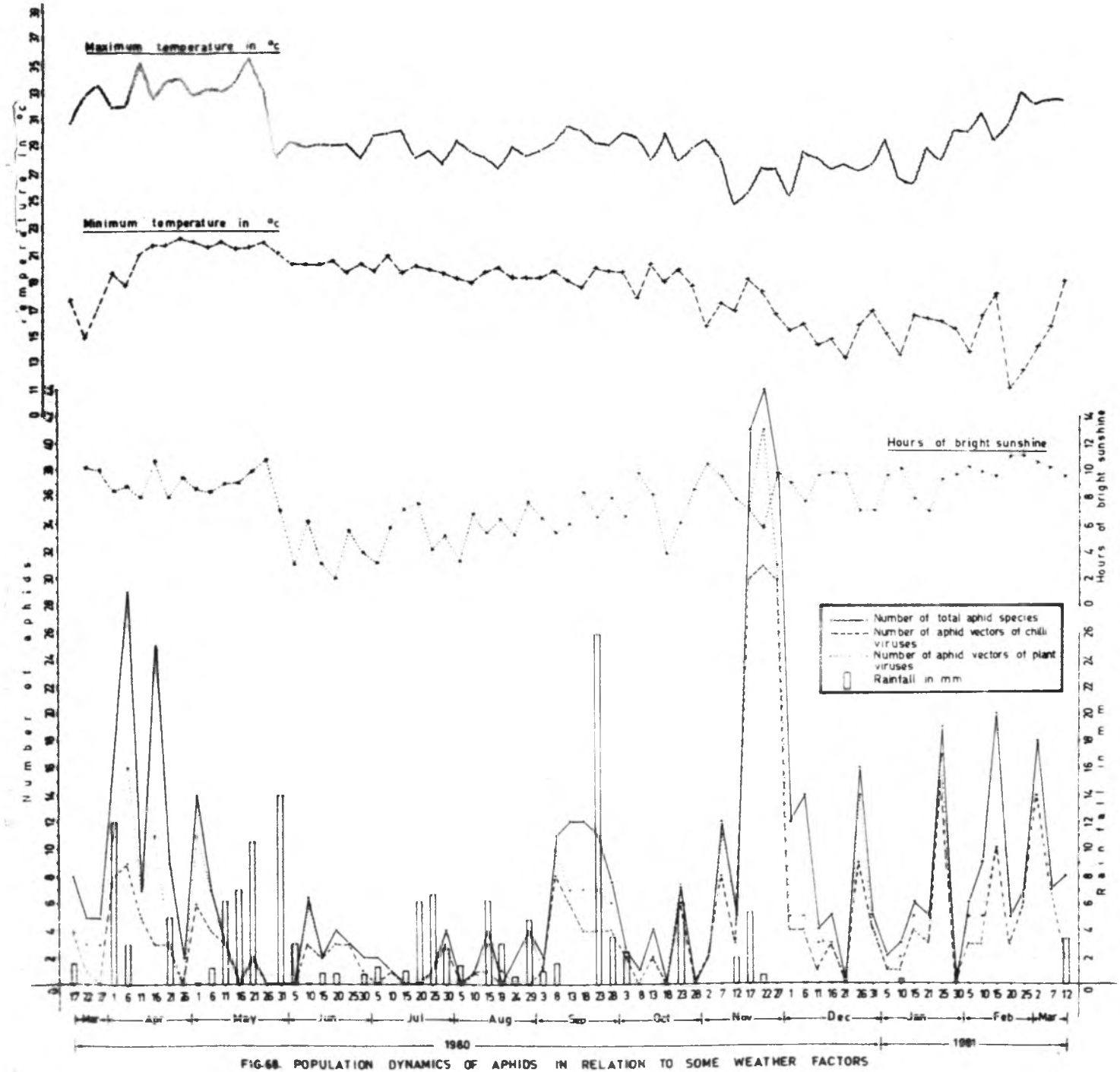

FIG.68. POPULATION DYNAMICS OF APHIDS IN RELATION TO SOME WEATHER FACTORS

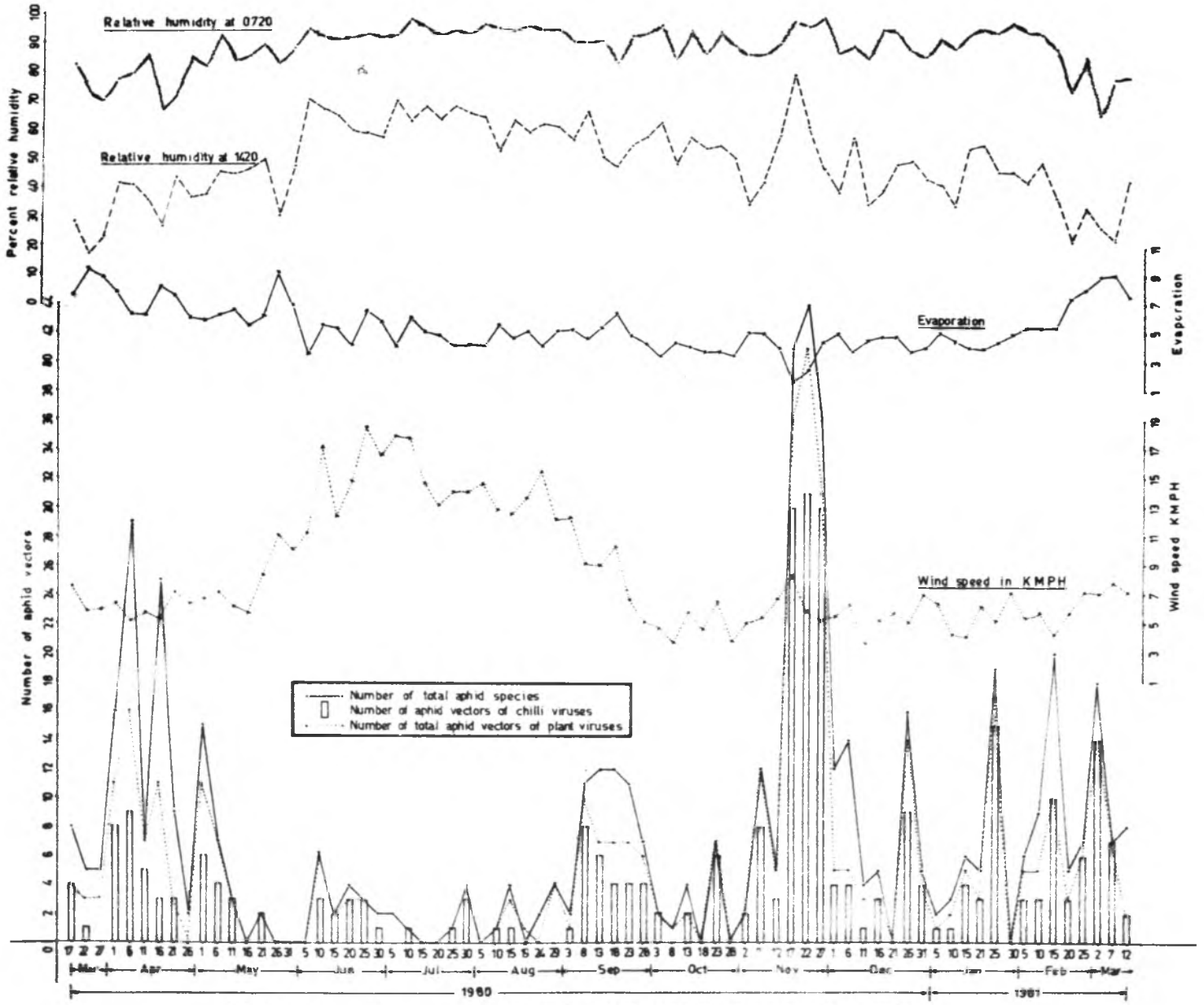

FIG.68 (Contd) POPULATION DYNAMICS OF APHIDS IN RELATION TO SOME WEATHER FACTORS

total population of aphid vectors of plant viruses but was significant only with maximum temperature and wind speed.

c) Total population of reported aphid vectors of chilli viruses

Here, total population of aphid vectors transmitting chilli viruses were calculated and correlated with weather data. Results show that there was positive correlation between total population of aphid vectors of chilli viruses and relative humidity at 07.20 and 14.20 hrs but was significant only at 14.20 hr and not at 07.20 hr. Rainfall, maximum and minimum temperature, wind speed, sunshine and evaporation showed negative correlation with the total population of aphid vectors of chilli viruses but only maximum temperature and evaporation showed significant correlation.

(d) & (e) Population of Aphis craccivora and A.gossypii

Population of A.craccivora and A.gossypii showed positive correlation only with relative humidity at 07.20 and 14.20 hrs, but was not significant. Population of A.craccivora and A.gossypii was negatively correlated with rainfall, maximum and minimum temperature, windspeed, sun-

shine and rate of evaporation, but only maximum temperature, wind speed and evaporation showed significant correlation.

f) Population of Aphis fabae

Population of A.fabae was positively correlated with minimum temperature at one per cent level. Rainfall, maximum temperature, relative humidity at 07.20 and 14.20 hrs showed positive correlation with the population of A.fabae but was insignificant. Windspeed, sunshine and evaporation showed negative correlation but was significant only with wind speed.

g) Population of Aphis spiraecola

Population of A.spiraecola showed positive correlation with rainfall, relative humidity at 07.20 and 14.20 hrs but was insignificant.

h) Population of Aphis spp.

Here total population of all the species of Aphis was calculated and was correlated with the weather factors. Results showed that maximum and minimum temperatures, and relative humidity at 07.20 and 14.20 hrs showed significant positive correlation with the population of species of Aphis.

Rainfal, sunshine and evaporation though showed positive correlation with the total population of a Aphis species but was insignificant.

B. Infection Pressure of Different chilli viruses on Hebbal farm during 1980-81

This study was made to know the occurrence of different viruses on the farm at different periods during the year. California Wonder plants were used as trap plants throughout the study and the infection pressure of different viruses on the farm is presented in the Table 28 (Fig.69).

It was found that totally five aphid transmitted and two (TRSV and TSWV), non-aphid transmitted viruses occurred during 1980-81. Among the aphid transmitted viruses, maximum spread was due to PVY followed by CMV, PVBV, PVMV and TBV.

There were two peak periods of infection by all the aphid borne viruses on the farm during the year, one was during the months of March, April and May and second was during the months of October, November, December and January. There was least pressure of infection during the months of July, August and September on Hebbal Farm. Infection pressure of all aphid transmitted viruses followed almost a similar pattern. There was constent occurrance of

Table 28: Infection pressure of different chilli viruses on Hebbal farm during 1980-81 (in per cent diseased plants)

Sl. No	Months		Aphid transmitted viruses						Non aphid transmitted viruses			Total
			PVBV	PVMV	PVY	TEV	CMV	Total	TRSV	TSWV	Total	
1	March	1980	3	5	13	1	9	31	1	1	2	33
2	April	1980	9	7	6	0	7	29	0	1	1	30
3	May	1980	10	6	14	0	7	37	1	0	1	38
4	June	1980	2	0	1	0	10	13	4	0	4	17
5	July	1980	2	1	2	0	0	5	0	0	0	5
6	August	1980	3	3	1	0	1	8	5	0	5	13
7	Sept.	1980	3	4	2	0	3	12	2	0	2	14
8	October	1980	2	1	10	2	2	17	3	0	3	20
9	November	1980	4	2	6	3	4	19	0	0	0	19
10	December	1980	2	6	9	1	4	22	3	5	8	30
11	January	1981	5	2	8	0	3	18	4	6	10	28
12	February	1981	4	4	2	0	4	14	2	1	3	17
	Total		49	41	74	7	54	225	25	14	39	264
	Average		4.1	3.42	6.17	0.6	4.5	18.75	2.0	1.16	3.2	22.0

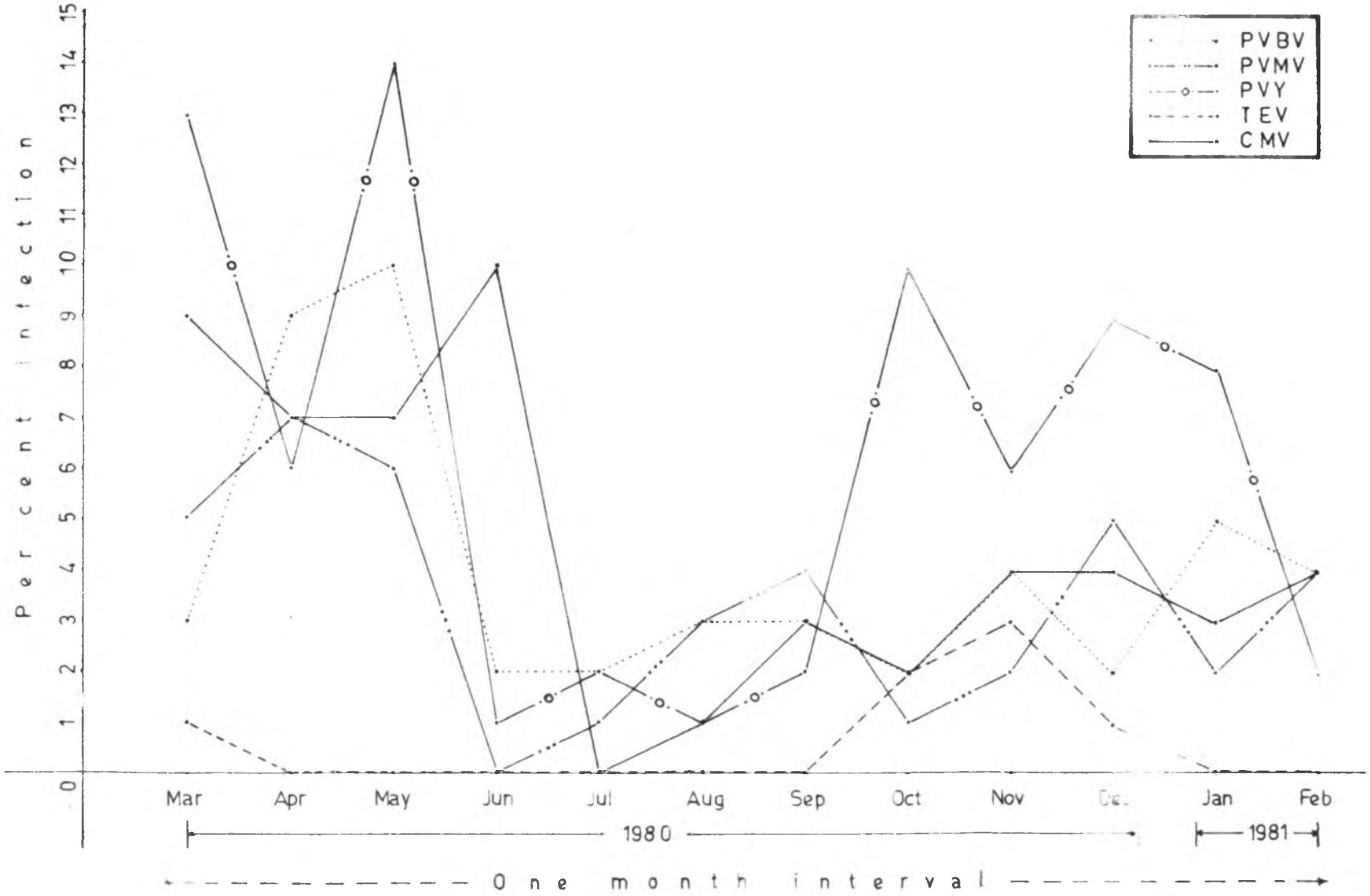

FIG.8 INFECTION PRESSURE OF DIFFERENT APHID TRANSMITTED VIRUSES OF CHILLI ON HEBBAL FARM DURING 1980-81

PVBV and PVY throughout the year. Incidence of PVMV and CMV was not found in the month of June and July respectively. Infection pressure was least in TEV which occurred only during the months of March, October and December.

Further, to know the relation between different aphid population and infection pressure of different viruses during different months of the year; total population of aphid species, aphid vectors of plant viruses as reported, aphid vectors of chilli viruses and the important aphid vectors were grouped and presented in the Table 29. Correlation coefficients between infection pressure of total and individual viruses was worked out and the data are presented in Table 30.

By observing the population of total number of aphids and aphid vectors during different months of the year, it is found that the infection pressure of all the aphid transmitted viruses at different months showed positive correlation with the total population of aphids, aphid vectors of plant viruses, aphid vectors reported as of Capsicum viruses, Aphis craccivora, A.gossypii, A.fabae, A.spirecola and total number of Aphis spp., however, it was not significant. Similarly infection pressure of PVBV at different months also showed positive correlation. Infection pressure of PVMV during different months showed positive correlation only with the population of total number of aphid species, aphid

Table 29: Population Dynamics of different aphids and aphid vectors on Hebbal farm during 1980-81 (Total of one month)*

Sl. No.	Months	Total No. of aphids	No.of aphid vectors	No.of aphid vectors of chilli viruses	No. of *Aphis craccivora*	No.of *Aphis gossypii*	No. of *A.fabae*	No. of *A.spiraecola*	Total No. of *Aphis* spp.
1	March 1980	18	10	5	0	5	2	0	13
2	April 1980	88	48	28	8	6	4	7	61
3	May 1980	26	23	15	2	8	8	1	23
4	June 1980	17	15	12	0	9	0	2	14
5	July 1980	8	5	5	0	5	0	0	7
6	Aug. 1980	12	9	2	0	2	5	0	7
7	Sept. 1980	55	38	27	18	9	10	0	44
8	Oct. 1980	14	12	10	3	2	1	0	6
9	Nov. 1980	140	125	104	56	23	18	10	115
10	Dec. 1980	56	34	25	8	6	7	7	33
11	Jan. 1981	35	28	24	10	8	1	2	44
12	Feb. 1981	47	29	25	5	10	4	1	25
	Total	516	376	282	110	93	60	30	392
	Average	43	31.33	23.50	9.17	7.75	5	2.5	32.67

* Extract from the Table 25

Table 30: Correlation coefficient between infection pressure of different aphid transmitted chilli viruses and population dynamics of different aphid and aphid vectors during 12 months of 1980-81 on Hebbal Farm

Sl. No.	Aphid	Correlation coefficient					Total of viruses
		PVBV	PVMV	PVY	TEV	CMV	
1	Total Number of aphids	+ 0.271	+ 0.26	- 0.021	+ 0.52	+ 0.067	+ 0.20
2	Nor of aphid vectors	+ 0.193	+ 0.08	- 0.006	+ 0.63*	+ 0.025	+ 0.14
3	No. of aphid veotor of chilli viruses	+ 0.115	- 0.026	- 0.019	+ 0.66*	- 0.013	+ 0.082
4	No. of Aphis craccivora	+ 0.03	- 0.083	- 0.047	+ 0.68**	- 0.110	+ 0.003
5	No. of A.gossypii	+ 0.112	- 0.115	- 0.09	+ 0.49	+ 0.150	+ 0.06
6	No. of A.fabae	+ 0.20	+ 0.253	- 0.052	+ 0.52	- 0.070	+ 0.174
7	No. of A.spiraecola	+ 0.22	+ 0.26	+ 0.08	+ 0.51	+ 0.160	+ 0.27
8	Total No. of Aphis spp.	+ 0.30	+ 0.15	+ 0.007	+ 0.51	+ 0.052	+ 0.19

Note: * Significant at 5 per cent level

** Significant at 1 per cent level

vectors of plant viruses, A.fabae, A.spirecola and all of Aphis spp. Potato virus-Y showed positive correlation only with the population of A.spiraecola and total population of Aphis spp. And CMV showed positive correlation only with the total population of aphids, aphid vectors of plant viruses, A.gossypi, A.spiraecola and of Aphis spp. Infection pressure of TEV was positively correlated with the population of all the aphids and aphid vectors as shown in the Table 30, but showed significant relation only with the population of aphid vectors of plant viruses, chilli viruses and A.craccivora. No correlation was found with the population of Myzus persicae which occurred irregularly only from 23rd September to 7th March. Only A.craccivora, A.gossypii and A.fabae were found to be in large numbers throughout the year. However, A.gossypii an early appearing aphid vector occurred in tremendous numbers and showed marked coincidence between its population and occurrence of viruses in the field. Present studies showed that all the aphid transmitted viruses were recorded earlier than the appearance of aphid vectors in large numbers.

C. Nature of spread of PVMV in the field

Earlier experiments showed that the most severe virus of Capsicum in Karnataka was PVMV. Therefore its nature of spread in the field was studied in four crop periods viz.,

March-May, June-August, September-November and December-February where from planting to end of the experiment in each crop period was 3 months. The results are presented in the Tables 31, A, B, C & D. It is clear from the Tables, that there was generally 1 to 5 per cent diseased plants with a single infector plant in the centre, after 24 to 36 days of planting of the chilli in each of all the four crops taken in one year. After 37 to 42 days of planting the spread of PVMV was 8 to 21 per cent. It was 38.5 to 60.5 per cent after 67-73 days of planting, and maximum spread was found in March to May crop (60.5 per cent) and least was in September to November crop (38.5 per cent). After 90 days of planting, the spread of PVMV was 60 to 70.5 per cent. Maximum spread (70.5 per cent) was found in the March to May and June to August crops as compared to other periods (Fig.70).

i) Rate of spread of PVMV

Rate of spread of PVMV in the chilli crop taken in four periods during 1980-81 was calculated once in five days by using Van der Plank's formula as discussed in Material and Methods. The results are presented in the Table 31 (Fig.71).

It can be seen from the Table that generally the spread was more in the beginning (Fig.70). From 24 to

Table 31 A: Nature of spread of PVMV in the field during 1980-81

I. March to May, 1980

a) Date of planting = 2-3-1980

Sl. No.	Date of observations	Per cent spread		Rate of spread $r = \frac{230}{t_2-t_1} \log \frac{x_2(1-x_1)}{x_1(1-x_2)}$		Counted doublets		Calculated doublets $P = \frac{X(x-1)}{n}$	
		P.I	P.N.	P.I	P.N.	P.I.	P.N.	P.I.	P.N.
1	10-3-80(IPS Available)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	15-3-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	21-3-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	26-3-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	31-3-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	6-4-80	4.0	0.0	32.56	0.0	0.0	0.0	0.13	0.0
7	11-4-80	8.0	0.0	12.88	0.0	1.0	0.0	0.57	0.0
8	16-4-80	22.0	2.0	14.19	0.0	8.0	0.0	4.63	0.02
9	21-4-80	37.0	8.5	14.30	28.40	19.5	0.5	13.36	0.67
10	26-4-80	50.0	11.0	10.51	6.15	33.0	1.0	24.66	1.26
11	1-5-80	54.0	13.0	3.20	3.62	38.0	2.5	28.87	1.81
12	6-5-80	58.0	13.5	3.22	0.66	43.0	3.5	33.22	1.99
13	11-5-80	60.5	14.0	2.09	1.30	47.0	3.5	36.20	2.07
14	16-5-80	63.0	15.0	2.09	2.22	49.5	3.5	39.22	2.26
15	21-5-80	65.0	15.0	1.79	0.00	51.5	3.5	41.85	2.26
16	26-5-80	68.0	15.5	2.70	0.63	57.0	3.5	45.81	2.45
17	31-5-80	70.5	15.5	2.20	0.00	58.0	3.5	49.06	2.45
18	Total diseased plants	71.5 (1 TMV)	18.0 (2 PVY 0.5 CMV)						

Note: Diseased plants due to other viruses than PVMV coming from outside were excluded from this data (Average of two replications)

IPS = Infector plant source

P.I. = Plot with infector plant

P.N. = Plot with no infector plant

Table 31B.: Nature of spread of PVMV in the field during 1980-81

II. June to August, 1980

a) Date of planting = 1-6-1980

Sl. No.	Date of observation	Per cent spread		Rate of spread $r = \frac{230}{t_2-t_1} \log \frac{x_2(1-x_1)}{x_1(1-x_2)}$		Counted doublets		Calculated doublets $P = \frac{X(x-1)}{n}$	
		P.I	P.N.	P.I.	P.N.	P.I	P.N.	P.I.	P.N.
1	10-6-80 (IPS available)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	15-6-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	20-6-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	25-6-80	5.0	0.5	36.54	0.0	0.5	0.0	0.21	0.0
5	30-6-80	8.5	2.0	10.18	14.15	2.0	0.0	0.64	0.06
6	5-7-80	13.5	2.5	9.49	2.62	3.0	0.0	0.71	0.10
7	10-7-80	21.0	3.0	10.06	1.92	9.5	0.0	4.29	0.15
8	15-7-80	24.0	3.5	3.37	0.0	12.0	0.0	5.61	0.15
9	20-7-80	28.0	4.5	3.92	3.08	12.5	1.0	7.81	0.28
10	25-7-80	35.0	7.0	6.47	14.68	18.0	1.5	12.15	0.58
11	30-7-80	40.5	8.0	4.72	1.89	22.5	1.5	16.03	0.78
12	5-8-80	43.5	8.0	2.40	0.00	25.50	1.5	18.69	0.81
13	10-8-80	51.0	10.0	5.99	6.97	34.50	2.5	25.51	1.15
14	15-8-80	59.0	13.5	6.41	7.05	42.00	5.0	34.22	2.11
15	20-8-80	61.5	14.0	2.07	0.60	46.00	5.0	37.21	2.31
16	25-8-80	64.5	15.0	2.55	2.03	49.50	6.0	40.96	2.59
17	30-8-80	70.5	17.0	5.43	2.94	56.00	7.5	49.00	3.36
18	Total diseased plants	74.0 (2 PVY 1.5 CMV)	21.5 (1.5 PVY 2.5 CMV 0.5 TMV)						

Note: IPS = Infector plant source; P.I. = Plot with infector plant; P.N.= Plot with no infector plant

Table 31 C: Nature of spread of PVMV in the field during 1980-81

III. September to November 1980

a) Date of planting = 1-9-1980

Sl. No.	Date of observation	Per cent spread		Rate of spread $r = \frac{230}{t_2-t_1}\log\frac{x_2(1-x_1)}{x_1(1-x_2)}$		Counted doublets		Calculated doublets $P = \frac{x(x-1)}{n}$	
		P.I.	P.N.	P.I.	P.N.	P.I.	P.N.	P.I.	P.N.
1	8-9-1980(IPS available)	0	0	0	0	0	0	0	0
2	13-9-80	0	0	0	0	0	0	0	0
3	18-9-80	0	0	0	0	0	0	0	0
4	23-9-80	0	0	0	0	0	0	0	0
5	28-9-80	1.0	0	11.17	0	0.5	0	0.01	0
6	3-10-80	6.5	0	30.01	0	1.5	0	0.38	0
7	8-10-80	12.5	1.0	13.46	0	2.0	0	1.44	0
8	13-10-80	15.5	1.5	4.49	14.05	3.0	0	2.31	0.02
9	18-10-80	17.5	1.5	2.63	0.00	4.0	0	3.01	0.02
10	23-10-80	25.0	2.0	8.71	4.15	8.0	0	6.25	0.04
11	28-10-80	25.0	2.0	0.00	0.00	8.0	0	6.25	0.04
12	2-11-80	31.5	4.0	6.28	18.28	13.5	0	10.03	0.12
13	7-11-80	38.5	4.0	6.21	0.0	19.0	0	14.86	0.12
14	12-11-80	46.0	6.5	6.20	10.15	27.0	0	20.95	0.36
15	17-11-80	53.5	8.0	6.02	4.37	33.5	1.0	28.51	0.57
16	22-11-80	58.0	9.0	9.02	2.22	40.0	1.5	33.22	0.76
17	27-11-80	61.5	9.5	2.84	1.44	43.0	1.5	37.21	0.83
18	Total diseased plants ..	63.0 (3 CMV)	10.5 (2 TMV)						

Note: IPS = Infector plant source
PI = Plot with infector plant
PN = Plot with the infector plant

Table 31 D: Nature of spread of PVMV in the field during 1980-81

IV. DECEMBER to FEBRUARY 1980-81

a) Date of planting = 1-12-1980

Sl. No.	Date of observation	Per cent spread		Rate of spread $r=\frac{230}{t_2-t_1}\log\frac{x_2(1-x_1)}{x_1(1-x_2)}$		Counted of doublets		Calculated doublets $P=\frac{x(x-1)}{n}$	
		P.I.	P.N	P.I.	P.N.	P.I.	P.N.	P.I.	P.N.
1	6-12-80 (IPS available)	0	0	0	0	0	0	0	0
2	11-12-80 ..	0	0	0	0	0	0	0	0
3	16-12-80 ..	0	0	0	0	0	0	0	0
4	21-12-80 ..	0	0	0	0	0	0	0	0
5	26-12-80 ..	2.0	0.5	22.30	0	0	0	0.02	0
6	31-12-80 ..	8.0	0.5	29.12	0	0.5	0	0.72	0
7	5-1-81 ..	12.5	2.5	10.60	11.17	2.5	0	1.56	0.03
8	10-1--81 ..	15.0	3.0	4.03	4.15	3.5	0.5	2.26	0.03
9	15-1--81 ..	18.5	4.5	5.10	7.23	5.5	1.5	3.36	0.18
10	20-1--81 ..	21.5	5.0	3.69	1.65	7.5	2.5	4.53	0.24
11	25-1--81 ..	27.0	6.5	5.90	6.74	10.5	2.5	7.11	0.38
12	30-1--81 ..	32.5	7.5	5.16	3.25	15.5	2.5	10.36	0.51
13	5-2--81 ..	39.5	9.0	6.03	3.87	23.5	3.5	15.27	0.76
14	10-2-81 ..	44.0	10.0	3.66	2.41	27.5	3.5	19.36	0.94
15	15-2-81 ..	48.0	11.5	3.18	3.05	33.5	4.5	22.57	1.27
16	20-2-81 ..	55.0	13.0	5.56	2.72	41.0	6.0	29.74	1.65
17	25-2-81 ..	58.5	15.0	2.83	3.45	45.5	7.0	33.66	2.19
18	2-3-81 ..	60.05	15.0	1.64	0.00	46.0	7.0	36.00	2.19
19	Total diseased plants	63.50 (2 PVY 1 TEV)	19.5 (3 PVY 1.5 PVBV)						

Note: IPS = Infector plant source
PI = Plot with infector plant
PN = Plot with the infector plant

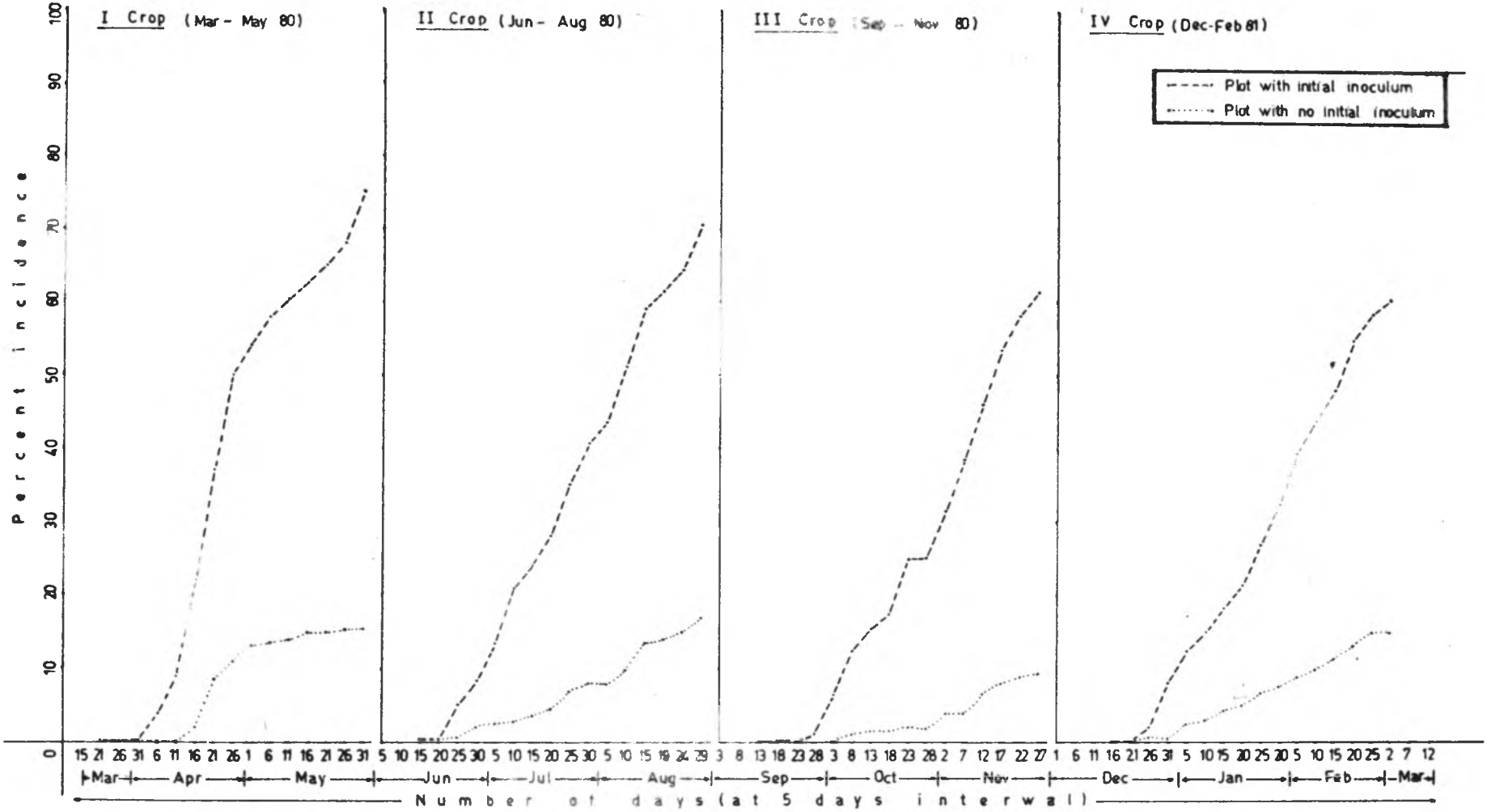

FIG. 70 PERCENT SPREAD OF PVMV IN CHILLI CULTIVAR BYADGI KADDI

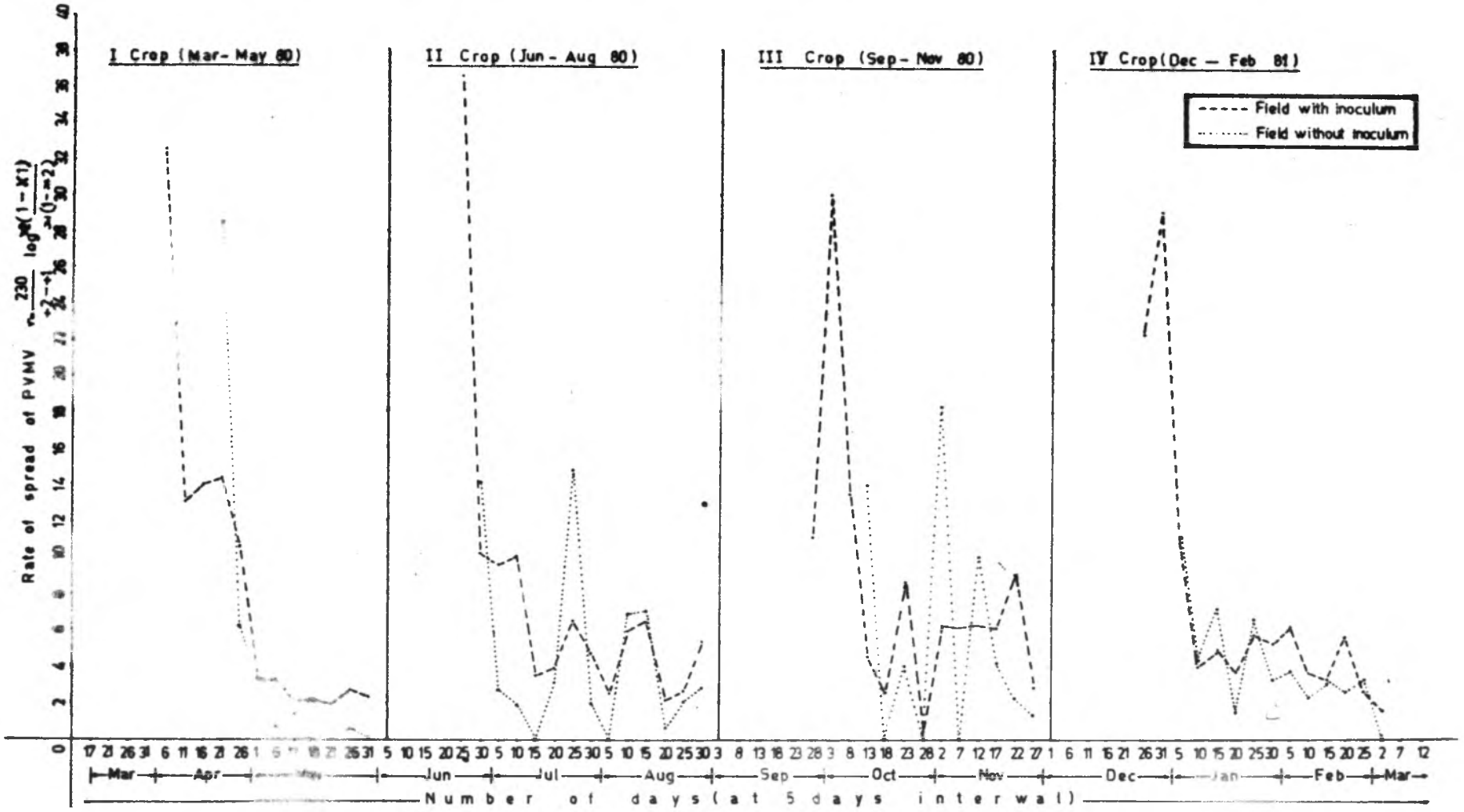

FIG. 71. RATE OF SPREAD OF PVMV IN CHILLI CULTIVAR BYADGI KADDI

36 days after planting of chilli, rate of spread was 32-36.54 per cent per day. From 37 to 42 days after planting the rate of spread was 4.03 to 13.46 per cent per day. It was only 2.09 to 6.21 per cent increase in diseased plants per day from 67-73 days after planting but still the rate of spread was high i.e. 5.99 to 6.21 in June to August and September to November crops. After 90 days of planting, the rate of spread of PVMV in the Capsicum crop taken during March to May, September to November and December to February, came down to 1.64 to 2.2 per cent per day, but it was still high in June to August crop compared to in other periods.

ii) Pattern of spread of PVMV in the Capsicum field

To know the nature of spread, actual number of doublets or pairs of diseased plants were calculated once in five days. And by using Van der Plank's formula as discussed in Material and Methods, expected number of doublets were calculated and are presented in the Table 31.

Results show that, in the beginning, i.e. from 24-36 days after planting, the actual number of doublets were found to be lesser than the expected number of pairs. That means, in the spreading stage, PVMV behaved as if it spread from out side the source of inoculum. Immediately after next five days it proved that the spread was found to be

internal in all the four crops periods during 1980-81. Thereafter, at subsequent five day interval up to 90 days of planting, counted doublets always showed significantly more than the expected number of pairs indicating that the spread was within the crop (Fig.72 and 73).

iii) Common aphid species found in Capsicum plot on the farm

From each crop taken once in three months during 1980-81, totally ten alate aphids at random were collected and identified to know if there were any aphid species introduced from outside than the ones liberated in the beginning of the experiment. The results are presented in the Table 32. From the Table, it is clear that there were totally eight different species prevalent on chilli crop on Hebbal farm. Aphid, Aphis craccivora was found in maximum number in all the four crops followed by A.gossypii and Myzus persicae. There was no A.fabae during June, July and August 1980. Others, were A.spiraecola, Hysteroneura satariae, Rhopalosiphum rufiabdominalis were found only during September, October and November.

D. Effect of infection of PVMV on chilli plants of different ages

This was studied to know the effect of age of infection of plants on their agronomic parameters in the field.

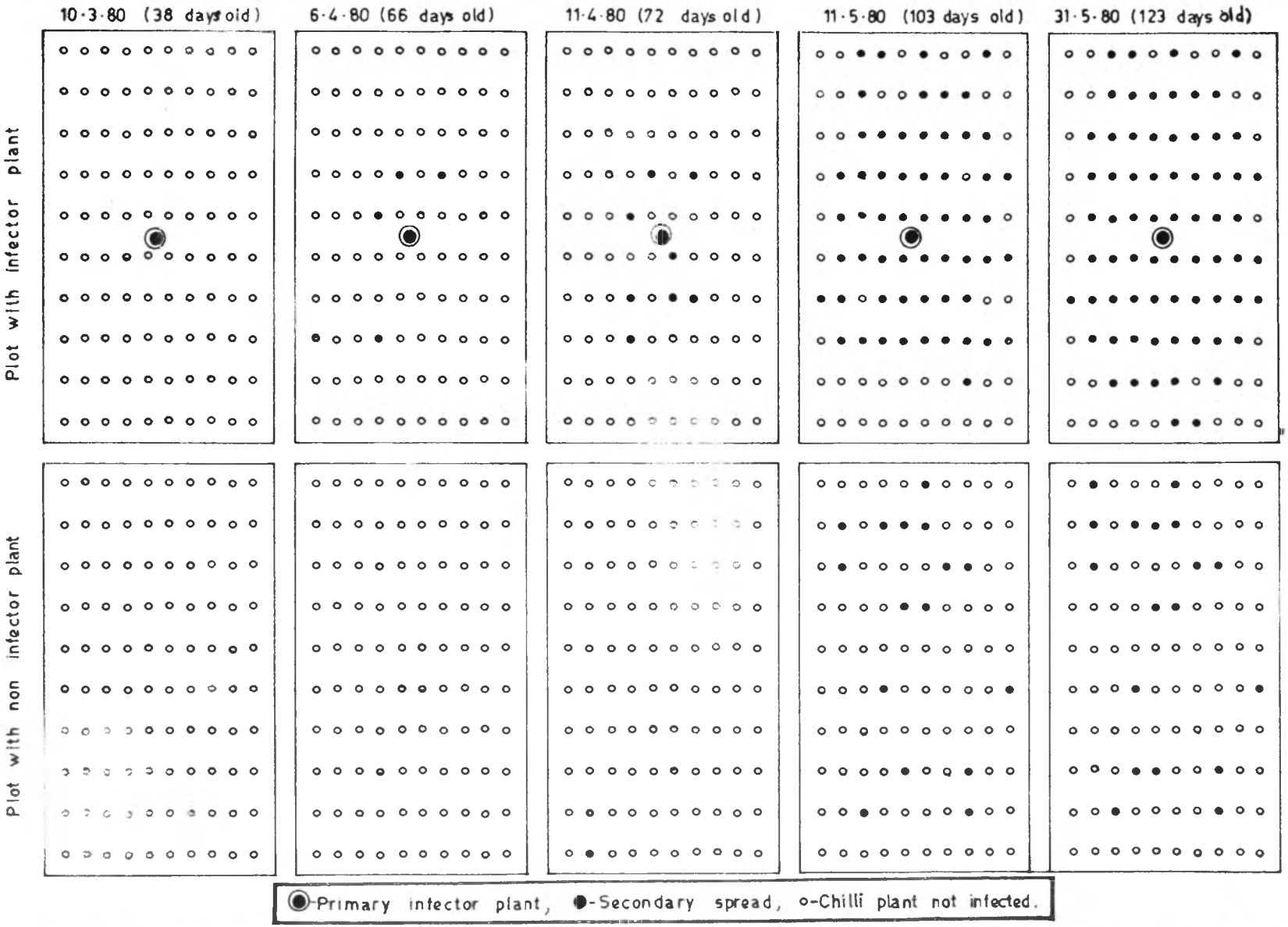

FIG. 72. PATTERN OF SPREAD OF PVMV IN THE FIELD OF BYADGI CHILLI CROP DURING MARCH TO MAY 1980

Fig. No. 73. Capsicum annuum cv. Byadgi Kaddi chilli plants infected with PVMV in the field (Field Spread)

Fig.73

Table 32: Prevalence of different aphid species on chilli crop taken during 1980-81

Sl. No.	Growth periods	No.of aphids collected from the plants	Identification of different aphid species on Capsicum (in per cent)							
			Aphis craccivora	A.gossypii	A.fabae	A.spiraecola	Hysteroneura setariae	Rhopalosiphum rufiabdominalis	Myzus persicae	Aphis spp. (unidentified)
1	March, April and May, 1980	10	30	40	20	-	-	-	10	-
2	June, July and August, 1980	10	40	20	-	-	-	-	20	20
3	September, October and November, 1980	10	30	30	20	-	-	-	20	-
4	December, January and February, 1980-81	10	10	20	20	10	10	10	20	-
	Total:	40								

Therefore plants of Byadgi chilli, during the course of spread of PVMV from a single infector plant in the centre of the plot, were tagged when they started showing initial symptoms on 40-45, 70-75 and 90 days after planting and grouped into three classes. Finally 90 days after planting in the field, height, girth of stem, number, green and dry weight of leaves, number of branches, number, length, green and dry weight of fruits, length, fresh and dry weights of root were observed and analysed statistically and the data are presented in the Table 33.

The infected plants showed considerable reduction in most of the growth parameters (Fig.74 and 75). But the plants infected at 40-45 days showed maximum and significant reduction in growth and yield characters followed by those of plants infected at 70-75 days (Fig.76). Later infection did not significantly decrease the growth of plants compared to healthy plants.

The interaction, between age of infection x crop period did not show any significant effect on growth of chilli crop.

L. Assessment of loss in yield of Capsicum annuum cvr. Byadgikaddi due to PVMV in the field

This experiment was conducted to know how much loss would occur if PVMV spreads from a single infector plant in

Table 33: Effect of PVMV on Capsicum CVR Byadgi infected at different ages in the field

Sl. No.	Treatments: Age of initial expression of symptoms	Growth parameters per plant: Height of the plant	Girth of the stem	No.of leaves	Green weight of leaves	Dry weight of leaves	No.of branches	No.of fruits	Green weight of fruits	Dry weight of fruits	Average length of fruit	Average length of root	Fresh weight of root	Dry weight of root
	I. March to May 1980													
1	a) Healthy ..	67.38	4.10	430.4	32.64	3.49	11.2	54.8	90.76	14.98	14.98	27.2	12.16	2.85
2	b) 90 days old plant	68.60	3.66	321.2	15.88	2.09	9.6	37.2	44.34	6.02	13.66	24.0	9.66	1.93
3	c) 70 - 75 days old plant	64.90	3.22	270.8	14.02	2.15	9.4	21.6	20.96	3.17	10.86	24.8	6.58	1.61
4	d) 40 - 45 days old plant	60.30	2.96	625.0	20.90	2.41	10.4	3.0	1.78	0.30	2.40	24.7	5.98	1.68
	II. June to August 1980													
5	a) Healthy ..	78.4	4.34	511.0	35.26	5.24	12.8	66.6	112.54	17.07	15.60	27.8	14.54	3.79
6	b) 90 days old plant	73.8	3.84	418.4	18.10	3.00	11.2	32.2	58.50	7.39	14.50	26.6	11.50	3.12
7	c) 70- 75 days old plant	67.2	3.40	349.8	16.10	2.92	8.2	21.6	28.40	3.91	12.20	26.2	6.42	1.92
8	d) 40- 45 days old plant	65.2	3.30	732.4	24.40	3.68	11.6	3.8	2.56	0.30	2.80	26.8	8.88	2.33
	III. September to November 1980													
9	a) Healthy ..	64.30	4.06	519.8	32.40	3.76	12.8	55.2	100.36	14.84	15.24	28.4	13.70	2.93
10	b) 90 days old plant	64.20	3.78	386.8	16.86	2.09	11.6	37.6	49.88	5.76	14.40	24.8	9.78	2.16
11	c) 70-75 days old plant	64.72	3.12	338.0	13.36	2.50	8.2	18.4	25.20	3.18	10.74	23.0	7.76	1.65
12	d) 40-45 days old plant	58.14	2.84	725.6	22.96	2.84	12.6	1.0	0.12	0.06	1.20	21.4	6.06	1.47
	IV. December to February 1980-81													
13	a) Healthy ..	56.76	4.48	462.8	26.88	3.38	13.4	34.2	51.38	13.98	14.56	24.32	10.54	3.12
14	b) 90 days old plant	53.76	3.82	342.8	12.92	2.10	12.6	29.6	25.94	4.46	16.40	23.00	9.12	1.79
15	c) 70-75 days old plant	52.10	2.76	359.0	11.74	1.90	9.4	13.4	13.22	2.32	11.64	20.34	7.60	1.44
16	d) 40-45 days old plant	47.32	2.02	437.0	11.56	1.80	14.0	2.0	0.80	0.10	1.40	18.36	5.38	1.63
17	G.M.	62.97	3.48	451.92	20.35	2.835	11.19	27.01	39.12	6.11	10.76	25.50	9.10	2.22
18	Treatments.. ..	**	**	**	**	**	**	**	**	**	** NS	**	**	**
19	SEM for periods of the year	2.2	0.122	37.95	2.76	0.31	0.51	2.87	5.26	0.27	0.66	1.22	0.62	0.19
20	C.D. at 5 per cent	4.44	0.245	75.90	5.52	0.62	1.02	5.75	10.52	0.54	-	2.43	1.24	0.40
21	C.D. at 1 per cent	5.91	0.33	-	7.34	0.82	1.40	7.64	13.99	0.72	-	3.23	1.65	0.32
22	SEM for age infected	2.22	0.122	37.95	2.76	0.31	0.51	2.87	5.26	0.27	0.66	1.22	0.62	0.19
23	CD at 5 per cent	4.44	0.245	75.91	5.52	0.62	1.02	5.75	10.52	0.54	1.31	2.43	1.24	0.40
24	CD at 1 per cent	5.91	0.33	100.96	7.34	0.82	1.40	7.64	13.99	0.72	1.75	3.23	1.65	0.52
25	SEM for period of the year X Age infected	NS	*	NS	NS	NS	NS	*	*	*	*	NS	NS	NS
26	CD at 5 per cent	4.44	0.245	75.91	2.76	0.62	1.02	5.75	10.52	0.54	1.31	2.43	1.24	0.39
27	CD at 1 per oent	-	0.49	-	-	-	-	11.50	21.04	1.08	2.62	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-

Note: * Significant at 5 per cent; ** Significant at 1 per cent; NS = Not significant; Weight = in g; Length = in cm

Fig. No. 74. Capsicum annuum cv. Byadgi Kaddi symptoms on plants infected with PVMV.

From left to right, all are of same age

1 = Healthy
2 = Infected on 90 day after planting
3 = " " 70-75 day after planting
4 = " " 40-45 " " "

Fig. No. 75. C annuum cv. Byadgi Kaddi: stunting of roots of plants infected with PVMV

From left to right, all are of same age

1 = Healthy
2 = Infected on 90 day after planting
3 = " " 70-75 day after planting
4 = " " 40-45 " " "

Fig. No. 76. C. annuum cv. Byadgi Kaddi total number of chilli fruits per plant infected with PVMV

From left to right, all are of same age

1 = Fruits from healthy plant
2 = " " plant infected on 90 day after planting
3 = Fruits from plant infected on 70-75 day after planting
4 = Fruits from plant infected on 40-45 day after planting

Fig.74

Fig.75

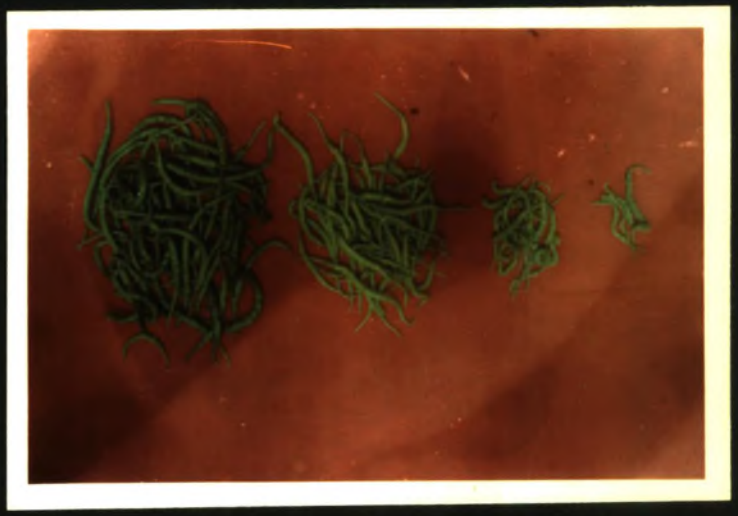

Fig.76

the centre of the plot of 100 plants and develops into an epidemic during three months' crop period. The experiment was repeated four times during 1980-81 on Hebbal farm with proper controls. At the end of each period, yield of green chilli per hectare was worked out and the results are analysed and presented in the Table 34 (Fig.77). Average green yield of chilli per plot with one infector plant of PVMV having with 68% incidence by the end of experiment gave 821.73 kg/ha, and was significantly lesser than the yield from the plot having no infector plant with 17.3% incidence recording 1237.87 kg/ha. Therefore, it accounted for a loss of 416.14 kg/ha of green chilli in the cvr. Byadgikaddi.

Chilli crop taken during the period from December to February significantly gave lower yield than the other three crops.

14) Etiology of Murda malady of chilli in Karnataka

During the survey of chilli mosaic diseases in five extensive chilli growing districts of Karnataka, this malady was discussed with the farmers and acquainted with the different terminology & different symptoms of this disease in Karnataka. Based on this background, young leaves of plants with 'Murda', symptom were carefully collected and brought

Table 34: Effect of PVMV epidemic on the green yield of Capsicum annuum cvr Byadgikaddi

Average yield of green chilli in kg/ha

Sl. No.	Treatments**	Crop period				Average	Average per cent of infection
		March to May 1980 (a)	June to August 1980 (b)	September to Nov.80 (c)	December to February 1980-81 (d)		
1	Field with source of PVMV	918.82	1062.06	875.48	430.56	821.73	68.0
2	Field without source(control)	1406.50	1636.14	1162.52	746.31	1237.87	17.3
3	Difference (Loss)	487.68	574.08	287.04	315.75		

* = Significant at 5 per cent level; ** = Significant at 1 per cent level

NS = Non-significant

1. GM = 1029.80
2. Treatments = **
3. SEM for crop periods = ** = 104.61
4. SEM for source of inoculum ** = 73.97
5. SEM for growth periods x source of inoculum = NS = 147.94
6. CD for growth period at 5% = 247.40 at 1% = 366.03
7. CD for source of inoculum = 174.94 at 5%

(1) Crop periods:

b	a	c	d
1349.10	1162.66	1019.00	588.43

(2) Field with source of inoculum:

Field with no source	Field with source of inoculum
1237.87	821.73

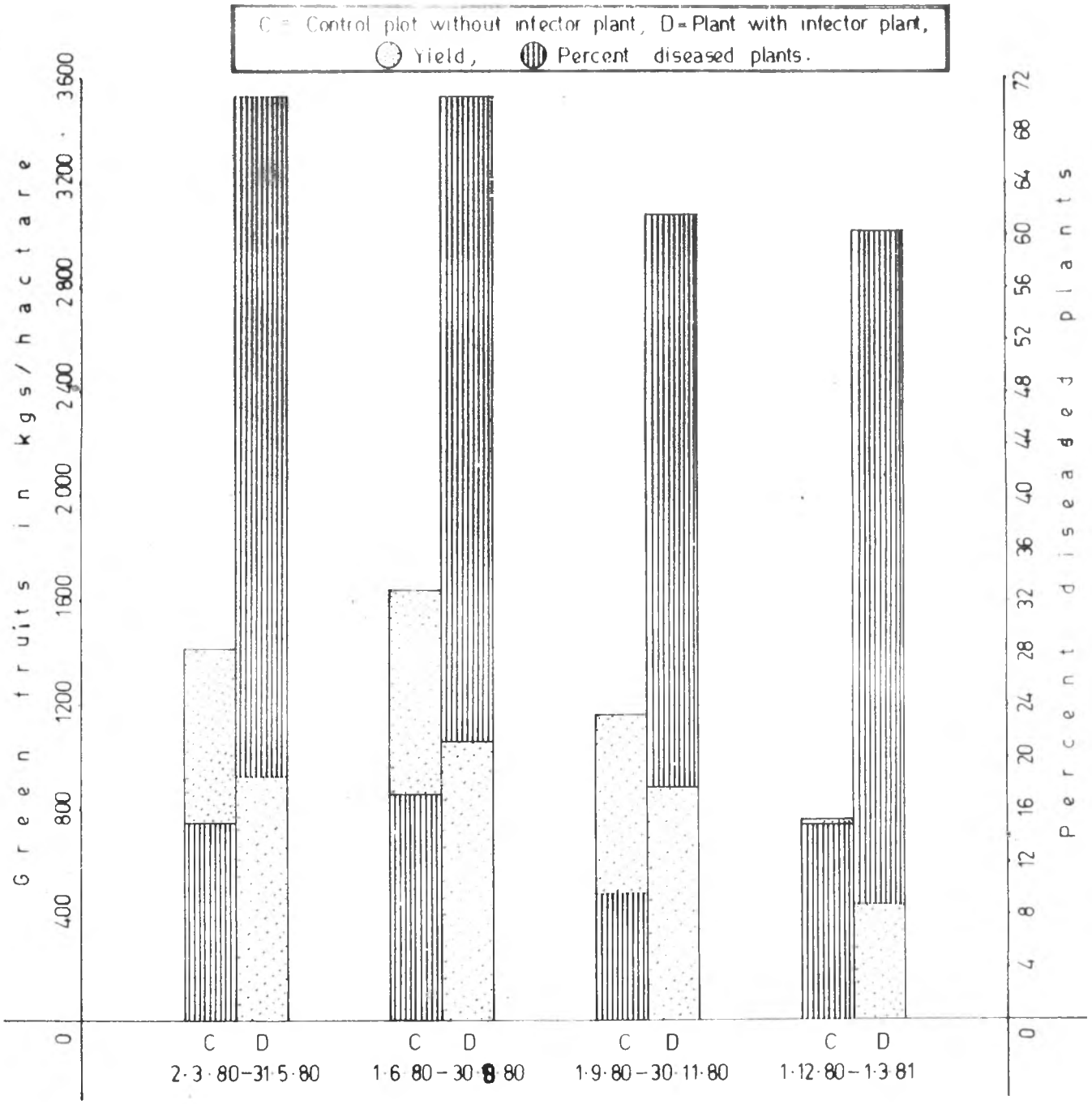

FIG.77. EFFECT OF PVMV INCIDENCE ON THE YIELD OF BYADGI CHILLI ON HEBBAL FARM DURING 1980-81

to the laboratory. A total of two hundred fifty three isolates showing malformation of leaves and stunted growth of plants were collected from different fields of five districts, Dharwad, Belgaum, Shimoga, Mysore and Gulbarga.

a) Identification of sap transmissible plant viruses from the collected isolates

The total of 253 isolates showing 'murda' syndrome in the farmers field were collected and numbered and sap inoculated on California Wonder chilli plants. Out of these 65.13 per cent isolates were successfully transmitted indicating the presence of sap transmissible viruses causing 'Murda' syndrome in the farmers field, and 34.87 per cent isolates were not transmitted indicating the presence of non-sap transmissible agents in the field. Among the districts, Dharwad collections showed 72.05 per cent transmission and least percentage of transmission of 57.89 percent was obtained with the isolates from Gulbarga district.

Further identification of individual viruses were made based on the Key used for the mosaic causing viruses in the present studies. The results are presented in the Table 35. Further confirmations of these viruses were made by studying the physical properties, insect transmission, serology and electronmicroscopy of the representative groups of the viruses. Table shows that out of 253 isolates

Table 35: Analysis of 'Murda' syndrome in Karnataka

Sl. No.	District	Total isolates collected as murda isolates	Per cent isolates showed transmissible viruses				
			Total isolates transmitted	Total isolates non-transmitted	CMV	PVY	PVMV
1	Dharwad ..	68	72.05	27.94	25.00	13.24	33.82
2	Belgaum ..	56	71.43	28.57	33.93	7.14	30.36
3	Shimoga ..	54	64.81	35.18	29.63	12.96	22.22
4	Mysore ..	37	59.45	40.54	37.84	10.81	10.81
5	Gulbarga ..	38	57.89	42.10	28.95	7.89	21.05
	Total ..	253	AVERAGE 65.13	34.87	31.07	10.41	23.65

31.07 per cent isolates belonged to CMV, 10.41 per cent to PVY and 23.65 per cent to PVMV. Out of 68 isolates collected from Dharwad district, 33.83 per cent isolates belonged to PVMV, 25 per cent to CMV and 13.24 per cent to PVY. Therefore in Dharwad district maximum isolates showing 'Murda' syndrome were due to PVMV followed by CMV and PVY which were sap transmissible viruses. Maximum isolates from Belgaum, Shimoga and Gulbarga showed CMV followed by PVMV and PVY. Maximum isolates from Mysore i.e. 37.84 percent isolates, belonged to CMV followed by PVY and PVMV.

Symptoms of each of these viruses on California Wonder and Byadgikaddi has already been described in detail under Capsicum viruses. A brief description of symptoms of each virus on California Wonder and Byadgikaddi is presented in the Table 36 (Figs.78, 79 and 80).

Out of 253 isolates collected from the field 34.87 percent isolates were not transmitted to California Wonder seedlings. This showed that there might be other factors like thrips, mites etc., which are reported to be the causes or due to other unknown factors in the field. So each factor was tested for the production of Murda syndrome.

b) Effect of Scirtothrips dorsalis

Both adults and nymphs of S.dorsalis were found in

Table 36: Description of typical symptoms induced by different etiological agents of 'Murda' malady on *Capsicum* in Karnataka

Sl. No.	Name of the agents	Symptoms
1	PVY	First vein clearing of leaves after 6-7 days of inoculation followed by irregular and discontinuous vein banding with slight upward curling, crinkling and rat tailing of leaves, plant stunted.
2	PVMV	First vein clearing of leaves after 8-10 days of inoculation followed by formation of filiform leaves with various types of deformation of leaves, plant stunted with little leaves.
3	CMV	Vein clearing started from base of leaves after 7-10 days of inoculation, slight downward curling of leaves, crinkling and mosaic mottling and in some cases rat tailing of leaves, plant is too much stunted.
4	Thrips (*Scirtothrips dorsalis*)	Most severe damage was on tender stems, buds and young leaves, characteristics curling of leaves was seen 8 days after infestation of thrips, dorsal side curling was the most important symptoms after 16 days in glass house, interveinal wrinkling and puckering of leaves. After 20 days all young leaves showed peculiar curling, thrips feed on flowers and buds which drop off, plant stunted and top dried.
5	Mites (*Polyphagotarsonemus latus*)	On young leaves as yellow chlorotic grains, curling down of the lamina to the ventral side on 15th day of infestation, such leaves were more thicker and brittle, more brown in colour and burnt appearance with more elongated petioles, stunted plant with one or two curled leaves on dead top of plant.

Fig. No. 78. Capsicum annuum cv. Byadgi Kaddi plant showing 'Murda' syndrome on inoculation with PVY
Left = Infected Right = Healthy

Fig. No. 79. C. annuum cv. Byadgi Kaddi plant showing 'Murda' syndrome on inoculation with PVMV

Fig. No. 80. C. annuum cvs. Byadgi Kaddi and California Wonder plants showing 'Murda' syndrome on inoculation with CMV
Left = Inoculated Byadgi Kaddi plant
Right = " California Wonder plant

Fig.78

Fig.79

Fig.80

sheltered boat shaped curled leaves and leaf buds. Young ones were found mostly on tender leaves. Most severe damage was observed on tender stems, buds and young leaves. The characteristics curling of leaves was seen eight days after infestation with thrips on Byadgikaddi (Fig.81). Dorsal curling, the most important symptom produced by thrips, appeared on 16th day of infestation on plants. The other characters observed were intervenal wrinkling and puckering of leaves. After 20 days, almost all young leaves showed peculiar curling. Thrips also feed on flowers and buds, which dropped off. Inoculation with sap from such leaves infested with thrips to California Wonder plants failed to produce the symptoms (Table 36).

c) Effect of mites, Polyphagotarsonemus latus

Young mite infested plants were observed by keeping them separately in small plastic cages (Fig.8) and daily records were made.

Yellow chlorotic grains on the young leaves were the first symptoms produced by mites. They caused downward curling of the lamina to the ventral side on 15th day (Fig.82) of infestation. Such curled leaves were thicker and brittle. Later these became brown in colour and exhibited burnt appearance. Such curled leaves showed more elongated petioles than the healthy leaves. Plants were stunted. After

Fig. No. 81. Capsicum annuum cv. Byadgi Kaddi plant showing 'Murda' on infestation with chilli thrips.

Fig. No. 82. C. annuum cv. Byadgi Kaddi plant showing 'Murda' on infestation with mites.

Fig.81

Fig.82

15th day of infestation these curled leaves started drying. Sap from such leaves on inoculation to healthy California Wonder and Byadgikaddi plants did not show any disease symptoms.

Such infested plants by mites and thrips when sprayed with 0.2% Kelthane and Rogar, showed significant recovery and produced healthy leaves after 15 days.

Therefore, the present analysis of etiological agents of 'Murda' revealed that there were three viruses involved in the farmers field to cause 'Murda' syndrome, and the present artificial infestation of mites and thrips also proved the syndrome found in the farmers' field. A comprehensive descriptions of symptoms by each agent on California Wonder and Byadgikaddi are presented in the Table 36. 'Murda' syndrome was found to be due to individually or together of PVY, PVMV and CMV, mites and thrips. Especially the plants infested at 40-45 days by each of the virus showed 'Murda' syndrome.

15) Preservation and storage of Capsicum viruses

The inoculum for all viruses was available by January 1980. Deepfreezed or lyophilized ampoules were prepared for all the viruses in February 1980. Per cent retention of

infectivity, tested on young seedlings of California Wonder was made, in the beginning, once in 15 days. The results of retention of infectivity at different intervals by each virus upto 450 days are presented in the Table 37.

It is clear from the table that the infectivity of PVY, PVBV and PVMV, was retained upto 180 days when fresh leaves were stored at -20°C. Infectivity of TEV and CMV was retained upto 120 days, TRSVto 60 and TSWV to 45 days of storage. Here when fresh leaves were stored at -20°C TSWV completely lost its infectivity after 45 days.

When standard leaf extract of each virus in buffer, stored directly at -20°C, most of the viruses lost their infectivity earlier than the leaves at -20°C. PVBV and PVMV retained their infectivity upto 120 days, PVY to 60, TEV to 45, CMV to 45, TRSV to 30 and TSWV to 30 days. CMV, TRSV and TSWV lost their maximum infectivity in 30 days of storage in buffered leaf extract whereas PVBV, TEV and TMV lost their maximum infectivity in 45 days of storage.

Viruses stored in lyophilized condition at -20°C retained their infectivity for longer time than the above two methods. PVBV, PVMV and TEV retained their infectivity upto 300 days, and PVBV and PVMV viruses lost their maximum infectivity after 180 days of storage whereas TEV showed

Table 37: Percentage retention of infectivity of different *Capsicum* viruses by different methods of storage

Sl. No.	Virus	Method of preservation	Days of storage							
			15	30	45	60	120	180	300	450
1	PVY	A ..	70	80	50	40	20	10	00	00
		B ..	50	30	20	20	00	00	00	00
		C ..	40	60	50	20	20	20	00	00
		D ..	80	50	30	70	40	40	20	30
2	PVBV	A ..	100	80	70	50	20	20	00	00
		B ..	70	30	30	20	10	00	00	00
		C ..	50	40	50	20	20	30	10	00
		D ..	100	90	80	30	60	60	50	50
3	PVMV	A ..	90	60	60	50	60	20	00	00
		B ..	70	30	30	50	20	00	00	00
		C ..	70	60	40	40	50	30	10	00
		D ..	60	50	90	60	50	60	50	40
4	TEV	A ..	100	100	50	20	20	00	00	00
		B ..	60	50	50	00	00	00	00	00
		C ..	70	80	30	00	30	40	50	00
		D ..	80	80	70	30	80	50	20	40
5	TMV	A ..	100	100	90	80	30	50	80	60
		B ..	100	90	60	00	20	00	00	00
		C ..	70	50	50	00	50	20	30	30
		D ..	100	80	50	40	50	50	60	60
6	CMV	A ..	100	50	00	40	20	00	00	00
		B ..	60	30	00	00	00	00	00	00
		C ..	70	80	50	50	00	30	00	40
		D ..	80	90	60	60	50	70	60	40
7	TRSV	A ..	80	70	30	10	00	00	00	00
		B ..	60	70	00	00	00	00	00	00
		C ..	50	40	00	40	30	20	00	00
		D ..	70	70	80	60	50	50	40	00
8	TSWV	A ..	30	40	20	00	00	00	00	00
		B ..	00	20	00	00	00	00	00	00
		C ..	00	30	30	00	20	00	00	00
		D ..	40	50	00	00	30	10	00	00

Note: A = Leaf material stored at - 20°C
B = Leaf extract in buffer stored at -20°C
C = Lyophilized leaf extract in buffer stored at 4°C
D = Leaf bits dried and stored over $CaCl_2$ at 4°C

its maximum infectivity, even after 300 days of storage. PVY and TRSV viruses retained their infectivity only upto 180 days. By this method, TSWV retained its infectivity upto 120 days which otherwise lost on 30th day of storage by the above method (Fig.9A).

When the leaf bits of infected California Wonder plants were dehydrated over $CaCl_2$ and stored in gelatin capsules over $CaCl_2$, most of the viruses remained active for longer period and showed more infectivity than many of the above methods. Viruses viz., PVY, PVBV, PVMV, TEV and CMV retained their maximum infectivity even after 450 days and TRSV and TSWV upto 300 and 180 days respectively.

Present results show that TSWV which lost its infectivity in a very short period could be retained its infectivity upto 180 days by dehydration of tissue and storage over $CaCl_2$ in gelatin capsules. Its maximum infection was retained even upto 120 days of storage. Therefore, among these four methods of storage of chilli viruses, tissue dehydration and storage in gelatin capsules over $CaCl_2$ at $4^{\circ}C$ was found to be superior over other methods tried here (Fig.9 B).

DISCUSSION

CHAPTER V

DISCUSSION

Survey

The survey conducted in commercial chilli growing areas viz., Dharwad, Belgaum, Shimoga, Mysore and Gulbarga districts, which included 122 fields in 28 villages of Karnataka revealed widespread occurrence of mosaic diseases on *Capsicum* Crop. A minimum incidence of mosaic disease of 11.8 per cent was recorded in Dharwad district and a maximum of 95 per cent in Gulbarga district compared to other areas. An average incidence of chilli mosaic during 1979 was 53.0 per cent in Karnataka. Further disease incidence varied from taluk to taluk in different districts. This difference may be attributed to different climatic factors, different cultivars or cultivation practices or a combination of both. It may also be due to variation in plant protection practices followed by the farmers. Some did not follow plant protection practices from the beginning. Therefore, natural incidence of chilli mosaic would have varied from field to field in the surveyed area.

A comparative study of disease incidence was also made both in rainfed and irrigated fields in Karnataka. It varied from 11.8 to 94.8 and 34.0 to 80.8 per cent in rainfed and irrigated fields respectively. The average incidence in rainfed fields was 50.13 per cent which was lower

than that in irrigated fields i.e. 58.33 per cent. This may be due to increased spread of viruses due to mechanical handling of plants during irrigation, application of manures and different intercultural practices, which are followed more intensively in irrigated crops than in rainfed crops.

Incidence of mosaic disease again varied in different cultivars in Karnataka. It was found that cultivars, Kollegal local, Nyamati, Konkani, Channagiri, Byadgikaddi, Jwala, Kasigai, Samba and Devanoor showed an average incidence of 26.9 to 40 per cent which is less than in other cultivars. Guntur variety was found to be highly susceptible showing 72.1 per cent incidence followed by Dabbi Office, Lodamugali, Umbragalli and others. Therefore, the field performance of Devanoor, Kasigai, Nyamati and Byadgikaddi was continued to be good whereas Chincholi cultivar in Gulbarga showed 64.36 per cent incidence. This difference might be due to differences in field resistance of the cultivars or crop management practiced by the farmers and also location of the field.

Field symptoms of chilli mosaic in different cultivars varied from mild to severe mottling, vein clearing, green vein banding, smalling and shoe string or rat tailing, and slight to medium cupping of leaves, and slight to severe stunting of plants. The leaf samples of diseased plants collected from the fields, when inoculated to the seedlings

of California Wonder and Byadgikaddi showed a marked differences in the symptoms from those observed in the field. This might be due to differences in the age of plants when infected in the field or due to infection by different viruses, either singly or in combination. Similar observations were made by Prasada Rao (1976) and Pandurangegowda (1979). It may also be due to differences in cultivars or climatic factors prevailed in the fields. Therefore, it is difficult to identify viruses of chilli on the basis of symptoms alone under field conditions.

Collection and establishment of virus isolates

Out of 1300 isolates collected, 80.46 per cent of isolates were successfully transmitted and produced mosaic symptoms on C.annuum cvs., California Wonder and Byadgikaddi, indicating the sap transmissible nature of the pathogenic agents. The maximum transmission of 91.00 per cent was obtained with the isolates collected from Dharwad district and least of 61.10 per cent was with the isolates from Gulbarga. The reason for non-transmission of some of the isolates might be due to presnence of factors such as non-sap inoculable leaf curl virus or due to damages by thrips and mites (Johnpulle, 1939), associated with the syndrome.

Grouping and identification of chilli virus isolates

Initial grouping of the isolates was made based on the symptoms on the seedlings of California Wonder. The virus isolates were categorised into nine groups based on similarity of symptoms. The symptoms developed in a period of one month after inoculation were considered for this purpose. Similarly, initial groupings were also made by PrasadaRao (1976) and Nandurangegowda (1979).

Further, chilli viruses could not be identified based on only symptoms in the field or in the glasshouse on a single cultivar. Therefore, initially, chilli viruses were identified by passing all the representative isolates of the groups through the selected differential hosts reported by PrasadaRao (1976), Villalon (1975), Zitter (1972), Sakimura (1940) and Pirone (1955). Accordingly nine groups were identified and numbered as G_1, G_2, G_3, G_4, G_5, G_6, G_7, G_8 and complex group G_9.

Further, confirmation of these viruses was done based on the detailed studies on host range, transmission physical properties, electron microscopy and serology with the representative isolate from each group.

Group 1

This virus was readily transmitted by sap inoculation and also by aphid vectors, A.gossypii, A.craccivora, M.persicae and H.setariae and not by R.maidis which resembled PVY reported by Mariappan et al. (1973) except for H.setariae which is an additional vector not tried by earlier workers. However, Jeyarajan and Ramakrishnan (1969) reported A.gossypii as the sole vector of PVY on chilli. This virus, on young leaves of California Wonder produced vein clearing followed by an irregular and discontinuous vein banding with slight cupping of leaves. Crinkling and rat tailing of leaves was also seen in some leaves. The symptoms, are similar to those reported by earlier workers produced by PVY on chilli (Prasada Rao, 1976; Pandurange Gowda, 1979; and Nagaraju, 1977).

It infected plant species belonging to the families, Amaranthaceae, Chenopodiaceae and Solanaceae. It produced necrotic local lesions on inoculated leaves of Chenopodium amaranticolor, C.quinoa and C.album and developed systemic symptoms on Datura metel, Physalis floridana, P.peruvianum, Petunia hybrida, Solanum nigrum, S.tuberosum, Nicotiana tabacum, cvs.'White burley' and 'Xanthi', N.rustica, N.glutinosa, C.microcarpum, C.pendulum and C.frutescence. It produced star shaped black necrotic lesions on detached leaves of Solanum demissum "A 6" potato.

This virus group had a DEP between 1:1000 and 1:5000, TIP between 55-60°C and LIV of 24 hours at 21-26°C. The DEP reported by Mariappan et al. (1973) for PVY was 1:1000 to 1:2000 and TIP of the same virus was 55°C.

The symptoms produced by this virus on Capsicum annuum resembled those produced by PVY on Capsicum reported by David and Stormer (1941) and Mariappan et al. (1973) but slightly differed from the strains of PVY on chilli reported by Rana et al. (1971) and Ragozzino et al. (1972). It also resembled PVY reported by Sakimura (1953), Jeyarajan and Ramakrishnan (1969) and Lockhart and Fischer (1974) in its host range and physical properties. The electron microscopy of the purified preparation revealed that it consisted of flexuous rods measuring 681 x 12.5 nm. This is in confirmation with that of PVY reported by earlier workers (Laird et al., 1964; Purcifull et al., 1970; Nelson and Wheeler, 1972; and Prasad Rao, 1976), as 694 mμ to 730 x 13 mμ. The slight variation in present particle morphology from the above reports may be due to the differences in the methods of purification followed or may be due to strainal variation. This virus positively reacted with the standard PVY antiserum indicating its relationship with PVY. Therefore, from the above studies, this virus has been identified as a strain of PVY.

Group 2

This virus was readily sap inoculable and transmitted by aphid vectors, M.persicae, A.gossypii and A.craccivora and not by R.maidis and H.setariae. On both the cultivars of C.annuum, it produced faint vein clearing symptoms twelve days after inoculation followed by a typical vein banding symptoms, later with various types of mosaic mottling often resulting in rat tailing. This virus had a very restricted host range limited to family solanaceae only. It produced systemic symptoms on D.metel, P.floridana, P.peruvianum, S.nigrum, N.tabacum cv. 'White burley', P.hybrida, C.microcarpum, C.pendulum and C.frutescence. It had a DEP between 1:5,000 to 1:10,000, TIP between 55-60°C and LIV of 24 hours at 21-26°C, while PVBV reported by Prasada Rao (1976) had DEP of eight hours at 21-28°C. The electron microscopy of the purified preparation of this virus showed the presenoe of flexuous rod shaped particles measuring 677 x 13 nm. The PVBV causing vein banding symptoms on Capsicum sp. similar to those of the virus group under study has been reported by Dale (1954), Simmonds and Harrison (1960), Lopezcardet and Blanco (1972). Although the virus under study resembled in its symptomatology, transmissibility through the vectors and host range, the strains of PVBV reported by Simons (1956), Bhargava and Joshi (1961), Joshi and Bhargava (1962), Prasada Rao (1976), Nagaraju (1977) and Pandurange Gowda (1979), but

it differed slightly from them in its physical properties and also not infecting N.glutinosa.

Electron microscopy studies of this virus group revealed flexuous rod shaped particles measuring 677 x 13 nm, which had close resemblance with the strain of PVBV reported by Prasada Rao (1976) 759 x 13 nm, Nagaraju (1977), 648 x 29 nm and Pandurange Gowda (1979) 450 x 20 nm. It showed positive reaction with the standard antiserum of PVBV and not with any other antisera tried indicating its relationship with PVBV. Therefore, this virus was considered as a strain of PVBV on capsicum.

Group 3

This virus was readily transmitted by sap inoculation and also by aphid vectors, M.persicae, A.gossypii, A.craccivora and H.setariae and not by R.maidis. Pepper veinal mottle virus was reported to be transmitted by these aphid species, by Lana et al. (1975), Zitter (1975) and Ong et al. (1979). Prasada Rao (1976) reported M.persicae and A.gossypii and A.craccivora by Pandurange Gowda (1979) as vectors in India. This virus produced vein clearing, mosaic mottling and filiform leaves with various types of deformities on both the cultivars of C.annuum used in these studies

The host range of this virus was restricted to the family solanaceae only producing mosaic mottling symptoms on C.microcarpum, C.pendulum, C.frutescence, P.hybrida, S.nigrum and P.peruvianum. The virus had DEP between 1:5,000 and 1:10,000, TEP between 55-60° C and LIV of 48 hours at 21-26°C. The electron microscopy of purified preparation of this virus showed the presence of flexuous rod shaped particles measuring 656 x 12.5 nm.

The viruses causing veinal mottle and other symptoms on Capsicum sp., similar to the virus group under study, have been reported by many workers as PVMV (PrasadaRao,1976; Nagaraju, 1977; Pandurange Gowda, 1979; Brunt and Kenten,1971 and Lana et al., 1975). This virus caused filiformed leaves and various types of mosaic mottling symptoms on Capsicum, P.hybrida, S.nigrum and was transmitted by M.persicae, A.gossypii and A.craocivora, and H.setariae. It also differed slightly in its physical properties from those reported by other workers.

Pepper veinal mottle virus has been reported to be transmitted by M.persicae and A.gossypii by Brunt and Kenten (1971) and also by A.craocivora (Lana et al., 1975). However, A.spiraecola and T.citricidus have been reportedas additional vectors of PVMV by Wijis (1973). In the present studies H.setariae has been found to be an additional vector. Further,

Wijis (1973) and Lana et al., (1975) reported that PVMV had a limited host range infecting Solanaceae plants only, while Brunt and Kenten (1971) reported that PVMV produced local lesions on Chenopodium amaranticolor, C.quinoa, C.murale, Tetragona expansa and Amaranthus caudatus in addition to infecting many plant species in Solanaceae.

The electron microscopic studies of this virus showed the presence of flexuous rods which closely equal to those of PVMV measuring 776 x 13 nm (Prasada Rao,1976), 648 x 29 nm (Nagaraju, 1977) and differed from those reported by Pandurange Gowda (1979) 407 x 19 nm. This virus positively reacted with the standard antiserum confirming its identity with PVMV. Therefore, the virus under study is considered as a strain of PVMV on chilli in Karnataka.

Group 4

This virus was sap inoculable and transmitted by aphid species, M.persicae, A.gossypii and A.craccivora.

The characteristic symptoms of this virus on Capsicum of both cultivars were prominent vein clearing on young leaves followed by mild chlorosis and cupping of leaves. After a month, young leaves showed green vein banding along the veins of the base of lamina and flagging of older leaves. In hot days plants

showed stuntedness with main stem much elongated. Capsicum frutescence Tabasco showed top necrosis. These symptoms agree with those described for a strain of TEV reported by McKeen (1954) on Capsicum spp.

The host range of this virus was confined to Amaranthaceae, Chenopodiaceae and Solanaceae, It produced necrotic local lesions on Chenopodium amaranticolor and C.quinoa. Infection was systemic producing mosaic mottling on Capsicum microcarpum, C.pendulum, Datura metel, D.stramonium, L.esculentum, N.physaloides, Petunia hybrida, Physalis floridana, Solanum nigrum, S.tuberosum and S.melongena. It produced mild necrotic etching on N.tabacum cvr. 'Xanthi' and 'White Burley', N.glutinosa, N.rustica and later developing mosaic mottling. The virus had DEP between 1:1,000 and 1:5,000, TIP between 60-70°C and LIV of 48 hours at 21-26°C.

The virus symptoms on Capsicum resembled those of TEV reported by other workers (Greenleaf, 1953, 1956 and McKeen, 1954). Anderson and Corbett (1957) called the disease caused by TEV as "Vein banding crinkle" in Central Florida. McKeen (1954) reported M.persicae as the principal field vector. Laird and Dickson (1963) reported M.persicae, A.gossypii, Macrosiphum solanifolii, M.pisi and A.spiraecola as vectors. Kassanis (1941) and Herold (1970) transmitted it by A.craccivora. The host range was similar to those of TEV

strains reported by several workers (Holmes, 1946; Weinbaum and Milbrath, 1976; Zitter, 1972; and Villalon, 1975). Present virus was also transmitted by A.gossypii and A.craccivora in conformity with the reports of the earlier workers. Physical properties of this virus slightly differed from those of the strains of TEV reported by other workers (Verma and Lal, 1964; Kassanis, 1941; Herold, 1970). Electron microscopic studies of this virus showed the presence of flexuous rods measuring 623 x 12 nm. The virus in its morphology and size resembled the TEV reported by above workers. Based on these characters, this virus is considered as TEV on chilli. However, the serological studies were not conducted because of the non-availability of the anti serum. Natural occurrence of TEV on Capsicum sp. has not been reported earlier from India.

Group 5

This virus was easily sap transmissible but not by any of the aphid species, tested viz., A.gossypii, A.craccivora, M.persicae, R.maidis, and H.setariae.

On sap inoculation to California Wonder and Byadgikaddi, it produced necrotic lesions on inoculated leaves followed by dark streaks on the stem, finally resulted in dropping of leaves. The plants showed various types of mosaic mottling on younger leaves and big yellow patches on older leaves.

It had a wide host range infecting many plant species belonging to families, Amaranthaceae, Cucurbitaceae, Chenopodiaceae, Fabaceae and Solanaceae. It produced chlorotic to necrotic local lesions on inoculated leaves of *G.globosa*, *Chenopodium amaranticolor*, *C.quinoa*, *C.album* and *P.vulgaris* var. Pinto, *Capsicum microcarpum*, *C.pendulum*, *Datura stramonium*, *D.metel*, and *N.glutinosa*. It produced white chlorotic specks on inoculated cotylendonary leaves of *Cucumis sativus*. It produced necrotic local lesions followed by systemic symptoms on *N.tabacum* var. 'Xanthi', whereas systemic symptoms were produced on *L.esculentum*, *Nicandra physaloides* and on *Nicotiana tabacum* var. 'White burley' initially vein clearing followed by mosaic mottling.

This virus had a DEP between 1:250,000 and 1:500,000, TIP between 95-100°C. The purified preparations of this virus under electron microscope revealed the presence of rigid rod shaped particles measuring 278 x 15 nm. The symptoms produced on chilli by this virus were similar to those of TMV reported by earlier workers (Palm, 1923; Holmes, 1937; Nakata and Takimoto, 1940; Doolittle and Beecher, 1942; Kovachevsky, 1942; McKinney, 1954; Adsuar *et al.*, 1971; Feldman and Oremianer, 1972). Green-leaf *et al.* (1964) reported a Samsun latent tobacco mosaic virus producing local lesions on *N.tabacum* var. 'Samsun' and 'Xanthi', *Nicotiana rustica*, *N.glutinosa*,

D.stramonium and C.amaranticolor which could not infect L.esculentum, and had DEP between 1:10,00,000 and 1:1,00,00,000 and TIP between 85 and 95°C. The virus under study had close resemblance with the TMV strain reported by them in host range and physical properties except the present virus was able to infect L.esculentum producing leaf distortion. This virus under study had also resembled the strains of TMV reported by PrasadaRao (1976), Nagaraju (1977) and Pandurange-Gowda (1979) on Capsicum sp. in symptomatology, host range and physical properties. It also resembles in physical properties with those of TMV reported by several workers (Nakata and Takimoto, 1940; Doolittle and Beecher, 1942; Eskarous, 1971 and Feldman and Oremianer, 1972).

The electron microscopic studies of TMV on pepper reported by Miller and Thornberry (1958) and Prasada Rao (1976) on chilli showed the presence of rigid rods measuring 300 x 15 nm and 325 x 15 nm on bell pepper by Nagaraju (1977) and 265 x 29 nm on chilli by Pandurange Gowda (1979). Present virus also showed positive reaction against standard antiserum of TMV indicating its relationship with TMV. However, it varied slightly in some of the physical properties and host range from TMV reported by other workers. Since it showed resemblance in many characters with the strains of TMV reported by the above workers, it was considered as a strain of TMV on chilli.

Group 6

It was readily transmissible by sap inoculation and also by aphid vectors, M.persicae, A.gossypii and A.craccivora and not by R.maidis and H.setariae. This virus produced vein clearing followed by mosaic mottling and later rat tailing of leaves. Leaves became small with light green colour. This virus had a wide host range infecting a large number of species in Chenopodiaceae, Cucurbitaceae, Fabaceae and Solanaceae. It produced chlorotic to necrotic local lesions on C.amaranticolor, C.quinoa, C.album and reddish brown necrotic lesions on V.sinensis var. 'Black Eye'. It produced mosaic mottling symptoms on C.sativus, N.glutinosa, N.tabacum var. 'White Burley' and 'Xanthi', N.physaloides, S.nigrum, C.microcarpum, C.pendulum and C.frutescens.

This virus had a DEP between 1:10,000 to 1:50,000,TIP between 65-70°C and LIV of 48 hours at 21-26°C. The electron micrographs revealed the presence of spherical particles with a diameter of 30 nm. Serological typing showed a clear precipitation band against standard CMV antiserum indicating its relation with CMV.

Doolittle and Walker (1923 and 1925) described symptoms of CMV on chilli which included downward curling of leaves with light green colour leading to mosaic mottling which were similar to the observations made with the virus under study.

Jha and Raychaudhuri (1956) reported chilli mosaic virus having TIP of 55-60°C, DEP of 1:25,000 - 1:30,000 and LIV of 15-22 days at room temperature and apart from other hosts, also infecting C.melo, Crotalaria juncea and carried symptomatology on Beta vulgaris. Present virus under study differed from it both in physical properties and also in its non-infectivity to C.melo, C.juncea and B.vulgaris.

This virus showed close resemblance to the virus reported by Mishra (1963) in its transmission through A.gossypii and A.craccivora and in its physical properties. It also resembled CMV strain of chilli reported by Anjaneyulu and Appa Rao (1967) in symptomatology, host range and transmission through A.gossypii and A.craccivora but differed in host range and slightly in physical properties. Szalay Marzso and Solymossy (1963) also reported the transmission of a strain of CMV on chilli through M.persicae and A.craccivora. In many characters the virus under study had close resemblance with those of the strains of CMV on chilli reported by Prasada Rao (1976), Nagaraju (1977) and Pandurange Gowda(1979).

The electron microscopy studies of the present virus indicated the presence of spherical particles with average diameter 30 nm in conformity with the measurements of CMV reported by earlier workers as 30 ± 1 nm (van Regenmortel,1961), 30 nm (Lockhart and Fischer, 1976) and 28-30 nm (Prasada Rao,

1976). The serological studies further confirmed that the present virus is related to CMV on chilli. Thus, this virus is considered as a strain of CMV on chilli.

Group 7

This virus was easily transmitted by sap inoculation, but not by aphids. It was also not transmitted through chilli seeds. This virus produced vein clearing after 6-7 days of inoculation followed by vein netting and small chlorotic rings limited by veins which later diffused into back ground with time, only on California Wonder and not on Byadgikaddi. Leaves produced later became abnormal in shape.

This virus had a DEP between 1:5,000 to 1:10,000, TIP between 60-65°C; and LIV of 24 hours at 21-26°C. This virus group had a wide host range infecting the plant species belonging to families, Amaranthaceae, Asteraceae, Chenopodiaceae, Cucurbitaceae, Fabaceae and Solanaceae.

It produced chlorotic to necrotic lesions on *G.globosa*, *Chenopodium amaranticolor*, *C.quinoa*, *V.sinensis* and *N.rustica*. It became systemic producing mosaic mottling on *Z.elegans*, *Cucumis sativus*, *C.melo*, *Cucurbita maxima*, *Capsicum microcarpum*, *C.frutescence*, *D.stramonium*, *L.esculentum*, *N.tabacum* Cvs. 'Xanthi' and 'White Burley', *Petunia hybrida*, *Physalis floridana*, *P.peruviana* and *S.melongena*.

Several workers have reported ring spots on peppers.

Nakata and Takimoto (1940) reported TMV producing ring spots which had TIP of 90°C, DEP of $1:10^6$. Doolittle and Zaumayer (1953) reported a ring spot strain of CMV which was transmitted by M.persicae and Dorsalis frangulae, and (Rao et al., 1970) reported a ring spot strain of PVX which had TIP of 72-75°C, DEP of $1:10^5$ to $1:10^6$ and LIV of 18-20 days at 20-30°C. But the present virus differs from all the above in its nature of transmission through aphids and physical properties.

However, this virus showed resemblance in some of its properties to tobacco ring spot virus isolated from Solanum capsicastrum (Smith, 1931), Anemone coronaria (Hollings,1965) and TRSV reported by McDaniel et al., (1971).

There are several reports about the transmission of TRSV by mites, nematodes (Fulton, 1962; Sauer, 1966), aphids (Shyama Rani et al., 1969; Smith, 1931), but the virus studied here differs from all the reports, in its inability to be transmitted by aphids.

TRSV from Anemone coronaria, gladiolus and brinjal had been purified and observed under electron microscopy by several workers (Hollings, 1965 and Sastry, 1974). Prasad Rao (1976) reported TRSV which produced only chlorotic small rings restricted by veins but he did mention further development of faint chlorotic ring lines after one month.

Perhaps he might have observed only small rings, or the strain under study might be a different one from that reported by PrasadaRao (1976). In many characters, the present virus resembled with those of the strain of TRSV reported by PrasadaRao (1976). The electron microscopic studies of this virus revealed the presence of innumerable number of spherical particles with an average diametre of 27-28 nm. But there are no reports of purification of TRSV from Capsicum spp. It reacted positively with the standard TRSVantiserum indicating its relation with TRSV on chilli. Thus, from the above studies it is clear that it had close resemblance with the strain of TRSV reported on Capsicum by Prasada Rao (1976) but deviated slightly in symptom production on California Wonder and physical properties. Therefore, it is considered as a strain of TRSV on Capsicum.

Group 8

This virus was transmitted by sap inoculation but at a low level of only 10-20 per cent. Only the nymphs of Thrips tabaci isolated from and maintained on onion plants transmitted it to C. annuum cvs California Wonder and Byadgi-kaddi and not by Scirtothrips dorsalis. Repeated insect transmission showed that adults of thrips did not transmit this virus.

This virus first produced pin head sized necrotic spots on inoculated leaves. Ten to twelve days after inoculation, young leaves showed chlorotic mottling with dense coalesced small rings and spots. One month old plants showed, on older leaves, small rings and concentric rings inside. The bright yellow chlorotic rings became later necrotic. Subsequent leaves became small. Fruits also showed some concentric rings. Pirone (1935) and Sakimura (1940) also made similar observations on Capsicum spp. infected with TSWV. This virus had a DEP between 1:500 and 1:1,000, TIP between 40 and 50°C and LIV of 2 hrs at 21-26°C. It had a wide host range infecting the plant species belonging to families Amaranthaceae, Boraginaceae, Chenopodiaceae, Cucurbitaceae, Fabaceae and Solanaceae producing chlorotic to necrotic spots on G.globosa, Z.elegans, Chenopodium album, C.amaranticolor, C.quinoa, Crotolaria juncea L., Pisum sativum, V.unguiculata cv. C-152, V.sinensis cv. Black Eye, Nicandra physaloides, Nicotiana tabacum cv. 'White Burley', N.rustica, Petunia hybrida, Physalis floridana and S.melongena. It produced systemic chlorotic rings on leaves 15 days after inoculation. It produced first necrotic spots which became systemic in E.sonchifolia, A.hypogaea, D.stramonium, L.esculentum, N.tabacum cv. 'Xanthi', N.glutinosa, P.peruviana and Cichorium intybus. This virus caused, first bigger brown necrotic spots with concentric markings on N.glutinosa.

These spots were very few in number on inoculated leaves and well differentiated from those produced by TMV on N.glutinosa. On L.esculentum cvr. Pusa Ruby, it produced big brown necrotic spots and later the young leaves became bronze in colour. After 2 months, young shoots produced abnormal thick leaves. On tomato fruits, it induced well developed chlorotic concentric rings. Similar observations have been made by Pirone (1935) on Capsicum and Prasad Rao et al., (1980) on tomato.

Transmission of this virus through T.tabaci and Frankliniella lycopersici and by rubbing method of mechanical inoculation with expressed plant juice was reported by Pittman (1927), Samuel et al. (1930) and Bald and Samuel (1931). Later, transmission of through T.tabaci on tomato (Todd et al., 1975), F.schultzeri and Scirtothrips dorsalis by Ghanekar et al. (1979) and S.dorsalis by PrasadaRao et al. (1980) on tomato and groundnut was reported. Gardner and Whipple (1934) reported non-transmissibility of this virus through the seeds of tomato, pepper and Datura.

Present virus isolate resembled in the host range the strains of TSWV reported by earlier workers (Gardner and Whipple, 1934; Sakimura, 1940; Ploper, 1948; Kendrick et al., 1951). According to Le (1964) TSWV had a TEP of 42-45°C DEP = 1:10000, and LIV of 5 hours at 20°C. Prasada Rao et al. (1980) reported DEP upto 10^{-3}, TIP = 45-50°C and LIV of 1-2 hours at 10-28°C of tomato isolate of TSWV.

From tomato Le (1964), Van Kammer *et al.* (1966), Milne (1970), Paliwal (1974) and Prasada Rao *et al.* (1980) had purified TSWV and observed it through the electron microscope. According to them the virus consisted of spherical shaped particles of about 70-90 nm in diameter. However, the attempts made in the present studies to purify this virus did not succeed.

From the above studies it is seen that the present virus isolate resembled in many characters with the strains of TSWV reported by earlier workers. Therefore this virus isolate has been considered as a strain of TSWV in Karnataka. Its natural occurrence on *Capsicum* sp. has not been reported earlier in India.

Development of differential key for the identification of viruses occurring on chilli

Devising differential key for the plant virus identification is a difficult proposition. This is because of the fact that many plant viruses have been incompletely characterised and secondly because of the presence of strains. Therefore, no one has been successful in devising a workable key for all the known plant viruses.

In the early days, symptomatology was the sole criterion for identification of plant viruses. As the information on the viruses began accumulating, it became

apparent that a virus could cause widely different symptoms on different host plant species. Similarly, different viruses can produce similar symptoms in a given host and that different strains of the same virus also could cause different symptoms on the same host. Moreover, the symptoms induced by a given virus strain in a given host species can vary greatly under different environmental conditions.

Cross inoculations made by Allard (1914) demonstrated that different viruses have different host ranges. Cross inoculations with other hosts combined with symptomatology on different species proved a better method for virus diagnosis rather than symptoms on the original species alone.

Brandes (1966) stated that a great number of isometric plant viruses have a diameter of about 25-30 nm. Since there is no reason why their morphological differentiation is so difficult. In such cases, the differential reactions produced on the test plants by different viruses or the different strains of the same virus are the most reliable means for identification and grouping of the viruses. Characterization of certain viruses was further made on the basis of methods of transmission and physical properties in crude plant sap.

It is important to determine host range while describing or identifying new virus isolates. But this property of virus seems to be not quite correlated, with its other properties. Gibbs and Harrison (1976) stated that even closely related viruses may have totally different host ranges. However, certain widely used test plants are important for virus identification.

Attempts were made by previous workers to differentiate and identify various viruses based on host range and differential host reactions (Pierce, 1935; Krylov, 1969; Senevirthe and Fosnette, 1970; Milbrath and Cook, 1971 and Zitter, 1972). Some of the other workers studied insect transmission and physical properties in addition to differential reactions (Ainsworth, 1935, 1940; Cohen and Nitzany, 1963; and Horvath, 1969). Differential reactions and serology alone were used by a few others (Gooding and Todd, 1967; Zitter, 1973; Makkouk and Gumpf, 1974 and Gooding, 1975; Gabrial et al., 1977). Differential host plants reaction only were used to differentiate and identify legume viruses (Hampton, et al., 1978).

Serology and electron microscopy in addition to host reaction or physical properties or both were also used by other workers (Kaitosowa, 1969; Milne et al., 1969; Demski,

1973; Lastra and Uzcategui, 1975; Marco, 1975). There are reports about the differential reactions of a single host plant differently to different viruses. For example, Datura stramonium reacts by producing local lesions to TMV, systemically to CMV, PVX and TEV and immune to PVY. Reactions on D.stramonium and C.frutescens var. Tabasco were used in differentiating PVY and TEV on chilli (Zitter, 1971; 1972; Mukkouk and Gumpf, 1974). Potato (A-6) alone was found to be very useful in differentiating PVA, PVX and PVY occurring on potato (Bokx, 1972). Gooding (1975) used Nicotiana tabacum cvr. Burley 21, Cucumis sativus cvr. National Pickling and D.stramonium for initial grouping of the viruses occurring on tobacco in North Carolina and later used serology for their identification. Kiriyama and Nishimura (1969) used 11 test plants and serological tests for the identification of tobacco viruses occurring in North Eastern Japan. Prasad Rao (1976) used 5 differential hosts, C.amaranticolar, C.sativus, N.physaloides, N.glutinosa and D.metel for identification of six chilli viruses. Madhusudan (1978) used three hosts C.sativus, L.esculentum and D.stramonium to differentiate six tobacco viruses.

Any differential key based on any single criterion may not be of practical utility. However, taking one criterion as standard and testing it against the other available characteristics may prove useful. The idea to use a set of

differential hosts to identify the viruses of chilli was taken mainly because of the existence of several viruses on chilli. Therefore, in the present studies a differential key consisting seven differential host plants has been evolved to differentiate and identify 8 Capsicum viruses, occurring in Karnataka. The reactions of these test plants were cross checked with the other characteristics like transmission, electron microscopy and serology. The differential host plants used in this key were selected after inoculating a large number of host plants and their reactions studied. The plants selected for the key are - Chenopodium amaranticolar, Cucumis sativus, Nicandra physaloides, Nicotiana glutinosa, Capsicum annuum cvr. California Wonder, Datura stramonium and D.metel. Viruses were categorised into eight groups on the basis of symptoms developed as under:

A. Chlorotic/Necrotic local lesion on Chenopodium amaranticolor

B. Systemic mosaic mottling on Cucumis sativus

C. Systemic mottle coupled with crinkled puckering and filiform leaves on Nicandra physaloides .. .. CMV

CC. No reaction on N.physaloides .. .. TRSV

BB. No systemic mosaic mottling on C.sativus

D. Systemic mosaic with puckering, blistering and deformation of leaves of Nicotiana glutinosa .. .. PVY

DD. Necrotic local lesion on N.glutinosa

E.	Concentric yellow rings on both leaves and fruits of Capsicum annuum cvr. California Wonder	TSWV
EE.	Bright yellow patches on young leaves of C. annuum cvr. California Wonder ..	TMV
DDD.	Systemic mosaic mottling with filiform leaves on Datura stramonium ..	TEV
AA.	No reaction on C. amaranticolar ..	
F.	Vein clearing followed by mosaic mottling and filiform leaves on Datura metel ..	PVBV
FF.	No reaction on D. metel ..	PVMV

Repeatedly new virus isolates from the field were collected and inoculated to the differential hosts in order to test the diagnostic key. The efficacy of this diagnostic key was cross-checked by serology. It was found that the differential key was efficient in identifying the commonly occurring eight Capsicum viruses so far known in the state.

Distribution of viruses causing chilli mosaic in Karnataka

Present studies showed the natural occurrence of nine groups of chilli viruses viz., PVY, PVBV, PVMV, TEV, TMV, CMV, TRSV, TSWV and mixture of TMV + CMV on Capsicum sp. in commercial chilli growing areas of Karnataka.

The percentage incidence of these in the fields has been worked out. The most prevalent was PVBV accounting

for 19.08 per cent followed by CMV (13.15 per cent), PVMV (12.38 per cent), TMV (9.92 per cent), PVY (9.61 per cent), TEV (5.46 per cent), TRSV (5.38 per cent), TSWV (3.38 per-cent) and mixture of TMV + CMV (2.08 per cent). The per-centage occurrence of these viruses in five districts of commercial chilli growing areas revealed that PVBV was more prevalent in Shimoga (23.05 per cent) followed by Mysore (21.15 per cent), Dharwad (20.98 per cent), Belgaum (16.97 per cent) and Gulbarga (11.11 per cent). Further among different districts, except Gulbarga in all the districts the maximum occurrence was of PVBV, whereas in Gulbarga maximum was that of CMV (18.18 per cent). While TSWV was less prevalent with a maximum of 5.90 per cent in Belgaum and 4.63 per cent in Dharwad district. However, it was least in Shimoga (1.17 per cent) and Gulbarga (1.51 per-cent). Mixed infection of TMV + CMV was found to be maximum in Belgaum (5.9 per cent) and Mysore (2.4 per cent). How-ever, it was not observed in Gulbarga district.

Again, the distribution of these viruses in diffe-rent taluks of each district varied from taluk to taluk. Chilli cultivar, Yedakota showed maximum infection by PVBV followed by Konkani, Samba, Channagiri, Nyamati, Byadgi Dabbi and DH 7-6-6. Some cultivars had all the viruses and some others showed a very few of the viruses. Devanoor and Sankeshwar cultivars showed maximum infection by TSWV compared

to others. Chilli cultivars, Dabbi office, Kollegal local and Gundakai showed maximum infection by TMV whereas Konkani, Sankeshwar, Raibag local, Umbragalli and Jwala showed maximum infection by mixture of TMV + CMV.

Prasad Rao (1976) reported the occurrence of six chilli viruses in addition to TMV + CMV mixture on Capsicum in South India, PVMV being the most prevalent one followed by PVY,CMV, TRSV, PVBV and TMV in the surveyed area. Nagaraju (1977) reported the occurrence of four viruses on bell pepper around Bangalore. According to him, PVMV was the most prevalent one followed by PVBV, TMV and CMV. According to Pandurange-Gowda (1979), in Kolar district, the most prevalent virus was PVBV (32.53 per cent) followed by PVY, PVMV, TMV and CMV. In the present studies, eight viruses in addition to the mixture of TMV + CMV, were found in commercial chilli growing areas of Karnataka, including the additional viruses (TEV and TSWV) over six viruses reported by Prasada Rao (1976). PVBV was more prevalent than other viruses on Capsicum in Karnataka. Similarly, Pandurange Gowda (1979) also reported that PVBV to be more prevalent than the other viruses on Capsicum in Kolar district.

Differences in the occurrence of different viruses in different cultivars were studied and analysed. This aspect was studied by the earlier workers. This survey throws light

on the occurrence of different viruses on all the important popular chilli cultivars.

Varietal reaction to severe strain of PVBV

After comparing the effect of few isolates of the most prevalent PVBV the most severe isolate was selected as a severe strain based on its reaction on the popular cvr. Byadgikaddi and used in this study.

Chilli cultivar, Mysore selection showed only vein clearing even after reinoculation showing tolerance to severe strain of PVBV.

Genotype Pentha C-1 (Top) was found to be moderately susceptible. The remaining were either susceptible or very susceptible to severe strain of PVBV. Jha (1953) reported that chilli varieties NP-20 and NP-23 as more resistant to chilli mosaic virus than the other 52 varieties. Anand et al. (1961) have screened 132 varieties of chilli belonging to six different species and reported that varieties Puri red, Puri orange, Kondiverum, G2 and a local variety were resistant against chilli mosaic. Ramanujam et al. (1965) reported that Puri red showed high resistance to leaf mosaic. Pant C-1 and Pant C-2 were found to be resistant to leaf curl virus (Mathai et al., 1971). Singh (1973) screened 105 different varieties and 5 species of chilli

against chilli mosaic and reported that puri red, puri orange, G2, Kondiverum and Suryamukhi as resistant. Selections made from NP-46A x Puri red is known to be mosaic resistant and has been released as 'Jwala' in 1973 (Tewari and Ramanujam, 1974; Tewari and Anand, 1977). However all these genotypes reported by earlier workers to be resistant to one or the other virus were not found tobe resistant or tolerant to PVBV in this study.

Effect of severe strain of PVBV on growth of Capsicum cultivars

There has been no report of any systematic study conducted in India with regard to effect of any virus causing chilli mosaic on the growth parameters of chilli cultivars. In the present study effect of severe strain of PVBV virus in Karnataka on the growth with respect to flowering; height; girth; number, green and dry weight of leaves, number of branches, number, length and green and dry weight of fruits, length, fresh and dry weight of roots of different chilli cultivars was investigated.

The results showed that the severe strain of PVBV significantly reduced the growth of the chilli cultivars with varying degrees. Usually the virus infected plants showed 1-16 days delay in flowering and also stunted growth.

Chilli genotypes, Pentha C-1 (Top), Perennial conical, Mysore selection, Line 7 Green Sel-2, EC 127967, X200, Line 9 Green Sel-4, Line 13 Green Sel-2 and NP46A were found less affected due to infection compared to others.

DH7-6-6 did not produce fruits at all and some cultivars viz., G4 and X 197 were stimulated to produce more axillary branches and became stunted and bushy in appearance. Byadgi (Kungagol) which is a commercial cultivar in Karnataka showed 94.74 per cent reduction in its green weight of fruits per plant due to infection. Among all the cultivars, Mysore selection was found to be least affected.

There are reports on the reduction of growth of chilli due to PVY infection (Jeyarajan, and Ramakrishnan, 1961). Aillaud (1971) reported the production of abnormal flowers of chilli plants due to CMV infection. TEV reduced the fruit yield of bell pepper from 6-53 per cent (Villalan, 1972). Joshi and Dubey (1977) reported less moisture and more dry matter content of chilli plants infected with CMV compared to healthy plants.

Marsh et al. (1977) studied the effect of PVMV on Capsicum and reported that inoculated plants produced smaller, lighter and distorted fruits which ripened unevenly. It caused losses of 46-90 per cent depending upon time of

inoculation. Same thing is also true with the present results where in Byadgi (Kundagol)cv. the green weight of fruits was reduced upto 94.74 per cent.

According to Tiwari and Anand (1977), most of the cultivated varieties of chilli in India are susceptible to chilli mosaic virus and tobacco leaf curl virus. The highly resistant Jwala (NP 46-A x Puri red) gave significantly higher dry fruit yield than NP 46-A due to chilli mosaic in field (Tewari and Anand, 1977). In the present studies, the severe strain of PVBV significantly affected the growth of the chilli cultivars and the effect varied with different varieties suggesting that there is a great degree of variability available in chilli germplasm and there is possibility of getting resistant genotypes for many of the viruses occurring on chilli. In these studies, Mysore selection appears to provide resistance to PVBV.

EPIDEMOLOGY

A. Population dynamics of different aphid species and aphid vectors on Hebbal farm

Aphids form the largest group of vectors among the insects transmitting the plant viruses. About three hundred species are involved as plant virus vectors (Mandahar, 1978). We have little detailed understanding of stability and change in field populations of aphids but only certain features of

aphid population dynamics have been revealed (Dixon, 1977). Since most of the plant viruses studied are known to be transmitted by aphids (Kennedy et al., 1962; Harris and Maramorosch, 1977) in order to know the prevalence of different aphid species and aphid vectors on Hebbal farm, aphids were trapped daily and collected once in five days from 17th March, 1980 to 12th March, 1981.

Different aphid species were identified and population counted and presented in Table 29 and Fig.67 . During the year of collection thirty two different aphid species were encountered on the farm. Among them, population of A.craccivora was maximum followed by A.gossypii, Aphis spp., A.fabae, M.persicae, A.spiraecola and Myzocallis polychaetus and revealed as major forms on Hebbal farm followed by others. However, in some aphids viz. R.nymphaeae, N.circumflexus, H.prunii, G.artocarpi and D.compositae only one individual was trapped in each case in a year. It is seen that, flight of A.craccivora could be observed from 8th September to 1st May, but was absent during May to July 1980, maximum during November 1980. Population of A.gossypii was uniform throughout the year and showed maximum population during November to February. A.fabae was observed throughout the year but was absent between 11th May and 10th August.

Population of M.persicae was completely absent from

1st May to 23rd September 1980; otherwise its flight was observed in other periods irregularly.

Srivastava et al. (1971) reported that the population of M.persicae, A.gossypii and A.fabae increased from fourth week of January to fourth week of February in plains. In most of the aphid spp, peak period of flight was during the months of November, March and April of 1980. Pandurange-Gowda (1979) reported the maximum flight of aphids during September to November and from January to March 1978 on Hebbal farm. Gonzalez and Rawlins (1969) reported the capture of peak number of alates including M.persicae in Moericke traps in New York during August and September.

The total number of aphid species trapped were grouped as vectors of plant viruses based on latest references made by Carter (1973), Mandahar (1978) and Maramorosch (1969) are presented in Table 24. Totally seventeen aphid species of the collection were identified as vectors of plant viruses and they were found to be more in number than others. Among the vectors, A.graccivora was found in maximum numbers followed by A.gossypii, A.fabae, M.persicae, A.spiraaecola, R.maidis, R.padi, H.coriandri, H.setariae, A.nerii, B.brassicae, T.citricidus, T.aurantii, A.nastartii, R.nymphaeae, N.circumflexus and H.pruni. Based on the literature, among vectors

trapped M.persicae comes first in transmitting maximum number of plant viruses followed by A.fabae, N.circumflexus, A.gossypii, B.brassicae, A.craccivora, A.nastartii, R.maidis and A.spiraecola followed by others (Table 24). On Hebbal farm common viruses, viz., CMV, PVMV, PVY, TEV and PVBV are found on Capsicum.

Harris and Maramorosch (1977) reported A.fabae, A.gossypii, M.persicae and T.aurantii as more polyphagus aphids. The enormous reproductive potential and behavioural patterns of aphids ensure their wide dispersal among population of virus host plants. Therefore, polyphagus aphids are better fitted than oligophagous aphids for field spread of many aphid borne viruses (Kennedy et al., 1959). Ong et al. (1979) studied the aphid vectors of PVMV in Peninsular Malaysia viz., A.craccivora, T.citricidus, A.spiraecola, A.gossypii, M.persicae, R.maidis and H.setariae, which were responsible for field spread of chilli virus. Laird and Dickson (1963) also reported the field spread of TEV and PVY in Southern California by M.persicae, A.gossypii, and A.spiraecola. Danko and Praslicka (1969) studied the occurrence of aphids particularly M.persicae and A.nastartii and their importance as vectors of CMV on Capsicum. Mariappan et al. (1973) reported A.gossypii, A.craccivora, A.nerii and and M.persicae as vectors of PVY of chilli and A.gossypii as

most efficient vector. In Poland, Gabriel (1961) found A.nastartii to be a more important vector of PVY than M.persicae. In contrast, Rasocha (1966) in Czechoslovakia reported M.persicae as more important vector than A.nastartii in potato plots. In the present studies, A.craccivora, A.gossypii, A.fabae, and A.spiraecola were found to be the important vectors of plant viruses on Hebbal farm. However, M.persicae though reported to be an important vector in population it stood fifth in the present studies.

Attempts were made to correlate total number of aphid spp. trapped, aphid vectors of plant viruses and vectors of chilli viruses and some important individual aphid vectors reported so far, with several meteorological factors collected from meteorological observatory in Hebbal farm.

a) Total population of aphid species

The increase in population of aphid species was positively correlated with high, maximum and minimum temperature, relative humidity at 07.20 and 14.20 hours, sunshine and evaporation at one per cent level and was negatively correlated with wind speed.

b) Total aphid vectors of plant virus

The increase in population of aphid vectors of plant viruses was positively correlated with high relative humidity

at 07.20 and 14.20 hours but was significant only with minimum temperature. Maximum temperature and wind speed only showed significant negative correlation with the population of aphid vectors of plant viruses.

c) Total aphid vectors of Capsicum viruses

Total population of aphid vectors of Capsicum viruses showed positive correlation with relative humidity at 07.20 and 14.20 hours but was significant only at 14.20 and not at 07.20 hours. Population of aphid vectors of Capsicum viruses showed negative correlation with the remaining meteorological factors but showed significant correlation only with maximum temperature and evaporation.

d) Population of A.craccivora and A.gossypii

Population of A.craccivora and A.gossypii showed positive correlation only with relative humidity at 07.20 and 14.20 hours but was not significant. Population of these two species of aphids showed negative correlation with the remaining factors but showed significant only with maximum temperature, wind speed and evaporation.

e) Population of A.fabae

Population of A.fabae showed positive correlation only with minimum temperature and negative correlation with the remaining meteorological factors.

f) Population of A.spiraecola

This showed positive correlation only with rainfall, relative humidity at 07.20 and 14.20 hours but was insignificant.

g) Total population of Aphis spp.

Here total population of all species of Aphis showed positive correlation with all meteorological factors studied except wind speed. The correlation was insignificant with rainfall, sunshine and evaporation.

The present results support the observations made by Delong and Mathewson (1925), Davies (1935), Thomos and Vevail (1940), Broadbent (1949), Stapley (1949) and Dixon (1973).

Broadbent (1949) observed low population of aphids in humid regions in wet season and claimed that high humidity probably affected the population by depressing multiplication rather than inhibiting flight.

Delong and Mathewson (1925) reported that high humidity combined with low temperature was apparently the most important combination of factors for retarding the development of aphids. Optimum conditions were high temperature and low humidity. The present findings agree with the

observation of Delong and Mattewson (1925). Stapley (1949) reported that aphid migration takes place under certain conditions where temperature was not lower than 65°F and humidity not higher than 70 per cent. Rainfall was found to be negatively correlated with aphid population which supports the statement made by Dixon (1973) that pea aphids feeding on buds, stem and on upper surface of leaves were greatly reduced.

Extraordinary weather conditions, particularly temperatures can have a marked effect on aphid numbers. Wind and rain have a greater effect on aphid numbers. Natural enemies can influence the rate of build up of aphids and by interacting with other factors can shape the dynamics of certain aphid species (Dixon, 1977).

Factors affecting movement of vectors are a complex of biotic and physical factors. For the aphids, Davies (1935) demonstrated with controlled laboratory experiments, that high humidities inhibited flight of M.persicae and temperatures from 70° to 90°F were the most favourable. Carter (1961) reported that changes in humidity to a lower level increased the activity, but aphids adjusted to humidities between 50 and 80 per cent, and flew readily at these humidities and temperatures of 80°F. High humidity and high temperature (90°F) some times inhibited flight. Carter (1961) reported

that forty three, twenty and eleven took off per minute of B.brassicae with full sunshine, thin clouds and dense clouds respectively. Swenson (1968) reported that the lowest temperatures at which any aphid was observed to take off was 15.5°C.

In most of the cases aphid flight was maximum during the months of November, March and April, 1980, when the weather factors were congenial for aphid flights. Present results agree, with the reports of the above workers. And A.craccivora came first in its population and A.gossypii was found throughout the year uniformly on Hebbal farm. M.persicae though an important vector, its occurrence on Hebbal farm was erratic and loses its importance as a major vector on the farm.

B. Infection presure of different Capsicum viruses on Hebbal farm during 1980-81

This was studied to know the occurrence of different viruses on the farm at different periods during the year. It was observed that totally five aphid transmitted and two non-aphid transmitted viruses occurred during 1980-81. Among the aphid transmitted viruses, maximum was of PVY followed by CMV, PVBV, PVMV and TEV.

There were two peak periods of infection by all the aphid borne viruses on the farm during the year, one was

during the months from March to May, and second was during the months from October to January. There was least infection during the months of July, August and September on the farm, that might be due to high rainfall and high humidity of 90 per cent which inhibited the aphid flight. Infection pressure of individual aphid transmitted viruses followed the same pattern as that of total number of aphid-transmitted viruses. There was constant pressure of PVBV and PVY throughout the year suggesting that these two viruses are more prevalent in this area. However, in distribution in the surveyed area, these two viruses rank 1st and 5th respectively. Incidence of PVMV and CMV was however, not found in the month of June and July respectively. Tobacco etch virus was found only in the months of March, October and December.

Infection pressure of all the aphid transmitted viruses on the farm showed positive correlation with the total population of aphids, aphid vectors of plant viruses, aphid vectors of Capsicum viruses, A.craccivora, A.gossypii, A.fabae, A.spiraecola and total number of Aphis spp. Similarly, infection pressure of PVBV at different months also showed positive correlation. Potato virus Y showed positive correlation only with the population of A.spiraecola and total population of Aphis spp. No correlation was found with the population of M.persicae which occurred only from 23rd September to 7th March and was scattered. Only A.craccivora, A.gossypii and

A.fabae were found to be in large numbers throughout the year. However, A.gossypii an early appearing aphid occurred in tremendous numbers and showed marked coincidence in its population with spread of viruses in the field.

Flying aphids will land on any available plant regardless of species and they are unable to distinguish host plants from non-hosts before landing (Muller, 1962). Host selection occurs after arriving on plant surface (Swenson, 1968). The numbers and distribution of infected plants with aphid borne viruses reflect the numbers and activity of aphid vectors (Swenson, 1968). These are responsible for the general dissemination of non-persistent plant viruses.

Occurrence and development of insect transmitted viruses in field depends on the appearance and the build up of the vector population in nature (Danko and Praslicke, 1969; Gonzalez and Rawlins, 1969; Srivastava et al., 1971 and Zitter, 1971).

Gonzalez and Rawlins (1969) observed the relation of aphid population to the field spread of lettuce mosaic virus in New York. Larger number of infected plants were detected only in late August and September, the time at which the greatest number of alates were captured. The other workers found that aphid numbers alone do not indicate the likely incidence of a particular virus (Plumb, 1976; Dickson and

Laird, 1959). Other factors considered important are the high potential and early migration associated with aphid vectors (Gill, 1970), the direction of aphid migration (Adlerz, 1978) and the long distance flights of viruliferous aphids (Wallin and Loonan, 1971).

van Hoof (1977) studied the infection pressure of PVY^{VN} in a crop of ware potatoes in the centre of Netherlands by using tobacco plants as baits and said that aphid species other than M.persicae were responsible for the infection observed. Further, that R.padi and Acyrthosiphum pisum flew much earlier than M.persicae and were vectors of PVY^{VN}. The infection pressure of non-persistent PVY not only depended on the type and prevalence of its sources of infection but also on its spread from the sources. In Poland Gabriel (1961) found A.nastartii to be a much more important vector of PVY, then M.persicae. In contrast, Rasocha (1966) in Czechoslovakia noted the correlation between the occurrence of PVY in tobacco bait plants and flight of M.persicae but not that of A.nastartii during 1962-64 in potato plants. Van Hoof (1979) studied the infection pressure of PVY in plots with beet, wheat and seed potatoes. No differences were found either between PVY^{N} infection in the border and that in the middle of a field, planted with ware potatoes. Van Hoof (1979) reported the spread of PVY

before the flight. In the present study also incidence of chilli viruses was found before the flight of aphid vectors on the farm. By these studies the more important vectors were found to be A.craccivora and A.gossypii than M.persicae. Further, infection pressure of the viruses can be studied more efficiently by use of the California Wonder trap plants than by trapping aphids alone is indicated.

C.Nature of spread of PVMV in field

Chilli virus, PVMV which is severe in Karnataka was studied for its spread keeping a single infector plant in the centre of the field along with few aphids of M.persicae. This was repeated by taking four crops of three months duration each during 1980-81.

There was 1 to 5 per cent diseased plants with a single infector plant in the centre after 24 to 36 days of planting of the chilli in each of all the four crops taken in a year. By 37 to 42 days, spread was from 8 to 21 per-cent and it was 38.5 to 60.5 per cent between 67 to 73 days of planting and maximum spread was found in March to May (60.5 per cent) and least was in September to November crop (38.5 per cent). After 90 days of planting, the spread of PVMV was 60 to 70.5 per cent the later being in March to May and June to August Crops compared to other two periods.

Rate of spread of PVMV in the chilli crop taken in four periods during 1980-81 was worked out by taking observations once in five days. In the beginning there was faster rate of spread of PVMV. By 24 to 36 days of planting of chilli, rate of spread was 32-36.34 per cent per day. After 37 to 42 days of planting the rate of spread was only 4.03 to 13.46 per cent per day and it was 2.09 to 6.21 percent between 67 to 73 days of planting. At 90th day of planting the rate of spread of PVMV calculated in the Capsicum crop taken during March to May, September to November and December to February came down to 1.64 to 2.2 per cent per day. The rate of spread per day became smaller as more number of diseased plants were available in the field which is in agreement with the reports of earlier workers. Spread of virus in the field depends on movement of vectors, from a nearby infected source and in this respect M.persicae is found to be a good vector as reported by Bald et al. (1946).

The rate at which the virus spreads between plants varied widely according to the type of virus, crop environment and mode of transmission. The spread of many viruses among woody plants is relatively slow (Thresh, 1974a).

Nature of PVMV in chilli field was studied by using the formula of vander Plank (1946). In the beginning i.e.

between 24 and 36 days of planting, the actual number of doublets were found to be nonsignificantly lesser than the expected number of pairs. Immediately after next five days, it proved that the spread was internal in all the four crop periods. Thereafter, at subsequent, five day interval upto 90 days after planting there was a good evidence that significant spread from plant to plant was within the crop. These results are in agreement with the reports of many workers (Puranik et al., 1973; Hollings, 1960; and Deshpande et al., 1972).

Some viruses are known to spread both into and within the crops and nearby infected plants soon became foci for secondary spread (Thresh, 1974a).

In the present studies, chilli plants harboured totally eight different aphid spp. A.craccivora, A.gossypil, M.persicae, A.spiraecola, H.setariae are known vectors of chilli viruses among them. They also might have involved in the secondary spread of PVMV in the field in addition to M.persicae, which was initially liberated.

Further, an analysis of the occurrence of viruses causing the disease in the affected plants at the end of each crop period in control plots as well as those with infector plants showed on an average that there were 8.30

per cent plants showing PVY, CMV and TEV viruses, 2.35 per-cent with PVY and CMV viruses respectively.

By this, it is evident that for the spread of the disease in the plot not only the aphids which were initially liberated in the plots were responsible but also others which came in from outside. However, the role of others bringing in the viruses was very low as evidenced by the data (Table 31).

Considering the total population of PVMV in plots with the source and without the source the pattern of spread was like that within the plots with the infector plant. However, such diseases seldom spread for long in a manner closely analogous with the logarithmic increase of capital at compound rates of interest. With virus diseases, the total amount of infection usually increases in a sigmoid manner with time (Thresh, 1974a). Thresh (1974b) reported the early appearance and rapid spread of non-persistent viruses depending upon the occurrence of local sources of infection within the crop or nearby distribution of such primary infection determines the pattern of spread.

Initial phase of spread is truely logarithmic in virus diseases when the number of new ifections that appear is directly proportional to the total number of infections

already present. Values of 'r' i.e., rate of spread, are usually greatest during early spread when there is a progressively increasing number of infected plants from which further spread can occur and a corresponding decrease in the importance of outside source. Spread is facilitated especially in annuals, by increasing the plant size and also the number and activity of vectors (Thresh, 1974a).

i) Effect of PVMV infection on chilli, at different ages of growth

Plants of Byadgi chilli in the field were tagged as infected at 40-45, 70-75, and 90 days of ages and studied their agronomic parameters. Plants infected at 40-45 days showed significantly lesser in most of growth characters. In most of the cases, plants infected at 90 days of age, did not show any significant decrease in growth over those of healthy plants. But the plants infected at 40-45 days showed maximum reduction in growth and yield followed by those of plants infected at 70-75 days and later infection did not significantly decrease the growth of plants compared to healthy plants.

Imoto (1975) reported less yield when the crop was infected during early growth. Similarly, Prasada Rao (1976) also reported that plants infected at early stages were severely affected.

ii) Assessment of losses in yield of chilli cvr. Byadgi Kaddi due to the epidemic of PVMV in the fields

This was studied to know how much loss would occur if PVMV spread from a single infector plant in the field developing into an epidemic in three months period. At the end of each period, yield of green chilli per ha was worked out. It is clear from the Table 34 that green yield of Byadgi Kaddi chilli with one infector plant of PVMV in the centre of the plot with 65 per cent incidence gave 821.73 kg/ha which was significantly lesser than the plot having no infector plant with 17.3 per cent incidence which gave 1237.87 kg/ha yield. Therefore, there was a loss of green chilli of 416.14 kg/ha of Byadgi Kaddi having one infector plant in the centre of the field during three months period.

Etiology of 'Murda' malady of chilli in Karnataka

Identification and grouping of sap transmissible isolates collected, into different viruses confirmed that out of 253 isolates 31.07 per cent isolates belonged to CMV, 10.41 per cent to PVY and 23.65 per cent to PVMV and the rest were non-sap transmissible. Out of the isolates collected from Dharwad district showing 'Murda' syndrome maximum were due to PVMV followed by CMV and PVY. Maximum isolates from Belgaum, Shimoga and Gulbarga were found to be CMV followed by PVMV and PVY. Maximum isolates from Mysore belonged to CMV followed by PVY and PVMV.

The term murda refers to various malformations of leaves and the plant in chilli. Involvement of thrips and mites in most cases, viruses in rare cases in the cause of this malady in Karnataka was quoted by Puttarudraiah (1959). White fly transmitted leaf curl virus was reported by Hussain (1932), Vasudeva (1954), Mishra et al. (1963), Capoor (1967) and Dhanraj et al. (1968).

Moghe (1971) investigated the causes of 'Churda murda' disease. Symptoms described by him included curling, crinkling mottling and puckering of leaves. He confirmed the causes of this as due to thrips and mites and some times infection was accompanied by a virus serologically related to CMV.

From the present investigations it can be definitely established, for the first time that two more viruses, PVY and PVMV to cause Murda syndrome in fields in addition to CMV and tobacco leaf curl viruses reported by earlier workers.

Among the isolates collected from different areas many isolates failed to be sap transmissible. Since these isolates were discarded, thrips and mites from chilli were used in the investigations to find out the difference if any in symptoms from those produced by CMV, PVY and PVMV.

Nymphs of Scirtothrips dorsalis when transferred to healthy chilli seedlings produced specific 'Murda' symptoms. The thrips were found to be sheltered in boat shaped curled leaves and leaf buds which were the result of their own infestations. They were found to cause severe damage on tender stems, buds and young leaves. According to Ramachandra Rao (1929), S.dorsalis caused twisting and deformation of leaves when successive leaves were attacked, the plants became stunted and dried (Park and Fernando, 1939).

Polyphagotarsonemus latus mites when enclosed on chilli seedling caused yellow chlorotic graining on young leaves followed by downward curling of lamina on 15th day of infestation, and other abnormalities.

Amin (1979) demonstrated that murda symptoms could be caused by thrips and mites by artificial infestation and further stated that they were the only causes of murda. However in the present investigation it is clearly established that thrips, mites, CMV, PVY and PVMV, all can cause independently 'Murda' symptoms and on closer observation the symptoms can be differentiated from one another (Table 36). However, symptoms produced by these agents in combination were not studied.

Thrip and mite induced leaf curl is due to mechanical injury to the leaf surface and perhaps also by a toxic substances introduced by the thrips and mites with the saliva into the leaf, during feeding (Peiris, 1944, 1953). Hence, the 'Murda' syndrome by mites and thrips is easily controlled by spraying chemicals like Rogar and Kelthane whereas virus infected plants are not cured by these chemicals. Moreover virus cause may be prevented by spraying insecticides (Puttarudraiah, 1959).

Preservation and storage of Capsicum viruses

This was studied to know the best method of preservation and storage of chilli viruses, for further laboratory experiments. The results showed that PVY, PVBV and PVMV retained their infectivity upto 180 days when fresh leaves were stored at -20°C, however, TSWV completely lost its infectivity after 45 days. When standard leaf extract of each virus in buffer stored directly at -20°C, most of the viruses lost their infectivity earlier than the above method. Viruses when stored in lyophilized condition at -20°C their infectivity lasted longer than the above two methods. PVBV, PVMV and TEV retained their infectivity upto 300 days. PVBV and PVMV viruses lost their maximum infectivity after 180 days of storage, whereas TEV showed its maximum infectivity even after 300 days of storage. PVY and TRSV viruses

retained their infectivity only up to 180 days. By this method, TSWV retained its infectivity up to 120 days.

When the leaf bits of infected California Wonder plants were dehydrated over $CaCl_2$ and stored in gelatin capsules over $CaCl_2$, most of the viruses retained for longer period and showed more infectivity than any of the above methods. Viruses viz., PVY, PVBV, PVMV, TEV and CMV, retained their maximum infectivity even after 450 days and TRSVand TSWV up to 300 and 180 days respectively.

Present results showed that TSWV which had lost its infectivity in 45 days could retain its infectivity up to 180 days by dehydration of tissue and storage over $CaCl_2$ in gelatin capsules. Its maximum infection was continued even up to 120 days of storage. Therefore, among these four methods of storage of chilli viruses, tissue dehydration and storage in gelatin capsules over $CaCl_2$ at 4°C was found to be simpler and superior over other methods.

According to Dewijs and Bachmann (1979) freeze drying is superior than deep freezing in PVY and remained active for 4 years at 4°C. A simple but effective of preserving many plant viruses is to dehydrate infected tissue chemically near 1°C (McKinney et al., 1965). Chemical

dehydration of virus containing plant tissue, a virus preservation method developed by McKinney et al. (1965) proved to be as good or even better for the long term preservation of PVY and several viruses (Bos, 1969) than freeze drying of clarified sap but a decrease in infectivity still occurred with PVY and other viruses. Bos (1969) published some successful results gained in Netherlands with a collection of 21 plant viruses in leaf material very simple dried and stored over $CaCl_2$.

SUMMARY

CHAPTER V

SUMMARY

1. The survey conducted to find out the incidence of chilli mosaic revealed that incidence ranged from 11.8 to 94.8 per cent with an average of 53.0 per cent. On an average the incidence was lowest in Shimoga (40.62 per cent) followed by Dharwad, Belgaum, Mysore and Gulbarga districts of Karnataka.

2. The average incidence of mosaic was lower in rainfed crop (50.13 per cent) than in irrigated crop (58.33 percent).

3. Among the popular commercial chilli cultivars grown in Karnataka, the average incidence of mosaic was least in cvr. Nyamati (35.71 per cent) and highest in cvr. Chincholi (64.36 per cent).

4. A total of 122 fields distributed in 28 villages in the above districts were visited and a total of 1,300 isolates of which 367, 271, 256, 208 and 198 were collected from Dharwad, Belgaum, Shimoga, Mysore and Gulbarga districts respectively. Of these 80.46 per cent of isolates were successfully sap transmitted while the others were not.

5. Based on the studies on insect transmission, reaction of host differentials, physical properties, electron

microscopy and serology, eight groups of viruses were identified as PVY, PVBV, PVMV, TEV, TMV, CMV, TRSV and TSWV and the ninth group was found to be a mixture of TMV and CMV.

5a. Potato virus Y(G_1) produced faint vein-clearing off the young leaves followed by mosaic mottling, irregular vein-banding in the cultivars, California Wonder and Byadgi Kaddi. Some leaves developed dark green raised blisters with slight upward bending, crinkling and rat tailing. It was transmitted by Myzus persicae, Aphis gossypii, A.craccivora and Hysteroneura setariae. Host range was confined to Amaranthaceae, Chenopodiaceae and Solanaceae. The virus had DEP of 1:1,000 to 1:5,000; TIP of 60-65°C and LIV of 24 hours. The purified preparation contained flexuous rods measuring 681.0 x 12.5 nm and was serologically related to PVY.

5b. Pepper vein-banding virus (G_2) produced a very faint vein-clearing on young leaves followed by dark green continuous vein-banding, various types of mosaic mottling of leaves, and stunted growth in both the cultivars of Capsicum. It was transmitted by M.persicae, A.gossypii and A.craccivora. The virus had a restricted host range limited to Solanaceae. It had DEP of 1:5,000 to 1:10,000; TIP of 55-60°C and LIV of 24 hours. The purified preparation

revealed flexuous rods measuring 677 x 13 nm and was serologically related to PVBV.

5c. Pepper veinal mottle virus (G_3) produced vein-clearing followed by mosaic mottling, later developing dark green patches in an irregular fashion on the leaves and subsequently distortion. Lateral buds produced filiform leaves and plants were severely stunted. It was transmitted by M.persicae, A.gossypii, A.craccivora and H.setariae. The virus had a restricted host range confining to a few species of Solanaceae. This had DEP of 1:5,000 to 1:10,000; TIP of 60-65°C and LIV of 48 hours. The purified preparation of the virus contained flexuous rods measuring 656 x 12.5 nm and was serologically related to PVMV.

5d. Tobacco etch virus (G_4) produced in both the cultivars a prominent vein-clearing of young leaves. Later they became mildly chlorotic with prominent to moderate cupping. In some cases, leaves showed marginal waviness and flagging of older leaves and elongation of the main branch. This virus was transmitted by M.persicae, A.gossypii and A.craccivora. Host range of this virus was confined to Amaranthaceae, Chenopodiaceae and Solanaceae only. It had DEP of 1:1000 to 1:5000, TIP of 65-70°C and LIV of 48 hours. The purified preparation of the virus revealed the flexuous rods measuring 623 x 12 nm.

5e. Tobacco mosaic virus (G_5) produced necrotic lesions on inoculated leaves within 3-4 days after inoculation which dropped later. The necrosis extended to the stem along the petiole. Plants which survived, were pale, chlorotic and developed yellowish irregular patches on leaves. The virus was not transmitted by any of the aphids tested. It had a wide host range infecting several species belonging to Amaranthaceae, Chenopodiaceae, Cucurbitaceae, Fabaceae and Solanaceae. It had DEP of 1:250,000 to 1:500,000, TIP of 90-100°C and LIV of 11 weeks at laboratory conditions. The purified preparation contained rigid rods measuring 278 x 15 nm and serologically related to TMV.

5f. Cucumber mosaic virus (G_6) produced vein-clearing of the young leaves, followed by mosaic mottling and in some cases exhibiting rat x tailing. This was transmitted by M.persicae, A.gossypii, and A.craccivora. It had a wide host range infecting plant species belonging to Chenopodiaceae, Cucurbitaceae, Fabaceae and Solanaceae. It had DEP of 1:10,000 to 1:50,000; TIP of 65-70°C and LIV of 48 hours. The purified preparation revealed spherical particles with diameter of 30 nm. It was serologically related to cucumber mosaic virus.

5g. Tobacco ring spot virus (G_7) produced vein-clearing on young leaves followed by small chlorotic rings limited by veins which later turned into wavy lines. Plants were not

much stunted. The virus was not transmitted by any of the five aphids tested. It had a wide host range infecting the species in Amaranthaceae, Asteraceae, Chenopodiaceae, Cucurbitaceae, Fabaceae and Solanaceae. It had DEP of 1:5,000 to 1:10,000; TIP of 60-65°C and LIV of 2½ hrs. The purified preparation confirmed presence of spherical particles with diameter of 27-28 nm. It was serologically related to tobacco ring spot virus.

5h. Tomato spotted wilt virus (G_8) produced on inoculated leaves a few scattered pin head necrotic spots five days after inoculation followed by mosaic mottling with dense small rings and spots. Older leaves showed concentric yellow rings which later became necrotic. Fruits of pepper also showed such chlorotic concentric rings. It was transmitted by the nymphs of Thrips tabaci from onion and not by any of the aphids tested. It had a wide host range infecting plant species belonging to Amaranthaceae, Asteraceae, Boraginaceae, Chenopodiaceae, Fabaceae and Solanaceae. It had DEP of 1:500 to 1:1,000, TIP of 45-50°C and LIV of two hours. Attempts made to purify the virus were not successful.

6. A differential diagnositic key was developed with h seven different hosts viz., Chenopodium amaranticolar, Cucumis sativus, Nicandra physaloides, Nicotiana glutinosa,

Capsicum annuum cv. California Wonder, Datura stramonium and D.metel to identify the eight viruses.

7. Studies on distribution and prevalence of chilli mosaic viruses in Karnataka revealed that PVBV to be most prevalent followed by CMV, PVMV, TMV, PVY, TEV, TRSV, TSWV and mixed viruses (TMV and CMV). Pepper vein banding virus was more prevalent in Dharwad, Belgaum, Shimoga and Mysore districts, whereas CMV was more prevalent in Gulbarga district than other viruses. Variation in the prevalence of these viruses in different taluks in each district and in different cultivated varieties was observed in the five districts.

8. Effect of severe isolate of PVBV on Capsicum genotypes varied among themselves against this virus. Genotypes, IC 13256, LEC 27, Line 6 Green Sel-2, Line 8 Green Sel-3, NP 46-A, Pentha C-1 (Top), Perennial conical and Puri red showed better performance against this isolate. Only one genotype, Mysore selection was found to be tolerant and the rest were either susceptible or very susceptible.

9. Analysis of growth parameters influenced by the severe strain of PVBV revealed that the infection involved reduction in height of plant, girth of stem, number, green and dry weight of leaves and fruits and delayed flowering to

a very great extent in many of the varieties tested. However, in one variety flowering was advanced by three days.

10. Studies on population dynamics of different aphid species and aphid vectors on Hebbal farm from the 17th March 1980 to the 12th March 1981 revealed the occurrence of 32 different aphid species. Among the aphids, population of Aphis xx craccivora was maximum followed by A.gossypii, Aphis spp., Myzus persicae and others. Flight of A.craccivora was observed from 8th September to 1st May. Population of A.gossypii was uniform throughout the year. In most of the aphids, peak period of flight was during the months of November, March and April 1980.

11. Among the aphid species prevalent on Hebbal farm, totally 17 aphid species were found to be the vectors of plant viruses, of which, Aphis craccivora, A.gossypii and A.fabae were found in maximum numbers throughout the year. Among the 17 species, Myzus persicae, A.fabae, Neomyzus circumflexus and A.gossypii are reported to transmit maximum number of plant viruses.

12. On Hebbal farm, CMV, PVMV, PVY, TEV and PVBV are the common aphid-borne viruses found on chilli cultivars.

13. Correlation study was also carried out between total population of aphids, aphid vectors of plant viruses

and chilli viruses and also important individual aphid vectors, and the weather factors on Hebbal farm. In most of the cases, these showed positive correlation with high temperature and relative humidity but showed negative correlation with the wind speed.

14. Studies on infection pressure of different chilli viruses on Hebbal farm during the year revealed the occurrence of five aphid transmitted viruses (TRSV and TSWV non aphid) Among the aphid transmitted viruses, maximum pressure was of PVY followed by CMV, PVBV, PVMV and TEV. Aphid-borne viruses had two peak periods, one during March to May and the other in October to January. There was constant pressure of PVBV and PVY throughout the year. Infection pressure of all the aphid transmitted viruses occurred at different months showed positive correlation with population of aphids. Aphis gossypii, an early appearing aphid vector occurred in large numbers and showed coincidence between its population and pressure of viruses. Aphid transmitted viruses were recorded earlier than the appearance of alates of aphid spp. in good numbers.

15. Nature of spread of PVMV in the field of cv. Byadgi-Kaddi was studied during 1980-81 on Hebbal farm. Studies on spread of PVMV in chilli starting with a single infected

plant along with initial population of M.persicae in plots of 100 plants each was made. The comparision with control plots without infector plant revealed that the spread was more of internal nature and greater in plots with initial source of viruses and vectors. Secondly the rate of spread was fast in the beginning after the introduction of inoculum source but became slower with time as the number of plants infected went on increasing.

16. Inspite of barrier crops of sorghum and Sunhemp there was introduction of viruses by vectors into the plot as evidenced,by: (a) the incidence of mosaic in control plots without the source, (b) Occurrence of other aphid transmissible viruses in the experimental plots. (c) Presence of different species of aphids other than M.persicae which was introduced initially.

17. Studies on the age of plants at the time of infection of chilli on yield revealed that the crop experiences higher yield loss if infected early, before 40-45 days and lower when infected between 70 and 75 days and negligible when infected 90 days after planting.

18. Studies on loss per hectare in a plot of chilli infected by PVMV revealed that on 90 day old crop when the

incidence was 68 per cent, the yield determined was 821.17 kg/ha as compared to 1,237.87 kg/ha in a plot having only 17.3 per cent incidence.

19. It is clearly established that 'Murda' syndrome comprising generally of many abnormalities of leaf and plant are caused by thrips and mites, and tobacco leaf curl and cucumber mosaic viruses reported earlier. The present investigations revealed that potato virus Y, and pepper veinal mottle virus are also responsible in causing this type of syndrome. Though the gross symptoms are confusing, it is possible to differentiate the symptoms produced by each one separately in glass house.

20. Among the four methods of preservation and storage of chilli viruses studied, tissue dehydration and storage in gelatin capsules over $CaCl_2$ at 4°C was found to be superior followed by lyophilization.

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CHAPTER VII

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* Original not seen

APPENDICES

APPENDIX I

Table 1: Area and production (kg/ha) of chillies and peppers (Green Chilli) in different countries (Anonymous, 1979)

	Area '000 ha	Production '000 tons	Kg/ha
World ..	1716	7182	7497
Africa ..	124	1032	6980
Nigeria ..	68	620	9119
Tunisia ..	35	128	3657
Ghana ..	23	70	3043
Egypt ..	10	165	15894
North Central America	80	780	9735
Mexico ..	53	474	8943
USA ..	22	248	10908
Canada ..	3	32	11250
South America ..	18	155	8706
Argentina ..	8	79	11000
Peru ..	8	14	5538
Bolivia ..	2	4	1952
Chile ..	2	23	10952
Asia	1318	3097	5228
India ..	826	511	619*
China ..	142	1340	9443
Korea ..	70	112	1600
Pakistan ..	52	82	1577
Srilanka ..	50	43	780
Turkey ..	47	480	10213
Japan ..	4	186	42318
Europe	152	2117	13914
Yugoslavia ..	40	340	8500
Spain ..	28	537	19179
Romania ..	22	182	8273
Italy ..	20	486	24831
Hungary ..	18	200	11111
Bulgaria ..	17	260	15291
Greece ..	3	39	13133
USSR ..	60	677	11738

*Dry ripe chillies

Table 2: Area and production of dry chillies in different States and Important districts of India : 1979-80

		Area '000 ha	Production '000 tons	Kg/ha
ANDHRA PRADESH	..	158.5	162.4	1025
Kamman	..	17.1	17.0	994
Guntur	..	16.0	23.6	1475
Warangal	..	14.9	11.4	765
Krishna	..	12.7	13.8	1086
Karimnagar	..	12.4	14.6	1177
Kurnool	..	8.9	8.1	910
Adilabad	..	8.5	5.1	600
Nellore	..	7.8	12.6	1616
Mahbubnagar	..	7.7	4.9	636
W.Godavari	..	7.5	7.2	960
Prakasam	..	7.0	11.1	1585
MAHARASHTRA	..	148.8	74.0	498
Nagpur	..	25.0	2.8	112
Nanded	..	18.7	5.7	305
Chandrapur	..	10.9	3.9	358
Osmanabad	..	9.7	3.4	350
Kolhapur	..	8.2	1.9	231
Dhule	..	7.5	6.0	800
Aurangabad	..	6.8	2.7	397
Amaravati	..	6.4	6.7	1046
KARNATAKA	..	139.3	41.8	300
Dharwad	..	60.3	14.4	239
Belgaum	..	14.4	6.6	458
Shimoga	..	11.8	0.6	51
Mysore	..	7.5	0.6	80
Chitradurga	..	5.4	1.5	278
Gulbarga	..	5.3	8.0	-
TAMILNADU	..	108.8	82.9	762
Ramanathpur	..	32.0	21.3	666
Tirunalveli	..	26.0	25.7	988
Tiruchanapalli	..	18.0	11.4	630
Madurai	..	8.0	6.5	812
Coimbatore	..	4.0	1.4	350
ORISSA	..	68.4	44.7	654
Koraput	..	10.7	8.3	776
Cuttack	..	9.3	5.3	570
Kalahandi	..	8.6	3.6	419
Sambalpur	..	7.0	5.4	771
MADHYA PRADESH	..	48.6	6.6	136
West Nimar	..	5.2	1.0	192
Dhar	..	4.0	0.5	150
Shohajpur	..	3.5	0.3	86

Table 2 - (Contd.)

	Area '000 ha	Production '000 tons	Kg/ha
RAJASTAN	48.6	6.6	136
Jodhapur	4.9	1.2	245
Chitorgarh	3.7	1.0	270
Kotah	3.4	1.2	253
Jhalwar	3.3	0.7	212
UTTAR PRADESH	22.3	8.1	363
Farrukhabad.. ..	4.4	1.4	318
Kanpur	1.8	0.6	333
Moradabad	1.6	0.5	312
Kheri	1.4	0.8	571
GUJARAT	13.1	8.4	641
Bhavanagar	1.8	1.1	611
Jamanagar	1.3	0.8	615
Kaira	1.2	0.9	750
BIHAR	12.9	11.3	876
Samastipur	4.4	2.5	568
Begasarai	2.4	2.8	1167
HARYANA	12.2	13.0	1065
Karnal	3.4	3.7	1088
Sonepat	2.1	2.3	1095
Ambala	2.1	2.0	952
ASSAM	10.5	6.2	590
Kamrup	2.7	1.6	593
Goalpur	2.1	1.3	619
PUNJAB	10.7	9.1	850
Patiala	3.1	-	-
Sangrur	2.5	-	-
HIMACHAL PRADESH	0.8	0.2	250
Siramapur	0.2	0.1	500
KERALA	1.2	1.1	917
Cannanore	0.8	0.7	875
JAMMU AND KASHMIR... ..	1.2	0.3	250
Srinagar	0.4	0.1	250
MANIPUR	2.5	1.5	600
INDIA	826.3	510.9	618

Table 3: Area and production of dry chillies in India in different years

Year	Area '000 ha	Production '000 tons	Kg/ha
1964-65	716	475	663
1965-66	634	364	574
1966-67	921	418	580
1967-68	788	501	636
1968-69	663	899	601
1969-70	682	895	579
1970-71	783	520	664
1971-72	753	494	656
1972-73	682	412	603
1973-74	789	497	673
1974-75	686	441	642
1975-76	740	526	711
1976-77	781	419	586
1977-78	791	543	687
1978-79	806	638	792
1979-80	826	511	618

Table 4: Area, total production and average yield of chilli crop during different years in Karnataka in different districts

	Name of the district	1973-74			1974-75			1975-76			1976-77			1977-78			1978-79	
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B
1	Bangalore	2331	636	273	2517	687	273	2378	649	273	2509	687	274	2620	655	250	2953	782
2	Belgaum	11559	15145	501	11890	5624	473	13251	6135	463	14640	7013	479	16965	7108	419	14196	6417
3	Bellary	1991	438	220	1970	592	255	2000	488	244	2444	587	240	2293	289	126	2215	622
4	Bidar	1931	425	220	1856	386	208	1972	402	204	1692	357	211	1757	371	211	1734	361
5	Bijapur	3268	464	142	3413	358	105	3364	316	94	3278	374	114	3736	560	150	3936	457
6	Chickmagalur	3499	773	221	3197	703	220	3649	803	220	3349	737	220	3895	1363	350	3869	1018
7	Chitradurga	9363	5618	600	9312	4172	448	7263	3987	549	3124	1662	532	3150	1474	468	9626	3215
8	Dakshina Kannada	3302	2077	629	3436	2941	594	3752	2184	582	3746	2255	602	3756	2261	602	3946	2340
9	Dharwad	35990	8709	242	40973	9792	239	44654	10620	238	51769	12425	240	51215	12292	240	53957	12896
10	Gulbarga	4794	1242	259	5269	933	177	5766	1026	178	5740	1177	205	5778	1184	205	6069	1135
11	Hassan	3864	3080	797	3973	3190	803	4085	3252	796	3034	2424	799	3784	1374	363	4081	2669
12	Kodagu	244	65	268	256	69	269	326	92	273	344	93	270	268	115	430	353	114
13	Kolar	2501	370	148	2326	337	145	1800	268	146	1772	259	146	1740	826	475	1862	540
14	Mandya	1199	480	400	1345	504	375	1323	504	381	963	371	385	1116	485	435	1535	626
15	Mysore	6325	2992	473	5735	2667	465	6102	2758	452	5891	2728	463	5588	2587	463	8217	3780
16	Raichur	2913	565	194	2414	451	187	2650	509	192	2795	534	191	2555	1047	410	2636	793
17	Shimoga	13941	4851	348	12143	5197	428	12223	4645	380	9980	3842	385	9038	3480	385	12376	4926
18	Tumkur	4497	881	196	4925	906	184	4933	888	180	3678	688	187	4530	1078	238	4594	960
19	Uttara Kannada	488	181	371	397	158	319	499	161	325	515	174	338	499	169	338	500	165
	Total..	114000	39638	348	117446	38677	329	122000	39690	325	121263	38387	317	124283	38718	335	138655	43816

Note: A = Area in hectare
B = Production in tonnes
C = Yield in Kg/ha

Table 5: Irrigated area under chilli crop in Karnataka during different years in hectares

Districts	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78
1	2	3	4	5	6	7	8	9
Bangalore	2567	482	436	448	537	1285	1171	1043
Belgaum	6548	3692	3137	3057	3184	4674	5101	5280
Bellary	1127	986	875	888	846	461	533	753
Bidar	942	43	44	42	239	409	622	478
Bijapur	3356	3215	1712	3073	3413	3364	3278	3488
Chickmagalur	-	18	91	261	127	118	48	169
Chitradurga	1109	1075	1190	1287	1154	1053	714	1394
Coorg	-	-	-	-	-	-	-	12
Dharwad	1010	412	412	430	474	4386	2187	2074
Gulbarga	4729	2144	508	1174	1754	2056	1903	2273
Hassan	-	-	-	-	-	-	-	-
Kolar	1827	2234	2375	2314	2134	1712	1730	1576
Mandya	-	-	-	-	-	-	4	48
Mysore	1864	1116	894	828	688	704	599	458
Uttara Kannada	72	48	45	47	60	36	36	31
Raichur	2293	1387	1433	1718	1741	2143	1942	1847
Shimoga	270	370	395	419	425	236	150	25
Dakshina Kannada	3495	2357	2206	2263	2260	2485	2473	2625
Tumkur	3138	1791	1862	2088	1991	1909	1445	1270
State	33947	21370	17615	20337	21027	27031	23936	24844

Table 6: Total area under chilli in different taluks of Gulbarga district in hectares during 1977-78

Sl. No.	Taluks	Area		Taluks	Important chilli growing villages
1	Afzalpur	384	1	Aland	Lodmugali
2	Aland	850			Aland
3	Chincholi	2020	2	Chincholi	Chimmanuchode
4	Chittapur	820			Chincholi
5	Gulbarga	500	3	Chittapur	Kalgi
6	Jewargi	216			Chittapur
7	Sedam	141			
8	Sahapur	129	4	Sedam	Neelhalli
9	Shorapur	95			Malakhed
10	Yadgir	293			
	Total	6069			

Table 7: Total area under chilli in different taluks of Shimoga district in hectares during 1977-78

Sl. No.	Taluks	Area		Taluks	Important chilli growing villages
1	Bhadravathi	236	1	Channagiri	Mavinkatti
2	Channagiri	3868			Hebbligeri
3	Honnali	3523			Dummi
4	Hosanagar	-			Kalkeri
					Narashettihalli
5	Sagar	50	2	Honnali	Savalanga
					Nyamathi
6	Shikaripur	3095			Honnali
7	Shimoga	1048	3	Shikaripur	Hosur
8	Soraba	1189			Nellikoppa
					Koggu
9	Tirthahalli	-			Shikaripur
	Total	13009	4	Shimoga	Kommin alu
					Bannikere
					Honnikeri
					Boodigere
			5	Soraba	Kuppagadde
					Hoya
					Hasbi
					Jadi
					Bommanalli

Table 8: Total area under chilli in different taluks of Dharwad district in hectares during 1977-1978

Sl No.	Taluks	Area		Taluks	Important chilli growing villages
1	Byadagi	4547	1	Byadagi	Byadagi
2	Dharwad	1985			Gumanahalli
3	Gadag	953			Teredahalli
4	Hangal	3487	2	Dharwad	Hebballi
5	Haveri	9768			Maradgi
6	Hirekerur	8949			Pudukalkatti
7	Hubli	6558			Karadiguddi
8	Kalaghatagi	1189			Yadawad
9	Kundagol	8722			Lakmapur
			3	Haveri	Haveri
10	Mundargi	282			Alakatti
11	Naragund	212			Devagiri
12	Navalagund	1318			Negalur
13	Ranebennur	1069			Hosaritti
14	Hona	246	4	Hirekerur	Hirekerur
15	Savanoor	4939			Masoor
16	Shiggon	1977			
17	Shirahatti	2021	5	Hubli	Hubli
					Bidanal
					Adaraguncchi
	Total ..	58222			Sherewad
					Halyal
			6	Kundagol	Kundagol
					Devanoor
					Kubyal
					Yeliwal

Area in thousand hectares under dry chilli crop in Dharwad district

1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	77-78
31.2	79.9	34.7	34.1	35.9	40.9	44.6	51.7	58.2

Table 9: Total area under chilli in different taluks of Mysore district in hectares during 1978-79

Sl. No.	Taluks	Area		Taluks	Important chilli growing villages
1	Chamarajanagar	372	1	H.D.Kote	Umbragalli
2	Gundlupet	795			H.D.Kote
3	H.D. Kote	680	2	Kollegal	Sandanpalle
4	Hunsur	882			Kollegal
5	Kollegal	585	3	Mysore	Yedakota
6	K.R.Nagar	108			Nagawala
7	Mysore	942			Marballi
8	Nanjanagud	1795	4	Nanjangud	Basavatagi
9	Periyapatna	648			
10	T.Narasipura	162			
11	Yelandur	18			
	Total	6987			

Table 10: Total area under chilli in different taluks of Belgaum district in hectares, during 1977-78

Sl. No.	Taluks	Area		Taluks	Important chilli growing villages
1	Athani	1601	1	Bailhongal	Bailhongal
					Nesaragi
2	Bailhongal	1433	2	Belgaum	Belgaum
3	Belgaum	1480			Sambra
					Balekundri
4	Chikkodi	2094	3	Chikkodi	Chikkodi
5	Gokak	1136			Nippani
6	Hukkeri	3678	4	Hukkeri	Hukkeri
7	Khanapur	703			Sankeshwar
8	Raibag	1386			Neroli
9	Ramadurga	73	5	Raibag	Raibag
10	Soundatti	456			Nagaral
	Total	14,045			