STUDIES ON OKRA (BHENDI) YELLOW VEIN MOSAIC VIRUS

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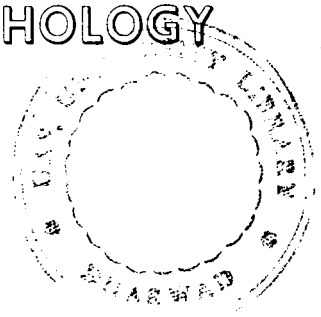

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CERTIFICATE

This is to certify that the thesis entitled "**STUDIES ON OKRA (BHENDI) YELLOW VEIN MOSAIC VIRUS**" *submitted by* **Mr. ZULFEQUAR AHMED,** *for the degree of* **MASTER OF SCIENCE (AGRICULTURE)** *in* **PLANT PATHOLOGY** *to the University of Agricultural Sciences, Dharwad, is a record of research work carried out 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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" . . . . . gratitude is the memory of the heart "

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Introduction

I. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench), also called as Bhendi, or Lady's finger, belongs to family Malvaceae, is one of the important vegetable crops grown extensively throughout the tropical, subtropical and warm sections of the temperate zones of the world (Charrier, 1984). Although okra thrives well under irrigated conditions during warm moist or hot summer season in light type of soils with fairly high organic matter content.

Bhendi is said to be a native of South Africa and has been predominantly a vegetable of the tropics (Thompson and Kelley, 1957). Originally it might have been present in Africa and India as a polyphyletic species, because its semi wild ancestor *Abelmoschus tuberculatus*, occurs in India (Grubben, 1977).

Fruits are eaten boiled or in culinary preparations as sliced and fried pieces and also used for thickening soups and gravies because of its high mucilage content. Okra fruits can be sliced and sun dried or canned and pickled for off season's use. Matured fruits and stems containing crude fibre are used in paper industry. Mucilaginous extracts of the green stem are commonly employed in India for clarifying sugarcane juice and in 'gur' industry. Sometimes, the seeds are roasted and used as a substitute for coffee (Martin, 1982).

Okra has good nutritional value, particularly for the high content of vitamin C (30 mg/100 g), calcium (90 mg/100g) and iron (1.5 mg/100 g).

The edible fruit (Basu and Gosh, 1943; Pal *et al.*, 1982) is valuable in the diet of the people of the developing countries where they depend on cereal crops in which vitamins and minerals are lacking. Dry seeds of okra contain 18 to 20 per cent of oil and 20 to 30 per cent crude protein (Berry *et al.*, 1988). It is a potential export earner, accounting for 60 per cent of export of fresh vegetables (Sharma and Arora, 1993) and also has export possibilities for canned products in European markets, especially during the winter months (Gopalkrishna Rao, 1974).

In India, it is grown on an area of 4.31 lakh hectares with a production of 40.33 lakh tonnes (Suresh Kumar, 2000). In Karnataka it occupies an area of 13,484 ha with 1,17,985 tonnes production of which Bangalore district alone accounted for 1,136 ha and 9,440 tonnes production (Anonymous, 1999).

Low yield in bhendi may be because of a number of diseases. Among several diseases, bhendi yellow vein mosaic is one of the most severe diseases which takes a heavy toll of the crop in India (Capoor and Varma, 1950; Muniyappa, 1980; Singh, 1980). The disease was first reported in Bombay by Kulkarni (1924). Viral nature of the disease was established by Uppal *et al.* (1940) and they gave the name "Yellow Vein Mosaic". The disease is now widespread in sub-tropical regions during rainy season from June to September and in tropical region during spring and summer crops from February to June (Capoor and Verma, 1950; Singh *et al.*, 1962, Sastry and Singh, 1974). In Karnataka, the disease is

more serious when sowing is carried out from January to May (Singh, 1980).

The yield loss due to the virus ranged from 50-90 per cent depending on stage of crop growth at which infection occurs (Sastry and Singh, 1974). Sinha and Chakrabarthi (1978) observed 86.00 per cent seed loss when bhendi plants were infected 33 days after sowing.

The symptoms of the disease consists of clearing of veinlets followed by chlorosis of veins, vein swelling, slight downward curling of leaf margins and twisting of petioles and general dwarfing and retardation of growth (Capoor and Verma, 1950).

It is difficult to control the BYVMV disease satisfactorily by using insecticides and antiviral chemicals. However, the cultivars resistant to BYVMV may be used. But in Karnataka, cultivar Pusa Sawani ranks first in respect of cropping area in 1960's and 70's and was reported to be field resistant to BYVMV (Singh *et al.*, 1962) and presently it has lost its tolerance (Jambhale and Nerkar 1981). However, now-a-days the major area is covered with Arka Anamika followed by Parbhani Kranti and Pusa Sawani.

Though the area under bhendi in Karnataka is more its production and productivity is low as compared to other states. It is due to several factors such as diseases caused by fungi, bacteria and viruses, which affect the bhendi crop both quantitatively and quantitatively. Thus the successful cultivation is hampered due to infection especially with viruses

causing severe yellow vein mosaic resulting in enormous losses in yield and quality.

Survey of the occurrence of diseases over a period of time in northern Karnataka is necessary to study the disease incidence and distribution. There is also a need to identify the nature of transmission and host range of the virus. It is difficult to eliminate viruses directly from infected plants. Hence the aim of management of viral diseases is to prevent the crop losses and quality deterioration through different ways, which include use of antiviral principles that may be defined as a substance. When present in plant tissue, they are capable of either acting directly or indirectly by increasing the level of host resistance resulting in reduction of virus infection.

The external symptoms of plants after virus infection are, no doubt, the gross manifestation of disturbances at cellular level which are not very well understood. Virus infection usually results in drastic histopathological changes in host plant (Esau, 1933). The histopathological changes are the first to occur after virus infection followed by the expression of external symptoms. Inspite of a number of reports on histopathology of virus infection, there is no systematic study in this area to bring about any relationship between internal changes and external symptoms brought about by any specific virus. In order to know and to contribute further to the knowledge on histopahtology of virus infected plants, the histopathology studies were undertaken in this in the present investigation.

The use of insecticides to reduce insect population may play a vital role in reducing disease spread. Cultivation of resistant genotypes is an effective and cheapest method to combat the disease. Hence, the present studies were undertaken with the following objectives.

1. Survey for viral disease of bhendi in northern districts of Karnataka
2. Symptomatology
3. Transmission studies
4. Host range studies
5. Histopathological studies
6. Management
    a. Evaluation of pesticides and plant botanics
    b. Screening of bhendi varieties against BYVMV

Review of Literature

II. REVIEW OF LITERATURE

Bhendi, a native of South Africa and has been predominantly a vegetable of the tropics. Low yield in bhendi may be because of a number of diseases. Among several diseases, bhendi yellow vein mosaic is one of the most severe disease which takes heavy toll of the crop in India.

Kulkarni (1924) was the first person to report the disease from Bombay in India. Hence, the present review has a direct or indirect bearing on the present investigations.

2.1 OCCURRENCE AND LOSSES

Bhendi yellow vein mosaic (BYVM) was first reported by Kulkarni (1924) and later studied by Uppal *et al.* (1940) and Capoor and Varma (1950). Study on the effect of BYVM infection on the growth and yield of bhendi was conducted by Sastry and Singh (1973b) and reported that the growth of the plants was very much stunted when plants were infected in the early stages of the crop. The estimated loss in yield was 93.8 per cent on 35 day old crop whereas 83.63 per cent on 35 days later. Chelliah and Murugesan (1976b) reported the estimation of loss due to BYVM disease, the number of fruits harvested from plants expressing symptoms of BYVM 30, 45 and 60 days after sowing was reduced by 76.0, 54.9 and 47.8 and the fruit number harvested was reduced to 4, 7 and 8 respectively as compared to 16 in the healthy plants. The corresponding yields were 27, 62 and 94 g/p, respectively as compared to 222 g/plant healthy plants.

Bhendi grown in Bihar suffered extensively from BYVM and the disease was particularly severe in vegetable belts where the crop was almost continuously cultivated throughout the year. The percentage of infection has been found to vary from 50-90 per cent (Jha and Mishra, 1955).

Sastry and Singh (1974) reported the effect of okra yellow vein mosaic virus infection on the growth and yield at different stages of plant growth revealed that the growth of the plants was very much retarded and produced comparatively very few leaves and fruits when the infection occurred within 35 days following germination and the average loss due to infection was as high as 93.80 per cent when the plants were infected within 35 days following germination and decreased to 83.63 and 49.36 per cent of 50 and 68 days after germination respectively. The average losses in the yield of okra was 4.38 quintals/ha when the total quantity of okra produced in control plots was 75.20 quintals/ha.

Sinha and Chakrabarti (1978) studied the effect of BYVMV when okra plants were infected at various growth stages and reported that the virus has an adverse effect on plant height, number of branches, number and size of fruits and seed yield. The highest loss of seed (86.13%) occurred in plants showing symptoms on the 33rd day after sowing and the least (32.85%) in those with symptoms on the 75th day however, there was no effect on germination.

Khan and Mukhopadhyay (1985a) reported the gradient study on the spread of okra YVMV and showed a steep rise during the early growth stages of the crop. The extent of final infection depended on the degree of initial infection.

Bhugabati and Goswami (1992) reported highest whitefly population in crops sown during May and incidence of BYVMV virus was also highest (100%) in crop sown in May and June. Disease incidence and whitefly population were lowest in October sown crops. Nath *et al.* (1992) reported dry, hot weather with little or no rainfall was conductive for disease development and also for multiplication of the vectors (*Bemisia tabaci*). Cooler weather with high Rainfall and Relative humidity was determental to whitefly multiplication and spread.

Nath and Saikia (1993) reported different sowing dates from February to March on okra. The incidence of OYVMV on okra cultivar Pusa Sawani varied from 75-91 per cent in plots sown between early April and end of June. The lowest yield of okra was obtained form the plots sown in May and June. A strong positive correlation was obtained between % of disease incidence and whitefly population (r=0.085) where as a strong negative correlation was obtained from disease incidence and fruit yield (r=0.84).

Chaudhary *et al.* (1995) reported that the incidence of bhendi yellow vein mosaic virus on okra ranged from 19.26 to 69.23 per cent.

Mohapatra *et al.* (1995) reported that the incidence of yellow vein mosaic virus on some improved and hybrid varieties of okra was recorded under field condition. Weekly incidence of the disease was compared with severity index and a minimum variation on the severity index was observed among the varieties. Pusa Sawani was the most susceptible and recorded 100 per cent infection while varieties like HRB-9-2, DOV-91-4 and Pashupati showed tolerance under field conditions.

Nath and Saikia (1995) reported the relationship between crop age and yield losses in okra. Maximum (94.42%) and minimum (32.65%) yield losses were recorded for plants infected at 35 and 63 days after sowing respectively. They suggested that early infection caused heavy yield reductions compared with late infection. Losses could be reduced by controlling spread of the disease by controlling the vector (*Bemisia tabaci*).

Mazumder *et al.* (1997) reported the incidence of bhendi yellow vein mosaic bigeminivirus and its vector *Bemisia tabaci* on okra cultivars Pusa Sawani, Parbhani Kranti and M-31. Lower disease incidence and whitefly populations were recorded on Parbhani Kranti and M-31 than Pusa Sawani.

Epidemiology

Fortnightly sowing of bhendi and the observation on the incidence of BYVM and the vector *B. tabaci* were recorded for a period of 2 years (Chelliah *et al.*, 1975), multiple regression analysis lead to the conclusion that in the 30-day-old crop, increase of whitefly population brought about

18.5 per cent of the disease, while 1 per cent decrease in relative humidity increased the disease incidence by 1.2 per cent. In the 45-day-old crop, minimum temperature alone exerted positive influence on the disease incidence. During the 45-60 days of crop age, increase in the maximum temperature by 5°C, resulted in 6.3 per cent increase of the disease. Significant increase of the disease incidence was observed in the bhendi crop sown in March-May (Chelliah and Murugesan, 1976a).

2.2 SYMPTOMATOLOGY

The earliest symptom of BYVMV infected plants is vein clearing (Kulkarni, 1924; Uppal *et al.*, 1940 Fernando and Uduravan, 1942; Raychaudhuri and Nariani, 1977; Nariani and Seth, 1958; Capoor and Verma, 1950). Vein clearing starts on the small veins and extends to the larger ones (Uppal *et al.*, 1940), sometimes the yellow network of veins is followed by the thickening of veins and vein lets (Nariani and Seth, 1958; Raychaudhuri and Nariani, 1977).

Vein clearing is soon followed by veinal chlorosis (Uppal *et al.*, 1940; Fernando and Uduravan, 1942; Raychaudhuri and Nariani, 1977; Nariani and Seth, 1958; Capoor and Verma, 1950). In severe cases, chlorosis will be followed by complete yellowing of leaves (Kulkarni, 1924; Uppal *et al.*, 1940; Raychaudhuri and Nariani 1977; Nariani and Seth, 1958).

Fernando and Uduravan (1942) reported that yellow vein banding may be followed by interveinal clearing and minute enations on the axial

side of leaves. The fruits that arise from diseased plants are malformed and bleached (Kulkarni, 1924; Fernando and Uduravan, 1942; Raychaudhuri and Nariani, 1977; Nariani and Seth, 1958).

2.3 TRANSMISSION

2.3.1 Mechanical Transmission

The virus was not transmitted by sap (Capoor and Varma, 1949; Costa, 1969; Uppal *et al.*, 1940; Raychaudhuri and Nariani, 1977).

2.3.2 Dodder Transmission

Capoor and Varma (1950) reported that the virus was not transmissible through dodder (*Cuscuta reflexa*). No reports were found, so far, on dodder transmission of BYVM.

2.3.3 Graft Transmission

Successful graft transmission of BYVM was reported by Capoor and Varma (1949) and Uppal *et al.* (1940) Manjula Rao (1985) reported side grafting method resulted in 87-100 per cent transmission. Inoculated plants took 15-20 days to show the symptoms.

Sharma and Sharma (1984) observed that *Abelmoschos manihot* sub sp *manihot* from Ghana was resistant to YVMV but it proved to be a symptomless carrier of the virus in grafting tests.

Salehuzzaman (1985) reported that resistant plant (SAON) was contact grafted with susceptible infected stock. Also buds of resistant

plant was grafted on infected plant. These buds later sprouted and developed into full plant, but in both contact and bud grafting, the resistant plant remained healthy although they continued to grow on infected plants.

2.3.4 Insect transmission

BYVMV was transmitted exclusively by whitefly *Bemisia tabaci* (Uppal *et al.*, 1940; Raychaudhuri and Nariani 1977; Varma, 1952).

Acquisition access period : Acquisition access period was reported as 4-6 hours (Raychaudhuri and Nariani, 1977), 12-24 hours (Varma, 1952). Preliminary fasting markedly increased the efficacy of whiteflies as vectors (Varma, 1952).

Inoculation access period : A feeding period of 30 minutes was sufficient to transmit the virus, but a five minute probe was not sufficient (Varma, 1955a and Varma, 1955b) and also report that whitefly *B. tabaci* is capable of harbouring different viruses simultaneously and can readily cause infection in healthy host plant susceptible to the respective viruses on the same day and can continue to do so for several days without having reaccess to the source of infection.

2.3.5 Seed Transmission

Transmission through seeds was not observed in bhendi seeds (Capoor and Varma, 1949; Uppal *et al.*, 1940; Costa, 1969).

Sorokin (1927) reported that mosaic affected cells of tomato leaves were almost isodiametrical and there was no differentiation of tissues into palisade and spongy parenchyma.

Easu (1933) reported that curly top disease induced pronounced changes in infected leaves of sugar beet the changes were cell enlargement near the veins, lack of intercellular spaces and chloroplast degeneration.

Stone (1942) noticed effect of the mild mosaic virus, on potato and observed little effect on leaf thickness and reduction in size and number of chloroplasts.

Esau (1944) stated that though the yellow areas of beet leaves affected with mosaic showed chloroplast deficiency in very early stages of development, a degeneration of chloroplasts also occurred in older leaves and she also reported that the cells were nearly isodiametrical, rather closely packed with no typical differentiation into palisade and spongy layers and green areas resembled healthy mesophyll or appeared hyperplastic.

Abott and Sass (1945) reported that yellow streaks in sugarcane affected with chlorotic streaks and noticed reduction in size and number of chloroplasts, often thinner than the adjacent areas and eventually became neorotic.

Mishra and Singh (1971) showed that leaves of Capsicum plants attacked by chilli mosaic virus were small with little differentiation between palisade and spongy parenchyma.

Mishra and Singh (1973) reported the loss of cellular differentitation between spongy and palisade leaf tissues of chilli plants infected by virus. They further reported that cells were angular and compactly packed with little or no intercellular spaces.

Joshi and Dubey (1975) observed the length and breadth of palisade cells of diseased chilli leaves infected with the cucumber mosaic virus which showed a clear distinction between palisade and spongy parenchyma and were quite reduced in size in comparison to healthy ones.

Kusum Mathur and Shukla (1977) reported histopathological changes in papaya leaves infected with papaya mosaic virus and showed that upper epidermis in yellow areas appeared enlarged and slightly altered in shape, but in green portion away from the veinal region, these cells were found shrunk and distorted. The pallsade cells increased in size, and deformed.

Prakash (1979) reported histological changes in leaf tissues due to chilli mosaic virus infection. He observed that thickness of leaf was reduced to 126 μm as compared to 168 μm of healthy leaf and also reported reduction in width and height of epidermal cells 25.20 and 21.00 μm as compared to healthy as 50.4 μm and 25.2 μm respectively. The

palisade chlorenchyme just below the upper epidermis consisted 58.8 µm length and 16.8 µm width in healthy leaf as compared to infected. Spongy cell diameter was reduced to 37.80 µm length and width was increased to 42.00 µm.

Sawant and Capoor (1985a) reported histopathological changes in leaves of bell pepper plants infected with bell pepper yellow mosaic virus showed poor development of different tissues which indicated hyperplasia and much reduction in chloroplast number.

Sawant and Capoor (1985b) reported anatomical changes induced in leaf of virus infected lima bean. There was poor development of different tissues in diseased plants indicating hyperplasia in leaf.

Thimmaiah (1992) reported histopathological changes due to insect pest in cotton variety DCH-32. The number of epidermal cells per unit length of (0.2 mm) in infected boll rind was 63.33 compared to healthy 93.33 mm.

2.5 HOST RANGE

Vasudeva and Samraj (1948) reported that Tomato leaf curl symptoms on *Nicotiana tabacum, Solanum tuberosum, Datura stramunium* when inoculated by grafting.

Capoor and Varma (1950) reported that the host range of the virus was limited to the family Malvaceae. They also indicated that in addition to *Abelmoschus esculentus, Abelmoscus moschatus, Abelmoschus manihot,*

and *Althea rosea* were also found susceptible to this virus. *Abelmoschus manihot* a commonly growing weed harbours this virus.

Ramakrishnan *et al.* (1964) transmitted tomato leaf curl virus to *Althea rosea, Carica papaya, Nicotinana tabacum,* through *Bemisia tabaci.*

TLCV was transmitted to *Ageratum conyzoides, Althaea rosea, Capsicum annum* through *B. tabaci* (Seetharama reddy, 1978).

Pun *et al.* (1999a) reported that okra yellow vein mosaic virus could be detected in five weed plant species, *viz.*, *Acalypha indica, Althaea rosea* (L.) Cav., *Croton bonplandianum Bail, Hibisucs rosa-sinesis* L. and *Parthenium hysterophorus* L. through direct antigen coating enzyme linked immuno sorbent assay (DAC-ELISA) using polyclonal antibodies (pc Abs) raised against African cassava mosaic virus (ACMV) and Indian cassava mosaic virus (ICMV). The reaction of antigen extract from infected okra leaves was stronger with pc Abs to ACMV.

2.6 MANAGEMENT

2.6.1 Cultural

Capoor and Varma (1950) suggested the following control measures (I) eradication of *Hibiscus tetraphyllus*, the wild host of the virus (ii) observing a closed season of atleast 2 months during summer between 2 successive corps (iii) roughing of diseased bhendi plants at the earliest stage of their infection and (iv) keeping the fields free from weeds which may help in the multiplication of the whitefly.

2.6.2 Chemical control

Sastry and Singh (1973a) conducted a field trial of insecticides for the control of the whitefly (*B. tabaci*) in relation to the incidence of BYVM. Results revealed that spraying in the initial stages of the crop just after germination is the most important. If the crop was not sprayed within 20 days after germination, the incidence of BYVM would be as high as 100 per cent resulting in low yields even if crop sprayed regularly after 20 days after germination. Four to six applications of systemic insecticides such as matasystox, rogor and dimecron as foliar sprays and one to two applications of the granular thimet and dysystox to the soil, not only reduced the whitefly population, but also the incidence of BYVM to a greter extent, when compared to the yield and profit of those plots where no insecticide has been applied.

Further trials were taken up by Sastry and Singh (1973b) on the restriction of BYVM spread through the control of the vector *B. tabaci*. Virus spread was restricted by 4 sprays, each of parathion (0.02%), oxydameton methyl (metasytox) (0.02%) or dimethoate (Roger) (15 kg/ha) at sowing (Sastry and Singh, 1973b). A higher incidence of BYVM occurred.

According to Palaniswamy *et al.* (1973) BYVM can be effectively minimized by the furrow application of aldicarb and carbofuran granules at 1.0 kg a.i/ha at the time of sowing. These treatments have accounted for 13.8 per cent and 76.2 per cent reduction in the disease incidence

respectively over control. Phorate, fensulhothion, and mephespholan have also reduced the incidence by more than 50 per cent over the control.

Chelliah (1976) reported that by the application of aldicarb granules (1.0 kg a.i/ha) a week after sowing and spraying with endosulfan (0.2%) at 30 and 50 days after sowing were effective in reducing incidence of BYVM.

Chakrabarthi and Mukhopadhyay (1977) evaluated 6 insecticides, *viz.*, methyl demetion (metasystox) (0.02%), phosphomidon, endosulfan, curbofuran and fenitrothion on Pusa Sawani variety of bhendi. The insecticides significantly reduced the number of diseased plants and the whiteflies, irrespective of the dates of sowing. The total yield of treated plants was also significantly higher than that of the control.

Uttasami *et al.* (1977) reported that application of aldicarb granules followed by endosulfan resulted in the reduction of BYVM incidence and enhanced fruit yield.

Basha and Balasubramanyam (1982) observed that the application of aldicarb (0.04% or 0.5 kg a.i./ha) on the 15th day of sowing followed by spraying with (0.03%) endosulfan twice on the 45th day and both day of sowing or spraying monocrotophos 0.04 per cent or endosulfan 0.05 per cent four times at fortnightly intervals commencing from 15 days after sowing were found to be effective in reducing the yellow vein mosaic disease of bhendi.

Khan and Mukhopadhyay (1985b) observed that the soil application of methyl phosphoro-dithioate (furatox-104) at 15 kg/ha followed by 4 sprays of metasystox (dimetons-methyl) 25 EC at 0.03 per cent at 15 days intervals from the sowing dates reduced incidence to 23.26 per cent as compared to control 81.22 per cent and average whitefly population was 59.66 compared to control 231 and enhanced yield to 59.45 q/ha over control from 23.8.

Singh and Singh (1989) observed that okra yellow vein mosaic virus was controlled by 3 sprays of phosphamidon (0.02%) or methyl demeton (metasystox) 0.02 per cent or single soil application of phorate 15 kg/ha or by early sowing or intercropping okra with cowpea or mungabean. The insecticides reduced numbers of *Bemisia tabaci* /plants and increased yields more effectively than the other treatments.

Murthy and Reddy (1992) observed that application of carbofuran granules to the soil at sowing, followed by 2 sprays of monocrotophos at fortnightly intervals to control the whitefly vector (*Bemisia tabaci*). Early treatment was important to prevent seedling infection during the first 20 days after sowing.

Anju Handa and Gupta (1993) reported that for control of whitefly (*Bemisia tabaci*) vector, carbofuran 3G was slightly better than phorate 10G. Two applications of both these insecticides at sowing and within 20 days later reduced disease incidence with consequent improvement in yield.

2.6.3 Plant extracts

Chowdhury *et al.* (1992) observed that Alcohol extracts were superior to aqueous ones in preventing infection by okra yellow vein mosaic virus and these from callistemon, datura, agavae and ginger gave a good degree of suppression of symptoms on okra sprayed in the field. A lower rate of disease dissemination was recorded in treated plants than in the control sprayed with water only. Mortality of the vector (*Bemisia tabaci*) was 20.80 per cent when they were confined for 30 min in a cage with plants treated with extracts.

Pun *et al.* (1999b) observed that among 17 plant species screened, pre-inoculation sprays with leaf extracts of *Prosopis chilenisis,* and *Bougainvillea spectabilis* were highly effective in reducing okra yellow vein mosaic virus infection, % reduction being 83.3 and 81.7 respectively, over control. Incubation period of the virus in plants treated with leaf extracts increased to 19.1 days and 19.3 days, respectively against 10.4 days in control plants.

Pun *et al.* (1999c) observed that among the 10 plant extracts tested for their efficacy in controlling pumpkin yellow vein mosaic virus, *Bougainvillea spectabilis* showed maximum inhibition of the virus transmission followed by *Boerhavia diffusa* by 93.3 and 91.7 per cent respectively over control, whereas *Vitex negundo* showed minimum reduction of 56.7 per cent over control.

The presence of AVPs in non host plant species effective against different viruses has been reported by several workers (Okvyama *et al.*, 1978).

2.7 SCREENING

Chauhan *et al.* (1981) have reported that cultivar IC-1342 showed the highest yield and number of fruits/plants of the 46 cultivars. The highest incidence of okra yellow vein mosaic virus noticed in Pusa Long Green-1 and Parkins Long Green, while the lowest was in IC-9273. None of the cultivars was resistant.

Sharma and Sharma (1984) screened 74 lines and varieties belonging to *Abelmoschos esculenthus* and related species during the *kharif* seasons of 1976, 1978 and 1980 in field condition. Only a line of *Abhelmischos manihot* sub sp. *Manihot* from Ghana was resistant.

Khan and Mukhopadhyay (1986) observed 5 varieties of okra screened under field conditions, 51-1 showed the lowest incidence of infection (24.36%) and gave the highest yield (4036 q/ha).

Dhankhar *et al.* (1989) reported that difference in disease incidence and yield potential were observed on screening 97 genotypes against Okra Yellow veln mosaic virus under natural conditions in the field. The cultivars IC-9273, Bavnia, 3(1) and IC-23592 were resistant. The highest yielding genotype was Selection-2 with a moderate disease reaction.

Singh and Gupta (1991) reported that during 1989-90, 24 okra varieties were screened for susceptibility to YVMV under field conditions in U.P. India. None of the varieties was highly resistant, 3 were resistant, 8 moderately susceptible, 3 were susceptible and 10 were highly susceptible.

Borah *et al.* (1992) reported that in a field trial with 22 genotypes exposed to whiteflies (*Bemisia tabaci*) carrying okra yellow vein mosaic virus, cultivar Arka Anamika remained free from disease and 5 other genotypes were highly resistant. The high yielding and highly resistant GoH-4 and GOH-6 were recommended for commercial cultivation in Assam.

Arora *et al.* (1992) observed differences among the 157 advanced germplasm lines and 7 cultivars/hybrids evaluated in the field for reactions to Okra yellow vein mosaic virus over 2 years. Incidence of YVMV was highest (100%) in Pusa Makhmali compared with only 0.64% in the resistant line EMS-8.

Sharma *et al.* (1993) evaluated eight varieties of okra for their comparative resistance to Okra YVM virus and marketable yield over a period of 4 years from 1986-1989. Punjab Padmini and Punjab-7 were high yielding cultivars which were resistant to virus. A mutant EMS-8 and the high yielding variety Parbhani Kranti were also resistant to the virus. Pusa Sawani and Pusa Makhamali were highly susceptible to the virus and were lower yielding cultivars.

Anju Handa and Gupta (1993) reported that among 14 cultivars screened in the field under natural condition by okra YVMV, Parbhani Kranti showed promising and a selection from Ghana was highly resistant.

Suresh Kumar (2000) evaluated 10 hybrids of Okra for comparative resistance to BYVMV, all the 10 hybrids exhibited desirable and significant heterosis over the susceptible check (PI 496702) for YVMV. Hybrids involving at least one immune disease to parent (Arka Abhay or Arka Anamika) were all found to be immune except Arka Abhay x Pusa Sawani which was moderately resistant.

Material and Methods

III. MATERIAL AND METHODS

In the present investigation the following work has been carried out *viz.*, survey, symptomatology, transmission studies, histopathological studies, host range studies and management on bhendi yellow vein mosaic virus during 1999-2001 at the Department of Plant Pathology, University of Agricultural Sciences, Dharwad

3.1 MAINTENANCE OF INOCULUM

3.1.1 Raising healthy bhendi plants

Bhendi seeds were sown in earthen pots of size 9 x 6 inches filled with soil + farmyard manure. When the plants were 7-15 days old, they were used for various experiments.

3.1.2 BYVMV culture

The culture of the BYVMV was obtained from the field and inoculated to healthy bhendi plants by using whiteflies (*Bemisia tabaci*) (Plate 1) and maintained in an insect proof glasshouse. The Pusa Sawani variety was used in all the transmission studies.

3.1.3 Vector culture

An aspirator comprising a glass tube (30 cm length and 0.5 cm diameter) and a rubber tube of 40 cm length was used for the collection of whiteflies. The whiteflies were collected by turning the leaves slightly upwards, and sucking into the glass tubes. The whiteflies were released

Plate 1. Microphotograph of whitefly (*Bemisia tabaci*)

on plants kept in insect rearing cages and subsequently maintained by frequently introducing the young plants into the rearing cage.

3.1.4 Whitefly rearing cage

A wooden frame measuring 45 x 45 x 30 cm was fixed with glass and muslin cloth. This frame was fitted on a wooden rectangular base (45.5 x 45.5 x 10 cm). Plants were kept inside the cage and the whiteflies were released (Plate 2).

3.2 SURVEY

3.2.1 Roving survey

Roving survey was carried out in some of the bhendi growing areas of Dharwad, Belgaum, Haveri and Gadag districts of Karnataka to record the incidence of yellow vein mosaic disease, during *kharif* 1999-2000 in the months of July-August and during summer 2000-2001 in the months of February-March when the crop stage was 1 to 2 months old. Five fields were selected randomly in every village. In each field, five lines were randomly selected and disease incidence was assessed by counting total number of plants and number of plants showing distinct symptoms. Observations were also recorded on type of insects feeding on the crop, irrigated or rainfed conditions, variety grown and severity of symptoms etc.

3.2.2 Fixed plot survey

To know the development and spread of yellow vein mosaic virus disease of bhendi, a fixed plot survey was conducted at MRS Dharwad

Plate 2. Rectangular wooden cage used for transmission studies

during *kharif* 2000 and summer 2001. Observations were recorded at 15, 30, 45 and 60 days after planting on per cent incidence of disease, type of symptom produced, type of insect vector feeding on the crop, etc.

3.3 SYMPTOMATOLOGY

To study the symptoms, the bhendi variety Pusa Sawani seeds were sown in earthen pots of size 9 x 6 inches filled with soil and farmyard manure. When the plants were 7-15 days old the whiteflies were released on plants kept in insect rearing cages. The plants were maintained in glasshouse and observed regularly for symptom development. Observations were recorded on type and severity of symptom and time taken for symptom development.

3.4 TRANSMISSION STUDIES

3.4.1 Mechanical transmission

The BYVMV infected leaves were harvested 15 days after inoculation and macerated in a pestle and mortar by adding 0.1 M phosphate buffer, pH 7.0, containing 1 per cent of 2-mercaptoethanol. The resulting pulp was strained through a muslin cloth. Inoculation was made by rubbing the surface of leaves with cotton swab dipped in the extract (inoculum). Excess inoculum was washed with water using a wash bottle and the inoculated plants were kept in an insect proof glasshouse for symptom production.

3.4.2 Dodder transmission

The growing ends of the dodder (*Cuscuta reflexa* Roxb.) collected from healthy *Lantana camera* was twined to young growing shoots of infected bhendi plants in an anticlock wise fashion. And the growing end of the dodder, established on diseased plant was twined on the young shoots of healthy test plants in an anticlock wise fashion. The dodder so established was allowed to grow as bridge between donor and receptor plants for 30 days and then removed. The test plants were kept in glasshouse for observations.

3.4.3 Graft transmission

Wedge grafting method was employed for the graft transmission study. The diseased scions from BYVMV infected plants were made into a V shaped structure. The scions were inserted into slanting cut made on the healthy stock plants of bhendi. The grafted portion was tied with a polythene strip and the scion was covered with a polythene bag. The inoculated plants were kept in a cool place in the glasshouse for symptom production.

3.4.4 Whitefly transmission

Whiteflies were collected from rearing cages and released into polyvinyl chloride (PVC) tubes in which a BYVMV infected branches were inserted previously and allowed to feed for 24 hours (acquisition access period) (Plate 3). The 10 viriliferous whiteflies were then released onto

Plate 3. Round polyvinyl chloride (PVC) cage used in various transmission experiments. Whiteflies was released on BYVMV infected plants for acquisition access

healthy bhendi plants by using, small plastic tubes and were allowed to feed for 24 hours (Inoculation access period). After inoculation, the plants were sprayed with 0.1 per cent dimethoate to kill all the whiteflies. The inoculated plants were kept in the glasshouse for symptom development.

3.4.5 Seed transmission

The matured seeds were collected from plants showing distinct yellow vein mosaic symptoms and also from healthy plants. Three sets of 25 seeds each from healthy and diseased plants of bhendi variety Pusa Sawani were sown in soil, sand and compost (2:1:2 w/w) ratio mixture in separate earthen pots. After recording germination percentage, the earthen pots with seedlings were kept in glasshouse for 1 month for symptom development. The seedlings were sprayed with monocrotophos (0.1%) at 15 days interval to avoid chances of insect transmission.

3.5 HOST RANGE

The host range studies are conducted by raising seedlings from healthy seeds in six inches earthen pots. Five plants of each species/ cultivar were insect transmitted through the vector *Bemisia tabaci*. Whiteflies were given a 24 hour acquisition feeding and 48 hour inoculation feeding period. The legume plants were inoculated on cotyledonary leaves before the emergence of trifoliate leaves. Other test plants were inoculated on second and fourth fully expanded leaves. With a view to obtain more information about the host plants susceptible to the virus. Selected plant species and cultivars belonging to diverse families

viz., Malvaceae, Euphorbiaceae, Leguminacae and Solanaceae were used. The test plants were examined periodically for symptom production. Observation on time taken for symptom development and type of symptoms produced were recorded.

3.6 HISTOPATHOLOGICAL STUDIES

To know the changes that occur at cellular levels due to penetration of virus into susceptible host, the following studies were undertaken by following standard procedure as detailed below.

1. **Sampling :** The leaves were selected randomly from healthy and infected plants of susceptible cultivar (Pusa Sawani) and washed thoroughly in tap water before fixing (6^{th} leaf of uniform age plant).

2. **Fixation :** The leaves were cut into pieces of 2.0 cm length. Then the leaves were fixed in vials containing formalin acetic acid and 70 per cent alcohol in the ratio of 1:1:18. The material was allowed to remain in the fixative for 24 hours.

3. **Dehydration:** Fixed material was thoroughly washed in 70 per cent alcohol and further dehydrated by passing through 80 per cent, 90 per cent and absolute alcohol. The dehydration was then carried out using n-butanol in combination with alcohol in the ratio of 1:3, 2:2, 3:1 and absolute butanol, leaving the material in each grade for a period of three hours.

4. **Embedding:** After the removal of n-butonol from the dehydrated material, it was embeded in paraffin wax by adopting paper boat

technique (Jensen 1962). The paper boats of appropriate size were prepared and inner surface of paper boat was smeared with glycerin. The dehydrated plant material was placed into the paper boats containing boiled molten wax and then again the molten wax was poured into the boats. For the easy cutting of blocks the material was arranged in linear rows.

5. **Microtoming and affixing the sections :** The paraffin ribbons were cut into thin sections of 8 μ thickness with the ERMA rotatiory microtomeblade and placed on the slides smeared with gelatin adhesive (1%) [1 g gelatin in 100 ml of warm water and added 0.5 g potassium dichromate]. The slides were then warmed over a weaning plate to facilitate flattening and stretching of the ribbon. The excess adhesive was drained on to blotting paper and slides were dried in a dust free environment.

6. **Deparaffinzing and hydrating the sections:** Sections were deparaffinized by using xylene and were later hydrated using the alcohol series listed below.

	Duration of the treatment
Xylene	5 minutes
Xylene + Ethanol	5 minutes
Absolute Ethanol	5 minutes
90 per cent Ethanol	5 minutes
70 per cent Ethanol	5 minutes
50 per cent Ethanol	5 minutes
Water	5 minutes

7. Staining schedule

- The sections were stained with 1 per cent safranin (1g safranin in 100 ml of absolute alcohol and diluted to 1:1 with distilled water) for 1 hour.

- Slides were washed thoroughly in water and then passed rapidly through 50%, 70%, and 90% Absolute alcohol.

- Counter staining was done with 0.5% fast green stain (0.5 gm fast green in 50 ml clove oil and 50 ml alcohol) for 1-5 min.

- Then the fast green was differentiated by placing in 50% clove oil, 25% alcohol and 35% xylene.

- The section was placed in xylene for 15 min and made three changes and finally mounted with cover slip swing with DPX mount

- After staining, the sections were observed under light microscope and the following observations were recorded i.e., on the size of different tissues of the plant samples, number of cells per unit area and thickness of the material were measured using a calibrated ocular micrometer with the help of stage micrometer. The following observations were recorded.

- In leaf: thickness of epidermal cell, length and width of epidermal cell, number of chloroplasts, length and width of palisade cells, diameter of spongy cells.

- In fruit : number of epidermal cells/mm

3.7 MANAGEMENT

3.7.1 Disease control

To know the efficacy of different insecticides, viricides and plant extracts the experiments were conducted at UAS Dharwad during *kharif* 2000 and also during summer 2001. A field experiment was laid out with the following treatments.

***Kharif* - 2000**

Design : Randomized Block Design (RBD)

Plot size : 3 x 2 mt

Replications : 3

Treatments : 8

Spacing : 60 x 30 cm

Variety : Pusa Sawani

T_1 - Rogor (dimethiote) (0.2%)

T_2 - Monocrotophos (Nuvacron) (0.1%)

T_3 - Metasystox (0.2%)

T_4 - Action 100 (0.2%)

T_5 - *Bougainvillea spectabilis* leaf extract (10%)

T_6 - *Azadiracta indica* Jussi (Neem) leaf extract (10%)

T_7 - Parthenium leaf extract (10%)

T_8 - Control

Design : Randomized Block Design (RBD)

Plot size : 3 x 2 mt

Replications : 3

Treatments : 7

Spacing : 60 x 30 cm

Variety : Pusa Sawani

T_1	-	Metasystox (0.2%) + carbofuran 3G (15 kg/ha)
T_2	-	Rogor (0.2%)
T_3	-	Action 100 (0.2%)
T_4	-	Carbofuran 3 G (15 kg/ha)
T_5	-	Parthenium leaf extract (10%)
T_6	-	Parthenium leaf extract (10%) + Rogor (0.2%) (R-P- R-P- R-) Alternate sprays
T_7	-	Control

Insecticides, viricides and plant extracts were sprayed at 15, 30, 45, 60 and 75 days after plant emergence. Observations were recorded on incidence and vector population at 15, 30, 45, 60, 75 & 90 days after plant emergence. The vector population before and after imposing treatments was also recorded. The data were analysed statistically. The per cent disease inhibition over control was calculated by using the formula given by Vincent (1927).

$$\text{Per cent disease inhibition} = \frac{C - T}{C} \times 100$$

Where,

C = per cent disease in control

T = per cent disease in treatment

3.7.2 Screening

Studies were undertaken to test the resistance of bhendi germplasm against yellow vein mosaic virus disease. A field experiment was conducted during *kharif* 2000 and summer 2001 under natural conditions at UAS, Dharwad. A total of 19 genotypes collected from Horticultural Department, UAS, Dharwad were planted in five rows of 10 meter length each. Susceptible bhendi cultivar, Pusa Sawani was planted at an interval of five rows of every five test lines as check. Per cent disease incidence was calculated by counting number of plants in each entry.

$$\text{Per cent disease incidence} = \frac{\text{No. of plants infected in a row}}{\text{Total number of plants in a row}} \times 100$$

The genotypes were later grouped into different categories based on 0 to 9 scale from immune to highly susceptible (Mayee and Datar, 1986). The scale used was as follows.

Scale	Description	Category
0	No symptoms on plants	Immune
1	1 % or less plants exhibiting symptoms	Resistant
3	1 to 10% plants exhibiting symptoms	Moderately resistant
5	11 to 20% plants exhibiting symptoms	Moderately susceptible
7	21 to 50% plants exhibiting symptoms	Susceptible
9	51% or more plants exhibiting symptoms	Highly susceptible

3.8 EFFECT OF YELLOW VEIN MOSAIC VIRUS INCIDENCE ON GROWTH AND YIELD PARAMETERS OF BHENDI

Fifteen bhendi plants (Pusa Sawani) showing distinct yellow vein mosaic symptoms at 35, 45 and 55 days after planting were selected and tagged for observation. The effect of yellow vein mosaic was studied on growth and yield parameters. Observations were recorded on plant height; fruit size (length X breadth) and number of fruits per plant.

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the investigations carried out on BYVMV during the year 1999-2000 and 2000-2001 are presented here.

4.1 SURVEY

4.1.1 Roving survey

Roving survey to know the incidence of bhendi yellow vein mosaic virus was undertaken in parts of Belgaum, Dharwad, Gadag and Haveri districts of Karnataka during August-October 2000 and March-May 2001, when the crop was 40 to 65 days old.

During *kharif* 2000, a total of 58 villages i.e., 16, 12, 14 and 16 villages in Dharwad Haveri, Belgaum and Gadag district, respectively were surveyed. Whereas, during summer 2001 a total of 86 villages i.e., 21, 27, 17 and 21 villages in Belgaum Gadag, Haveri and Dharwad districts, respectively were surveyed. All the plants in the randomly selected area of the fields were first counted and then number of plants showing yellow vein mosaic symptoms were recorded separately to calculate the per cent disease incidence. The disease incidence was recorded based on symptoms. The survey results presented in Table 1 and 2 clearly indicated that the incidence of disease varied from 0 to 78.60 per cent depending on the season in which the crop was grown. Incidence was low during *kharif* 2000, in August-October sown crops (0.0-18.5%) (Table 1) and high during summer 2001 in March-May sown crops (12.6-78.60%) (Table 2).

In *kharif* 2000 in Hukkeri taluk of Belgaum district, BYVMV incidence recorded was maximum 18.5 per cent followed by 17.5 per cent at Shigli of Shirahatti taluk of Gadag district on Pusa Sawani variety. Minimum incidence 1.5 per cent was recorded on Arka Anamika cultivar at Devagiri of Hanagal taluk of Haveri district (Table 1). During summer 2001 BYVMV was present in almost all parts of Belgaum, Dharwad, Haveri and Gadag districts, but it was high in Haveri district and very low in Dharwad district. Maximum incidence of 78.60 per cent was recorded in fields at Dhundshi in Shiggaon taluk of Haveri district grown with Pusa Sawani variety followed by 62.40 per cent at Devihosur (Haveri) with local variety, but minimum incidence (12.6%) was recorded at Kubihal of Kundagol taluk (Dharwad) with Arka Anamika cultivar (Table 2).

The disease incidence was more in Haveri, district followed by Belgaum, Gadag and Dharwad districts. All the varieties/hybrids grown in different parts of Haveri, Belgaum, Gadag and Dharwad districts were found susceptible to the bhendi yellow vein mosaic virus, but much of area had Arka Anamika. It was noticed that crop infected at early stage suffered more with severe symptoms like vein clearing, veinal chlorosis, complete yellowing of leaves, vein clearing and minute enation on the axial side of leaves. Fruits were also malformed and appeared bleached. Invariably whiteflies were found feeding on the bhendi in most of the field surveyed along with jassids, thrips and mites in some of the fields.

Table 1. Incidence of BYVMV in different parts of Dharwad, Haveri, Belgaum and Gadag districts during *kharif* 2000

Sl. No.	Place	Area (acres)	Irrigated or rainfed	Variety or hybrids	Stage of the crop (DAP)	Incidence (%)	Insects recorded	Symptoms
I	Dharwad district							
1	Dharwad taluk							
	Villages							
	Garag	1.5	RF	Varsha	55	6.5	Whiteflies	*Vein clearing *Veinal chlorosis
	Narendra	1	RF	Champion	45	4.5	Whiteflies	*Vein clearing
	Mugad	2.5	RF	Arka Anamika	45	0		
	Belur	2	RF	Arka Anamika	60	0		
	Dharwad	2	RF	Hybrid No.8	55	0		
2	Kundagol taluk							
	Villages							
	Saunshi	1.5	RF	Arka Anamika	60	0		
	Ingalagi	2	RF	Hybrid No.10	40	1.6	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit
	Hiramarthi	2	RF	Hybrid No.8	55	0		
	Kubihal	2.5	IR	Local	65	14.5	Whiteflies	* Vein clearing * Veinal chlorosis * malformed fruits
3	Kalaghatagi taluk							
	Villages							
	Dhumwad	1.5	RF	Arka anamka	50	0		
	Honalli	2.5	RF	Varsha	40	5.5	Whiteflies, jassids	* Vein clearing * Cupped shaped leaves *Malformed fruits
	Kalaghatagi	2	RF	Champion	55	4.5	Whiteflies, jassids	*Veinal chlorosis * Vein clearing
4	Hubli taluk							
	Villages							
	Gabbur	2.5	RF	Arka Anamika	65	0		
	Unkal	2	RF	Arka Anamika	50	0		
	Rayapura	1.1	RF	Namdari	40	2.5	Whiteflies, jassids, thrips	*Vein clearing *minute enation or leaves
	Sattur	1.5	RF	Champion	55	3.5	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
II	Haveri district							
1	Hangal taluk							
	Villages							
	Hangal	2	RF	Arka Anamika	65	0		
	Devagiri	2.5	IR	Arka Anamika	40	1.5	Whiteflies, thrips, mites	*Vein clearing *Completely yellowing of leaves
	Naregal	1	RF	Pusa Sawani	55	16.5	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit
2	Haveri taluk							
	Villages							
	Haveri	2.5	RF	Champion	65	3.5	Whiteflies	* Vein clearing * Veinal chlorosis * malformed fruits
	Devihosur	1	RF	Parbhani kranti	55	8.5	Whiteflies, jassids	* Vein clearing * Stunting of plants

Table 1. Contd....

Sl. No.	Place	Area (acres)	Irrigated or rainfed	Variety or hybrids	Stage of the crop (DAP)	Incidence (%)	Insects recorded	Symptoms
	Kurubagunda	3	IR	Arka Anamika	45	0		
3	Savanur taluk							
	Villages							
	Allipur	2	RF	Namdari	50	4.5	Whiteflies, jassids	Veinal chlorosis * Vein clearing
	Mavur	1.5	RF	Champion	45	2.5	Whiteflies, thrips	Vein clearing * Veinal chlorosis
	Savanur	2	RF	Champion	55	3.5	Whiteflies, jassids	*Veinal chlorosis * veinal clearing
4	Shiggaon taluk							
	Villages							
	Dhundshi	1	RF	Local	60	10.5	Whiteflies, jassids, thrips	*Vein clearing *minute enation or leaves
	Shiggaon	1.5	RF	Arka Anamika	55	0		
	Bankapur	2	RF	Arka Anamika	45	0		
III	Belgaum district							
1	Belgaum taluk							
	Villages							
	Sutagatti	1.5	RF	Arka Anamika	45	0		
	Honaga	2	IR	Varsha	55	3.5	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit
	Kakati	1	RF	Varsha	60	4.5	Whiteflies, thrips, mites	* Vein clearing * Malformed and bleachd fruits
2	Bailhongal taluk							
	Villages							
	Sampagoan	1.5	RF	Pusa Sawani	45	9.25	Whiteflies, jassids	* Vein clearing * Stunting of plants
	Bailwad	1	RF	Arka Anamika	50	0		
	Baihongal	2	RF	Arka Anamika	50	0		
3	Chikkodi taluk							
	Villages							
	Manjri	2.5	RF	Champion	60	3.5	Whiteflies, thrips	Vein clearing * Veinal chlorosis
	Ankari	2	RF	Champion	65	5.5	Whiteflies, jassids	*Veinal chlorosis * veinal clearing
	Nippani	3	IR	Hybrid No.8	85	1.7	Whiteflies, jassids	*Vein clearing *Veinal chlorosis *Yellowing of leaves
4	Athani taluk							
	Villages							
	Kagwad	1.5	RF	Hybrid No.10	40	0		
	Shiraguppi	2.5	IR	Hybrid No.8	55	1.8	Whiteflies, jassids, mites	*Vein clearing *Veinal chlorosis * malformed fruits
5	Hukkeri taluk							
	Villages							
	Sankeshwar	2	RF	Varsha	65	4.5	Whiteflies, jassids	*Vein clearing *malformed and bleached fruits
	Hanchanal	2.5	IR	Arka Anamika	40	0		
	Hukkeri	1	RF	Pusa Sawani	65	18.5	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit

Table 1. Contd....

Sl. No.	Place	Area (acres)	Irrigated or rainfed	Variety or hybrids	Stage of the crop (DAP)	Incidence (%)	Insects recorded	Symptoms
IV	Gadag district							
1	Gadag taluk							
	Villages							
	Gadag	1.5	RF	Arka Anamika	55	0		
	Balaganur	2.5	RF	Hybrid No.8	45	0		
	Kurthakoti	3	IR	Hybrid No.8	45	0		
2	Ron taluk							
	Villages							
	Asuti	3.5	IR	Hybrid No.10	60	0		
	Ron	3	IR	Arka Anamika	55	0		
	Sudi	2.5	RF	Arka Anamika	50	0		
	Chikkamannur	2.5	IR	Ankur	50	2.5	Whiteflies, jassids, thrips	*Vein clearing *minute enation or leaves
3	Shirahhatti taluk							
	Villages							
	Shigli	1.5	RF	Pusa Sawani	60	17.5	Whiteflies, jassids, mites	*Vein clearing *Veinal chlorosis * malformed fruits
	Bellatti	2	RF	Ankur	60	3.6	Whiteflies, thrips	*, vienal clearing *Minute enation on leaves * Malformed fruits
	Shirahatti	2.5	IR	Ankur	65	4.5	Whiteflies, jassids	*Vein clearing *malformed and bleached fruits
	Mugadi	2	RF	Varsha	50	4.5	Whiteflies, thrips, mites	*Vein clearing *Completely yellowing of leaves
4	Navalgund taluk							
	Villages							
	Morab	1.5	RF	Arka Anamika	40	0		
	Shalavadi	2	RF	Arka Anamika	55	0		
	Annigeri	2	RF	Ankur	65	2.5	Whiteflies, jassids	* Vein clearing * Stunting of plants
5	Nargund taluk							
	Villages							
	Shirol	2.5	IR	Champion	40	3.5	Whiteflies, jassids, mites	* Vein clearing * Cupped shaped leaves *Malformed fruits
	Konnur	2	RF	Ankur	45	6.5	Whiteflies, jassids	Veinal chlorosis * Vein clearing

Table 2. Incidence of BYVMV in different parts of Belgaum, Dharwad, Gadag and Haveri districts during summer 2001

Sl. No.	Place	Area (acres)	Irrigated or rainfed	Variety or hybrids	Stage of the crop (DAP)	Incidence (%)	Insects recorded	Symptoms
I	Belgaum district							
1	Belgaum Taluk							
	Villages							
	Honaga	2	IR	C.K.-7	55	29.44	Whiteflies, jassids	*Vein clearing *Veinal chlorosis *Yellowing of leaves
	Kakati	1	IR	Arka Anamika	50	20.24	Whiteflies, jassids, thrips	*Vein clearing *minute enation or leaves
	Vantamuri	1.5	IR	Hybrid No. 8	45	18.73	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
	Sutagatti	2	IR	Hybrid No. 8	55	19.20	Whiteflies, jassids, mites	*Vein clearing *Veinal chlorosis * malformed fruits
2	Bailhongal Taluk							
	Villages							
	Bailhongal	3	IR	Varsha	55	28.42	Whiteflies, thrips	* vienal clearing *Minute enation on leaves * Malformed fruits
	Sampagoan	4	IR	Namadari	50	26.33	Whiteflies, jassids	*Vein clearing *malformed and bleached fruits
	Bailwad	3	IR	Soumya F_1	60	24.24	Whiteflies, thrips, mites	*Vein clearing *Completely yellowing of leaves
	Hirebagawadi	2	IR	Hybrid No. 8	50	20.40	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit
3	Hukkeri Taluk							
	Villages							
	Hukkeri	2.5	IR	Soumya F_1	45	25.24	Whiteflies, thrips, mites	* Vein clearing * Malformed and bleachd fruits
	Sankeshwar	1	IR	Namdari	50	22.34	Whiteflies	* Vein clearing * Veinal chlorosis * malformed fruits
	Hanchanal	3	IR	Arka Anamika	65	20.80	Whiteflies, jassids	* Vein clearing * Stunting of plants
4	ChikkodiTaluk							
	Villages							
	Chickkodi	2	IR	Hybrid No. 8	50	18.25	Whiteflies, jassids, mites	* Vein clearing * Cupped shaped leaves *Malformed fruits
	Manjri	1.5	RF	Varsha	60	30.40	Whiteflies, jassids	Veinal chlorosis * Vein clearing
	Nippani	2.5	IR	Hybrid No. 8	55	20.50	Whiteflies, thrips	Vein clearing * Veinal chlorosis
	Ankali	2	IR	Arka Anamika	50	19.50	Whiteflies, jassids	*Veinal chlorosis * veinal clearing
5	Athani Taluk							
	Villages							
	Athani	1.5	IR	Varsha	45	28.44	Whiteflies, jassids	*Vein clearing *Veinal chlorosis *Yellowing of leaves
	Ugarkhurd	2	IR	Namdari	50	26.50	Whiteflies, jassids, thrips	*Vein clearing *minute enation or leaves
	Shedhal	1	RF	CK-7	55	32.50	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
	Kagwad	1.5	IR	Hybrid No. 10	60	18.20	Whiteflies, jassids, mites	*Vein clearing *Veinal chlorosis * malformed fruits

Table 2. Contd.....

Sl. No.	Place	Area (acres)	Irrigated or rainfed	Variety or hybrids	Stage of the crop (DAP)	Incidence (%)	Insects recorded	Symptoms
	Mangavati	2	IR	Varsha	45	28.20	Whiteflies, thrips	*, .vienal clearing *Minute enation on leaves * Malformed fruits
	Shiraguppi	2.5	IR	Hybrid No. 10	45	19.50	Whiteflies, jassids	*Vein clearing *malformed and bleached fruits
II	Haveri district							
1	Shiggon taluk							
	Villages							
	Tadas	3	IR	Namdari	60	28.60	Whiteflies, thrips, mites	*Vein clearing *Completely yellowing of leaves
	Dhundshi	1.5	IR	Pusa Sawani	65	78.60	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit
	Shiggaon	2	IR	Hybrid No. 10	45	17.50	Whiteflies, thrips, mites	* Vein clearing * Malformed and bleachd fruits
	Bankapur	3	IR	Hybrid No. 10	50	18.50	Whiteflies	* Vein clearing * Veinal chlorosis * malformed fruits
2	Savanur Taluk							
	Villages							
	Savanur	1.5	IR	Hybrid No. 8	55	18.60	Whiteflies, jassids	* Vein clearing * Stunting of plants
	Yalavgi	2.5	IR	Varsha	45	27.25	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
	Allipur	2	IR	C.K.-7	60	30.20	Whiteflies, jassids, mites	* Vein clearing * C pped shaped leaves *Malformed fruits
	Mavur	2.5	IR	Namdari	45	27.20	Whiteflies, jassids	Veinal chlorosis * Vein clearing
3	Hangal Taluk							
	Villages							
	Bommanahalli	1	RF	Parbhani Kranti	50	58.20	Whiteflies, jassids	*Veinal chlorosis * veinal clearing
	Navegal	1.5	IR	Parabhani Kranti	55	46.50	Whiteflies, jassids	*Vein clearing *Veinal chlorosis *Yellowing of leaves
	Hangal	2	IR	CK-7	40	28.50	Whiteflies, jassids, thrips	*Vein clearing *minute enation or leaves
	Devagiri	2.5	IR	Arka Anamika	45	18.50	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
4	Haveri taluk							
	Villages							
	Haveri	1.5	IR	Reshma F_1	45	23.20	Whiteflies, jassids, mites	*Vein clearing *Veinal chlorosis * malformed fruits
NH	Devihosur	2	IR	Local	60	62.40	Whiteflies, thrips	* .vienal clearing *Minute enation on leaves * Malformed fruits
	Kurubagunda	2	IR	Reshma F_1	55	22.50	Whiteflies, jassids	*Vein clearing *malformed and bleached fruits
5	Byadagi Taluk						Whiteflies, thrips, mites	*Vein clearing *Completely yellowing of leaves
	Villages							
	Byadagi	3	IR	Arka Anamika	50	19.50	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit
	Bisanlahalli	2.5	IR	Arka Anamika	50	18.80	Whiteflies, thrips, mites	* Vein clearing * Malformed and bleachd fruits
III	Dharwad District							
1	Dharwad Taluk							
	Villages							
	Dharwad	1.5	IR	Arka Anamika	50	18.20	Whiteflies	* Vein clearing * Veinal chlorosis * malformed fruits
	Narendra	3	IR	Hybrid No.8	55	20.20	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
	Navalur	3.5	IR	Hybrid No8	65	19.60	Whiteflies, jassids, mites	* Vein clearing * C pped shaped leaves *Malformed fruits

Table 2. Contd.....

Sl. No.	Place	Area (acres)	Irrigated or rainfed	Variety or hybrids	Stage of the crop (DAP)	Incidence (%)	Insects recorded	Symptoms
	Garag	3	IR	Champion	40	27.80	Whiteflies, jassids	Veinal chlorosis * Vein clearing
	Belur	2.5	IR	Arka Anamika	55	19.90	Whiteflies, thrips	Vein clearing * Veinal chlorosis
	Mugad	2.5	IR	Hybrid No.10	65	21.10	Whiteflies, jassids	*Veinal chlorosis * veinal clearing
2	Kalaghatagi Taluk							
	Villages							
	Aulakoppa	1.5	RF	Varsha	55	27.80	Whiteflies, jassids	*Vein clearing *Veinal chlorosis *Yellowing of leaves
	Dhumwad	2	IR	Champion	45	25.20	Whiteflies, jassids, thrips	*Vein clearing *minute enation or leaves
	Honalli	2.5	IR	Arka anamika	50	17.50	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
	Kalaghatagi	2	IR	Arka Anamika	45	18.70	Whiteflies, jassids, mites	*Vein clearing *Veinal chlorosis * malformed fruits
3	Kundagol Taluk							
	Villages							
	Hiremarthi	1.5	RF	Hybrid No.8	50	18.60	Whiteflies, thrips	*vienal clearing *Minute enation on leaves * Malformed fruits
	Kundagol	2	IR	Arka Anamika	60	22.65	Whiteflies, jassids	*Vein clearing *malformed and bleached fruits
	Kubihal	2	IR	Arka Anamika	55	12.60	Whiteflies, thrips, mites	*Vein clearing *Completely yellowing of leaves
	Saunshi	3	IR	Hybrid No.10	45	18.50	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit
	Ingalagi	2.5	IR	Arka Anamika	60	19.20	Whiteflies, thrips, mites	* Vein clearing * Malformed and bleachd fruits
4	Hubli Taluk							
	Villages							
	Sattur	1.5	RF	Pusa Sawani	60	55.20	Whiteflies	* Vein clearing * Veinal chlorosis * malformed fruits
	Rayapura	1.5	RF	Parbhani Kranti	55	42.40	Whiteflies, jassids	* Vein clearing * Stunting of plants
	Unkal	2	IR	Hybrid No.8	45	24.50	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
	Gabbur	3	IR	Arka Anamika	65	21.70	Whiteflies, jassids, mites	* Vein clearing * Cupped shaped leaves *Malformed fruits
	Bairidevarakoppa	2.5	IR	Champion	50	28.50	Whiteflies, jassids	Veinal chlorosis * Vein clearing
IV	Gadag district							
1	Navalgund Taluk							
	Villages							
	Tiralpur	1.5	RF	Pusa Sawani	65	52.20	Whiteflies, thrips	Vein clearing * Veinal chlorosis
	Bebhal	2.5	IR	Arka Anamika	55	22.50	Whiteflies, jassids	*Veinal chlorosis * veinal clearing
	Morab	2.5	IR	Arka Anamika	50	23.40	Whiteflies, jassids	*Vein clearing *Veinal chlorosis *Yellowing of leaves
	Alagwadi	1.5	IR	Hybrid No.8	60	20.50	Whiteflies, jassids, thrips	*Vein clearing *minute enation or leaves
	Shalavadi	1	RF	Parbhani Kranti	55	42.50	Whiteflies, thrips	* Vein clearing * Veinal chlorosis

Table 2. Contd.....

Sl. No.	Place	Area (acres)	Irrigated or rainfed	Variety or hybrids	Stage of the crop (DAP)	Incidence (%)	Insects recorded	Symptoms
	Annigeri	2	IR	Arka Anamika	55	21.60	Whiteflies, jassids, mites	*Vein clearing *Veinal chlorosis * malformed fruits
2	Nargund Taluk							
	Villages							
	Chikkanargund	1	RF	Pusa Sawani	60	48.50	Whiteflies, thrips	* vienal clearing *Minute enation on leaves * Malformed fruits
	Hadli	2	IR	Champion	55	28.60	Whiteflies, jassids	*Vein clearing *malformed and bleached fruits
	Shirol	4	IR	Varsha	55	27.20	Whiteflies, thrips, mites	*Vein clearing *Completely yellowing of leaves
	Konnur	3	IR	Champion	65	24.50	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit
	Kurlageri	2	IR	Arka Anamika	50	22.20	Whiteflies, thrips, mites	* Vein clearing * Malformed and bleachd fruits
3	Ron Taluk							
	Villages							
	Belvanki	1.5	IR	Arka Anamika	55	22.20	Whiteflies	* Vein clearing * Veinal chlorosis * malformed fruits
	Asuti	1	RF	Champion	45	28.50	Whiteflies, jassids	* Vein clearing * Stunting of plants
	Ron	1	RF	Parbhani Iorani	45	40.20	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
	Chikkamannur	1.5	IR	Arka Anamika	60	24.20	Whiteflies, jassids, mites	* Vein clearing * Cupped shaped leaves *Malformed fruits
	Sudi	2	IR	Namdari	55	26.20	Whiteflies, jassids	Veinal chlorosis * Vein clearing
	Nidagundi	1	IR	Arka anamica	50	22.50	Whiteflies, thrips	Vein clearing * Veinal chlorosis
4	Gadag Taluk							
	Villages							
	Balaganur	1.5	IR	Arka Anamika	50	22.50	Whiteflies, jassids	*Veinal chlorosis * ... veinal clearing
	Hombal	1	RF	Parbhani Krani	50	47.20	Whiteflies, jassids	*Vein clearing *Veinal chlorosis *Yellowing of leaves
	Gadag	2	IR	Namdari	60	29.40	Whiteflies, jassids, thrips	*Vein clearing *minute enation or leaves
	Kurthakoti	1	IR	Hybrid No.8	65	24.20	Whiteflies, thrips	* Vein clearing * Veinal chlorosis
	Lakkundi	1	IR	Namdari	50	27.80	Whiteflies, jassids, mites	*Vein clearing *Veinal chlorosis * malformed fruits
5	Shirahatti Taluk							
	Villages							
	Magadi	1.5	IR	Namdari	40	28.20	Whiteflies, thrips	* vienal clearing *Minute enation on leaves * Malformed fruits
	Shirahatti	2	IR	Arka Anamika	55	22.30	Whiteflies, jassids	*Vein clearing *malformed and bleached fruits
	Laxemegwar	1	RF	Pusa Sawani	65	56.20	Whiteflies, thrips, mites	*Vein clearing *Completely yellowing of leaves
	Shigli	1	IR	Arka Anamika	40	24.90	Whiteflies, thrips, jassids,	* Vein clearing * Minute enation on leaves * malformed fruit
	Bellatti	2	IR	Namdari	45	29.40	Whiteflies, thrips, mites	* Vein clearing * Malformed and bleachd fruits

4.1.2 Incidence of BYVMV on different cultivars

During the survey, field selection was randomly made irrespective of varieties cultivated. The number of fields surveyed under different varieties/hybrids varied and which represented the extent of cultivated area under each variety. The number of fields surveyed, average per cent disease incidence and insects recorded are presented in Table 3. The maximum area was occupied by Arka Anamika, in both the seasons followed by Hybrid No. 8 and Namdhari. The maximum average per cent disease incidence was observed in Pusa Sawani during both *kharif* 2000 (15.08%) and summer 2001 (58.14%) and minimum incidence was observed in commonly cultivated variety Arka Anamika during both *kharif* 2000 (0.07%) and summer 2001 (20.47%). Invariably whitefiles were found feeding on the bhendi in most of the fields surveyed in both the seasons.

4.1.3 Fixed plot survey

The fixed plot survey for the incidence of BYVMV was under taken at Main Research Station, Dharwad during *kharif* 2000 and summer 2001 and the over all disease incidence at different periods of crop growth has been presented in Table 4 and Fig. 1. It was noticed that the during *kharif* 2000 disease incidence ranged from 0.0 to 3.5 per cent. The highest disease incidence of 3.5 per cent was recorded at 60 days after planting followed by 1.5 per cent at 45 days after planting, 0.5 per cent at 30 days after planting and there was no disease incidence at 15 days after planting.

Table 3. Per cent BYVMV incidence on different Bhendi cultivars in the farmers field in Dharwad, Belgaum, Haveri and Gadag districts during *kharif* 2000 and summer 2001

Sl. No.	Name of cultivars	*Kharif* 2000			Summer 2001		
		Number of fields surveyed	Average per cent disease incidence	Insects recorded	Number of fields surveyed	Average per cent disease incidence	Insects recorded
1	Arka Anamika	21	0.07	Whiteflies	25	20.47	Whiteflies, Thrips
2	Hybrid No. 8	6	0.58	Whiteflies	12	22.11	Whiteflies, Thrips
3	Hybrid No. 10	3	0.53	Whiteflies	7	21.96	Whiteflies, Jassids
4	Varsha	6	4.88	Whiteflies, Thrips	7	32.13	Whiteflies, Thrips
5	Namdhari	2	3.50	Whiteflies, Jassids	9	27.19	Whiteflies, Thrips
6	Champion	9	3.83	Whiteflies, Jassids	6	31.43	Whiteflies, Thrips
7	Soumya F_1	-	-	-	2	23.29	Whiteflies, Jassids
8	C.K-7	-	-	-	4	37.28	Whiteflies, Thrips
9	Reshma F_1	-	-	-	2	22.85	Whiteflies, Jassids
10	Ankur	5	3.92	Whiteflies, Jassids	-	-	-
11	Parbhani kranti	1	8.50	Whiteflies, Thrips, Jassids	6	46.16	Whiteflies, Thrips, Jassids
12	Pusa Sawani	3	15.08	Whiteflies, Thrips, Jassids, Mites	5	58.14	Whiteflies, Thrips, Jassids, mites
13	Local	2	12.50	Whiteflies, Thrips, Jassids	1	55.40	Whiteflies, Thrips, mites
	Total	58			86		

Table 4. Fixed plot survey for the incidence of Bhendi yellow vein mosaic virus during *kharif* 2000

Place	15 DAP*			30 DAP			45 DAP			60 DAP		
	PDI**	Insects recorded	Symptom	PDI	Insects recorded	Symptom	PDI	Insects recorded	Symptom	PDI	Insects recorded	Symptom
Dharwad	0.0	-	-	0.5	Whiteflies	• Light vein clearing	1.5	Whiteflies Jassids	• Vein clearing • Veinal chlorosis	3.5	Whiteflies jassids thrips	•Vein clearing • Vein chlorosis • Completely yellowing of leaves • Veinal chlorosis • Minute enation on the axial side of leaves

* DAP - Days after planting
** PDI - Per cent disease incidence

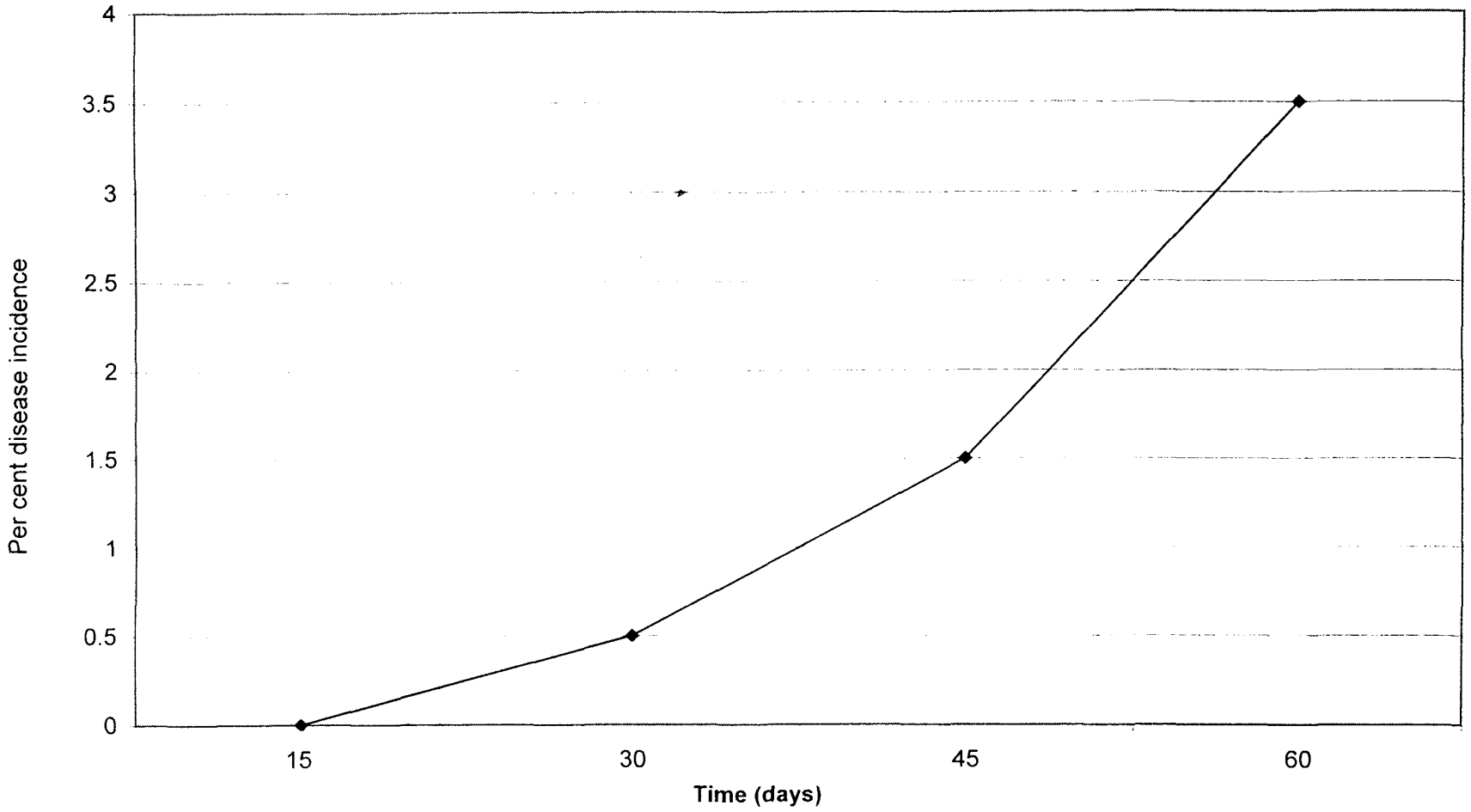

Fig. 1. Progress of Bhendi yellow vein mosaic virus during *kharif* 2000

During summer 2001 the disease incidence ranged from 8.5 to 66.5 per cent (Table 5 and Fig. 2). The highest disease incidence of 66.5 per cent was recorded at 60 days after planting followed by 45.5 per cent at 45.4 days after planting, 21.5 per cent at 30 days after planting and lowest incidence of 8.5 per cent was found at 15 days after planting.

During the first observation at 15 DAP vein clearing symptoms on the younger leaves were seen along with veinal chlorosis and complete yellowing of leaves symptoms persisted upto 30 DAP. At 45 DAP minute enation on the axial side of leaves observed and at 60 DAP the fruits were malformed and bleached. Insect vectors like whiteflies, jassids, thrips were seen feeding on Bhendi crop.

4.2 SYMPTOMATOLOGY

All the plants of Bhendi Cv. Pusa Sawani inoculated, developed vein clearing, vein chlorisis on upper leaves 10-15 days after inoculation (Plate 4). In some cases affected leaves showed crinkling, curling and minute enation on the axial side of leaves (Plate 5) and in severe cases affected leaves showed complete yellowing of leaf and later there was a reduction of leaf size (Plate 6).

4.3 TRANSMISSION

4.3.1 Mechanical transmission

The sap inoculation of virus causing bhendi yellow vein mosaic disease was carried out on bhendi cultivar 'Pusa Sawani' as described under "Material and Methods".

Table 5. Fixed plot survey for the incidence of Bhendi yellow vein mosaic virus during summer 2001

Place	15 DAP*			30 DAP			45 DAP			60 DAP		
	PDI**	Insects recorded	Symptom	PDI	Insects recorded	Symptom	PDI	Insects recorded	Symptom	PDI	Insects recorded	Symptom
Dharwad	8.5	Whiteflies jassids	•Vein clearing on the younger leaves	21.5	Whiteflies jassids thrips	• Vein clearing on the younger leaves • Veinal chlorosis • Complete yellowing of leaves followed by vein clearing	45.4	Whiteflies jassids thrips mites	• Vein clearing • Veinal chlorosis • Complete yellowing of leave followed by vein clearing • Minute enation on the axial side of leaves	66.5	Whiteflies jassids thrips	•Vein clearing • Vein chlorosis • Complete yellowing of leaves followed by vein clearing • Minute enation on the axial side of leaves • Finally the fruits from such diseased plants were malformed and bleached

* DAP - Days after planting
** PDI - Per cent disease incidence

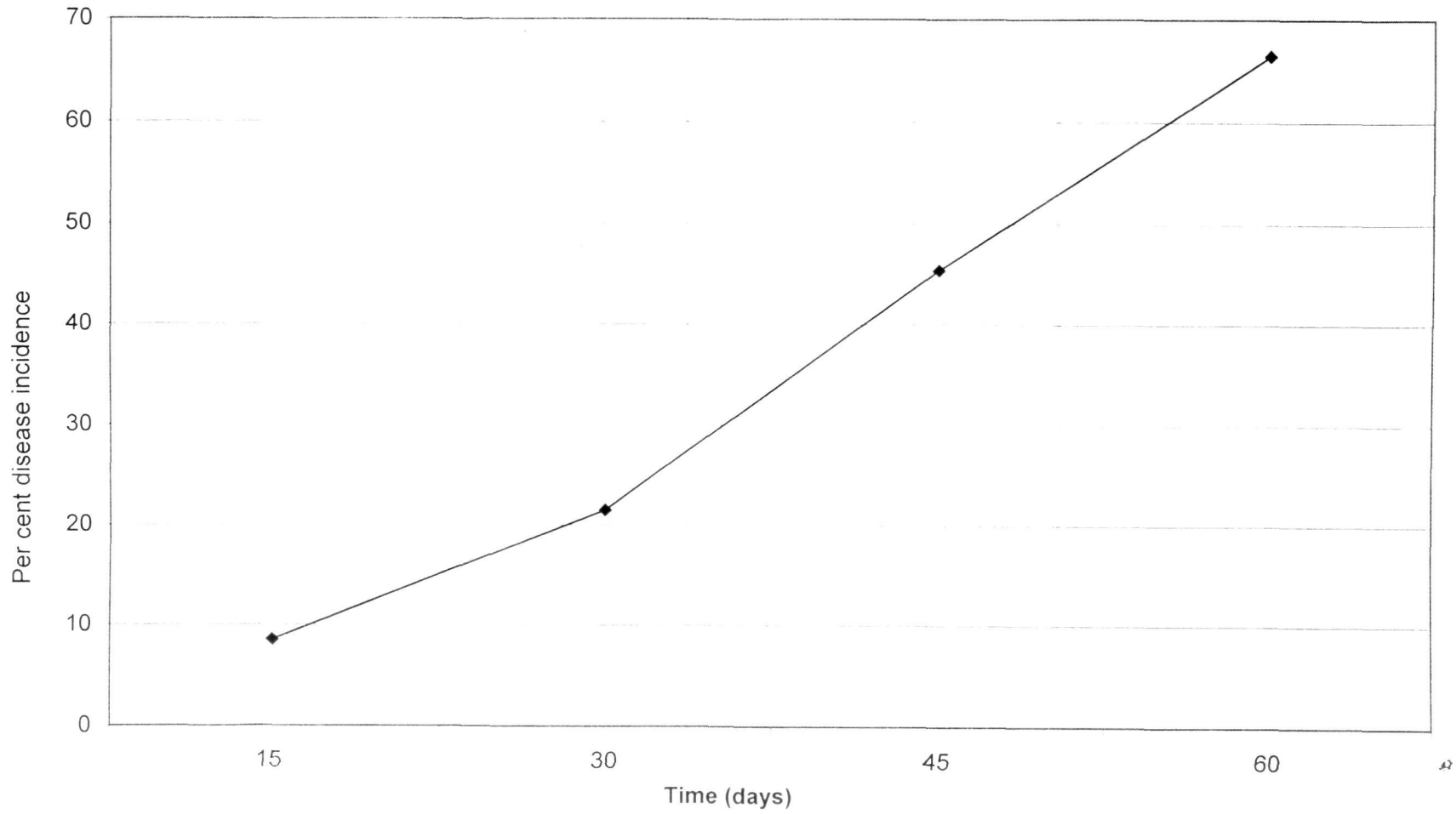

Fig. 2. Progress of Bhendi yellow vein mosaic virus during summer 2001

Plate 4. Bhendi leaf showing vein clearing and veinal chlorosis due to BYVMV

Plate 5. Bhendi leaf showing crinkling, curling and minute enation on axial side of leaf due to BYVMV

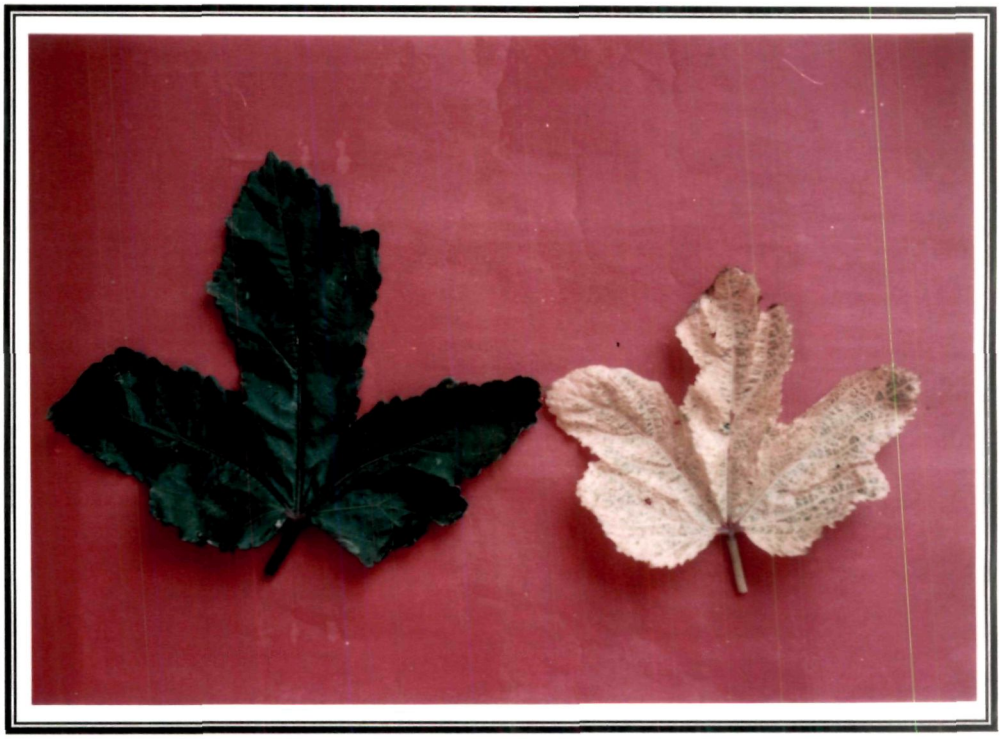

Plate 6. Bhendi leaf showing complete yellowing and reduction in size due to BYVMV

The results showed that the virus was not sap transmissible. None of the plants produced symptoms even upto 30 days after inoculation (Table 6).

4.3.2 Dodder transmission

Studies on dodder transmission of the virus was carried out as described in material and methods. The results indicated that the virus under study was not transmitted by dodder from bhendi to bhendi, as none of the plants inoculated by using dodder developed any symptoms even upto 30 days (Table 6).

4.3.3 Graft transmission

Attempts were made to transmit the virus causing Bhendi yellow vein mosaic disease through grafting as detailed in "Material and Methods".

The results demonstrated that the virus was transmissible through grafting as symptoms developed on grafted bhendi plants (Plate 7). Sixty two per cent of the grafted plants developed yellow vein mosaic symptoms within 20 days after grafting (Table 6).

4.3.4 Whitefly transmission

Whitefly *Bemisia tabaci* was used for transmission of BYVMV as described under materials and methods. *B. tabaci* transmitted BYVMV to bhendi and as 88 per cent of the inoculated plants developed yellow vein symptoms 10-15 days after inoculation (Table 6 and Plate 8).

Table 6. Transmission studies on BYVMV*

Sl. No.	Method of transmission	Total number of plants infected / Total number of plants inoculated****	Per cent transmission	Period taken for symptom expression (days)
1	Mechanical*	0 / 10	0	-
2	Dodder**	0 / 10	0	-
3	Graft*	6 / 10	62.00	20
4	Vector***	8 / 10	88.00	10-15

* Cv. Pusa Sawani
** Dodder - *Cuscuta reflexa* Roxb.
*** 10 viruliferous whiteflies were transferred to each plants
**** Whiteflies were given 24 hours acquisition and 24 hours inoculation access periods

Plate 7. Bhendi infected with BYVMV through grafting showing yellow vein mosaic

Plate 8. Bhendi plant infected with BYVMV through vector *Bemisia tabaci*

4.3.5 Seed transmission

Studies on seed transmission of virus causing Bhendi yellow vein mosaic disease was carried out as described in material and methods. Seed transmission results indicated that the virus was not seed borne in nature. None of the 18 plants emerged from seeds collected from diseased plants produced symptoms even upto 30 days after emergence. But rate of germination of seeds from diseased fruits was lower (66.2%) compared to seeds from healthy fruits (84.0%) (Table 7).

4.4 HOST RANGE STUDIES

The host range study of the virus was conducted to know the host plants susceptible to the virus. Thirteen plant species belonging to four different families *viz.*, Leguminaceae, Malvaceae, Euphorbiaceae and Solanaceae grown in insect proof glasshouse were inoculated with insect *Bemisia tabaci*, as described under "Materials and Methods". Plants were maintained in the glasshouse for symptom expression.

The results indicated that *Bemisia tabaci* transmitted bhendi yellow vein mosaic disease on plant species belonging to Malvaceae and Euphorbiaceae families (Table 8). The BYVMV induced dark green vein and yellow vein clearing symptoms on *Croton bonplandianum* 20-35 days after inoculation (Plate 9), whereas in malvaceae family out of 3 plants tested it produced symptom on 2 plants species. Curling and crinkling were produced on *Althaea rosea* (Plate 10) 20-35 days after inoculation. Other plant species did not develop symptoms.

Table 7. Seed transmission of Bhendi yellow vein mosaic virus

Sl. No.	Bhendi seeds	No. of seeds sown	No. of seeds germinated	Per cent germination	No. of plants showing symptoms	Per cent transmission
1.	Healthy fruits	25	23	84.0*	0.0	0.0
2.	Diseased fruits	25	18	66.2*	0.0	0.0

* Average of three replications

Table 8. Host range for Bhendi yellow vein mosaic virus

Sl. No.	Host plants	Cultivar	Family	Type of symptoms	Period taken for symptom expression (days)
1	*Abelmoschus esculentus* (L.) Moench	Pusa sawani	Malvaceae	Vein clearing, veinal chlorosis and minute enations on axial side of leaves	10-15
2	*Althaea rosea* (L.) Cav.	Holyhock	Malvaceae	Crinkling and curling	20-35
3	*Arachis hypogea* L.	TMV-2	Leguminaceae	-	-
4	*Capsicum annuum* L.	Byadagi kaddi	Solanaceae	-	-
5	*Crotonbon plandianum* Bail.	Local	Euphorbiceae	Crinkling, curling and vein clearing	20-35
6	*Glycine max* (L.) Merrill	JS-335	Leguminaceae	-	-
7	*Gossypium herbaceum* L.	DHH-11	Malvaceae	-	-
8	*Lycopersicon esculentum* Mill.	Megha (L-15)	Solanaceae	-	-
9	*Nicotiana tabacum* L.	Anand-23	Solanaceae	-	-
10	*Phaseolus vulgaris* L.	Arka Komal	Leguminaceae	-	-
11	*Pisum sativum* L.	Arka Ajit	Leguminaceae	-	-
12	*Vigna radiata* (L.) Wilezek	T-9	Leguminaceae	-	-
13	*Vigna mungo* (L.) Hepper	PS-16	Leguminaceae	-	-

Plate 9. *Croton bonplandianum* Bail, showing dark green vein and yellow vein clearing after inoculation with BYVMV

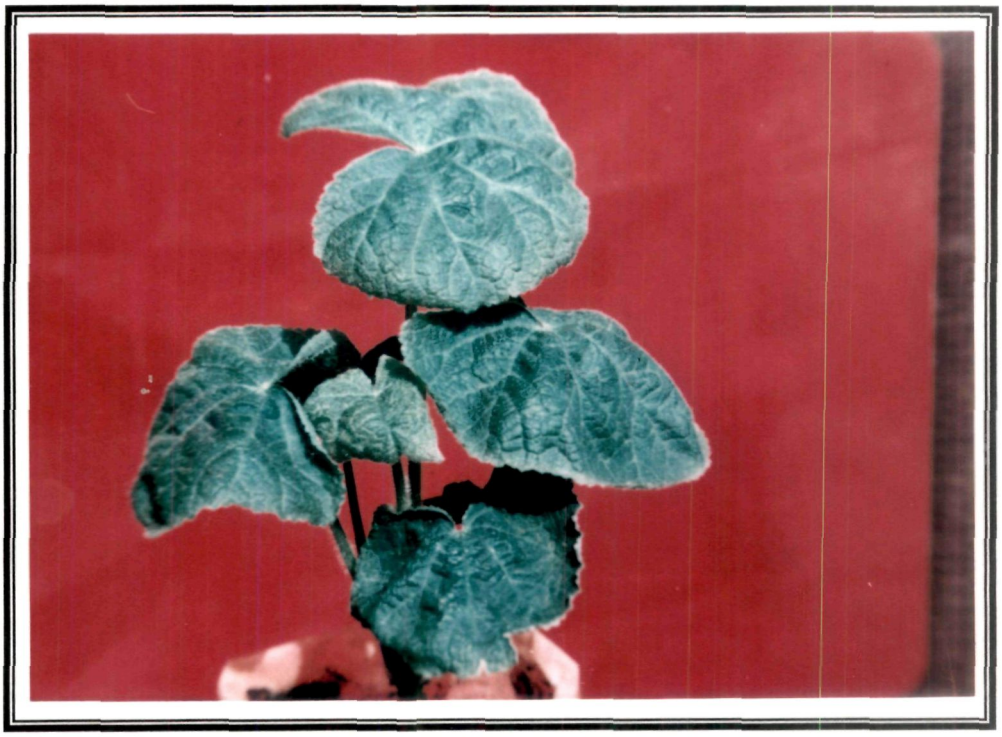

Plate 10. *Althaea rosea* (L.) Cav. showing symptoms of leaf curling and crinkling after inoculation with BYVMV

In the field the BYVMV was noticed on *Ageratum haustonianum* (Plates 11 and 12).

4.5 HISTOPATHOLOGICAL STUDIES

Studies were conducted to know the histopathological changes in leaf and fruit tissues of bhendi Cv. Pusa Sawani after yellow vein mosaic virus infection.

4.5.1 Histopathological changes due to BYVMV

The hispathological changes due to BYVMV infection in comparison with healthy and are presented in Table 9.

Leaf tissue: In the infected leaf samples, the leaf laminar thickness was reduced to 162.80 µm due to BYVMV infection as compared to healthy 168.40 µm. The per cent deviation was 3.32. There was reduction in number of chloroplasts in infected leaf tissue 34.72 µm compared in the healthy leaf (42.84 µm) and per cent deviation was 18.95. The epidermal cells width and height were reduced to 26.38 µm and 21.56 µm respectively compared to healthy (50.08 µm width and 25.62 µm height) and per cent deviation was 47.32 and 15.84 in width and height respectively. The palisades chlorenchyma just below the upper epidermis started loosing their columnar appearance with no intercellular spaces due to BYVMV and measured (42.81 µm in length and 28.80 µm in width) as compared to healthy (58.06 µm in length and 16.80 µm in width) and per cent deviation was 26.26 in length and -71.42 in width. Spongy cell

Plate 11. *Ageratum haustonianum* microplot showing plant infected with BYVMV showing yellow vein mosaic with reduction in size of plant

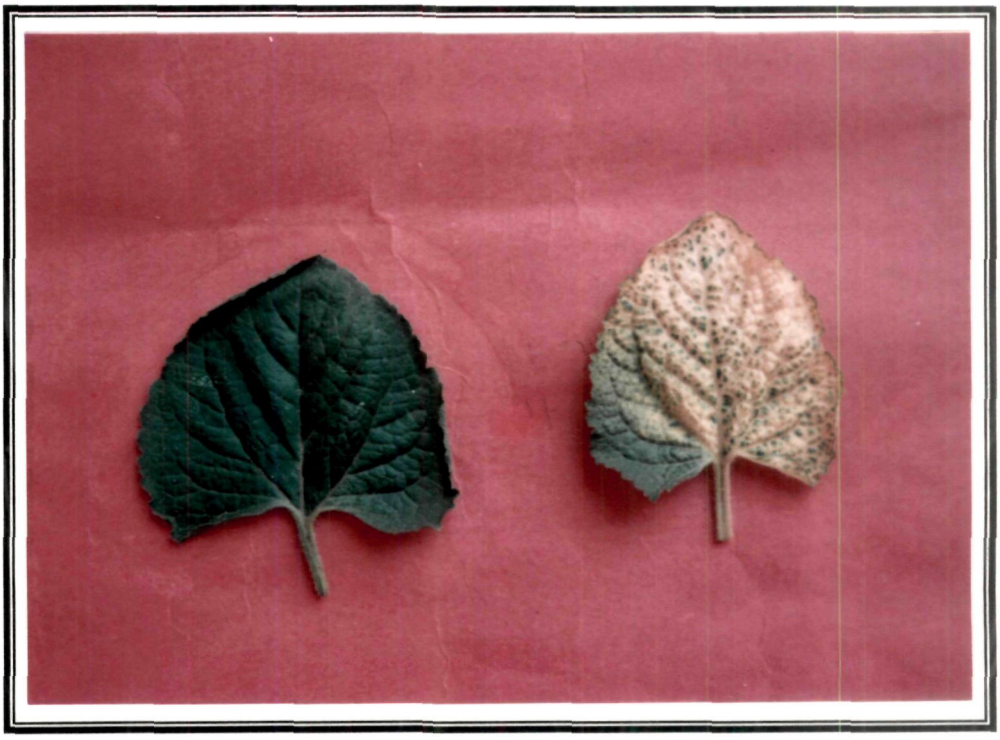

Plate 12. *Ageratum haustonianum* leaf showing yellow vein mosaic virus symptom after infection with BYVMV under field condition

Table 9. Histopathological changes in leaf and fruit tissues due to Bhendi yellow vein mosaic virus infection

Sl. No.	Tissues	Healthy (µm)	Infected (µm)	Per cent deviation from healthy
I	**Leaf**			
1	Leaf laminar thickness	168.40	162.80	3.32
2	Number of chloroplasts	42.84	34.72	18.95
3	Epidermal cell			
	Width	50.08	26.38	47.32
	Height	25.62	21.56	15.84
4	Palisade cell			
	Length	58.06	42.81	26.26
	Width	16.80	28.80	-71.42
5	Spongy cell diameter	33.72	29.47	12.60
II	**Fruit**			
1	Number of epidermal cells/mm	98.20	70.20	28.51

diameter was reduced to 29.47 µm due to BYVMV. Whereas, in healthy it was 33.72 µm and per cent deviation was 12.60 (Plates 13 and 14).

Fruit tissue: In case of fruit tissue there was not much histological changes, however, the number of epidermal cells/mm were reduced to 70.20 µm in fruit rind due to BYVMV as compared to healthy fruit rind (98.20 µm) and per cent deviation was 28.51 (Plates 15 and 16).

4.7 MANAGEMENT OF YELLOW VEIN MOSAIC VIRUS OF BHENDI

An experiment was conducted during *kharif* 2000 and summer 2001 at Main Research Station, University of Agricultural Sciences, Dharwad to evaluate the efficacy of different insecticides, viricides and plant extracts against the bhendi yellow vein mosaic disease, as described in material and methods. Per cent disease incidence and per cent disease reduction over control were computed.

4.7.1 Efficacy of insecticides, plant extracts and viricide

Observations recorded at 90 days after planting indicated that the soil application of carbofuran 3G (15 kg/ha) twice (once at the time of sowing and 20 days after sowing) + five sprays of metasystox (0.2%) (Plate 17) at an interval of 15 days reduced the virus disease incidence to the maximum extent of 29.33 per cent which was significantly superior to other treatments. Next best treatments were Rogor (0.2%) (34.33%), soil application of carbofuran 3G (15 kg/ha) twice (once at the time of sowing and 20 days after sowing) (43.14%), alternate sprays of Rogor (0.2%) and

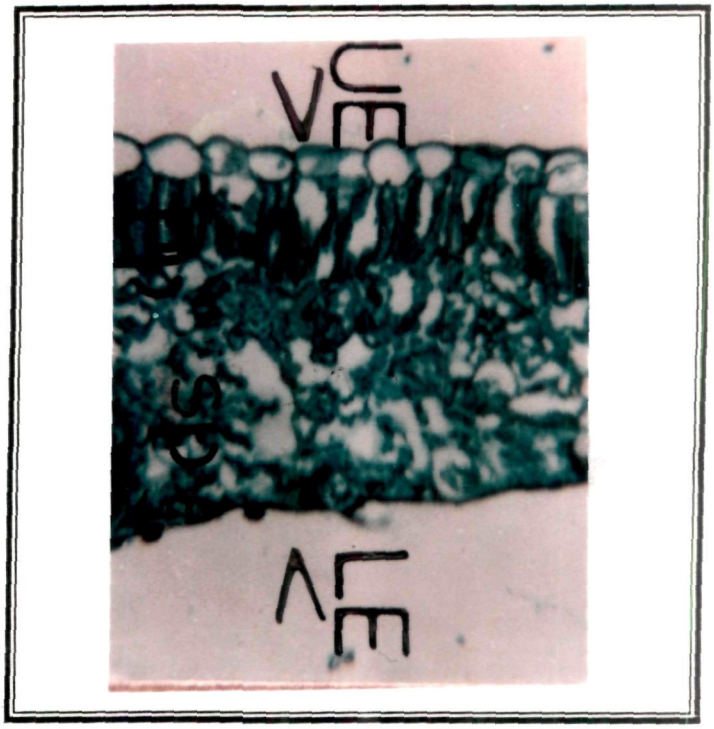

Plate 13. Cross section of the leaves showing healthy palisade and spongy parenchyma cell (x 100)

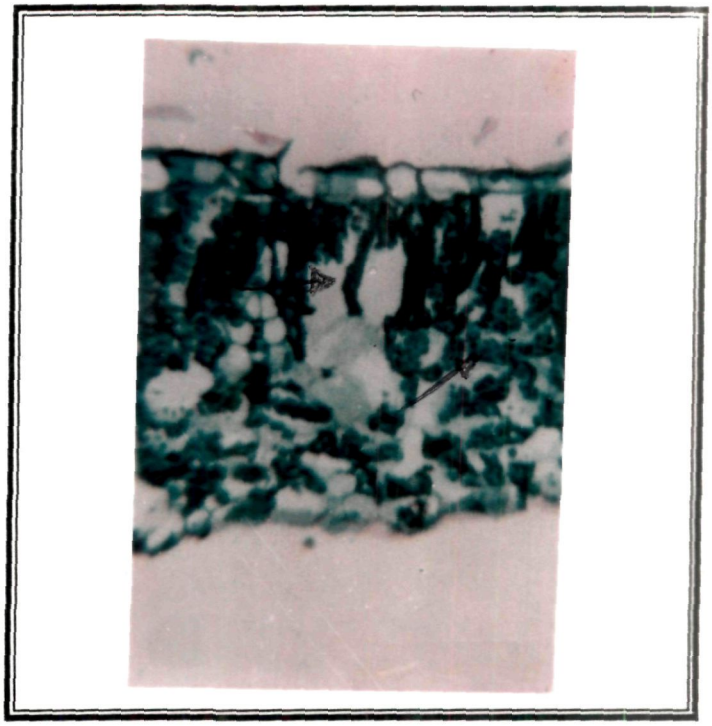

Plate 14. Cross section of the leaves showing palisade cells started loosing their columnar appearance and there was no clear cut differentiation into palisade and spongy layers due to BYVMV infection (x100)

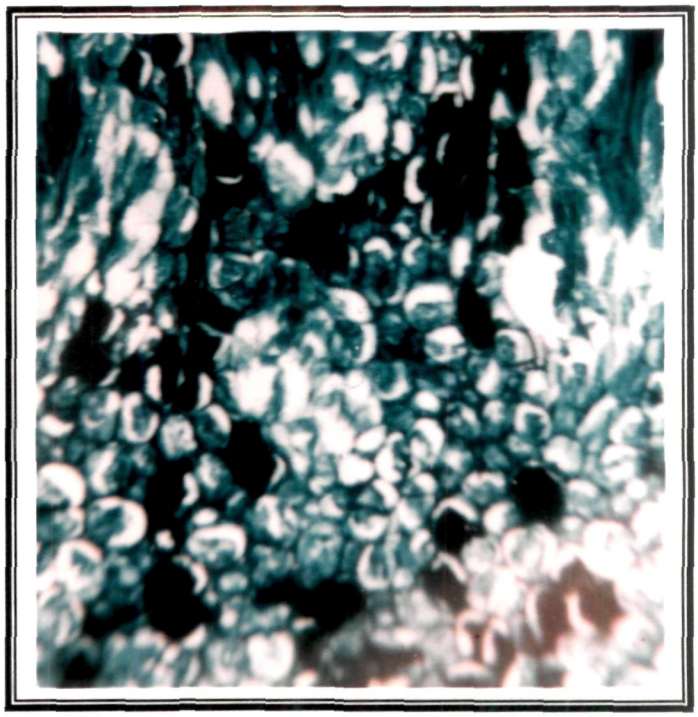

Plate 15. Cross section of the healthy fruit rind showing number of epidermal cells/mm

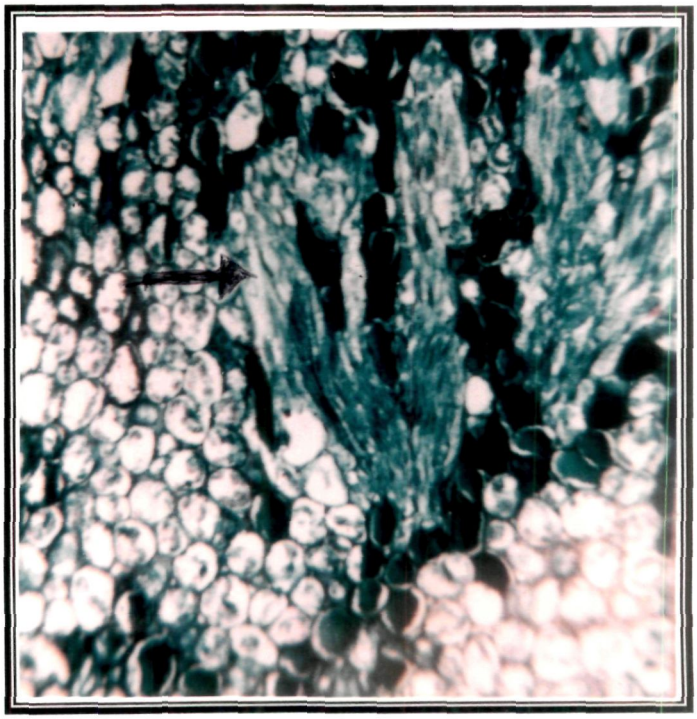

Plate 16. Cross section of BYVMV infected fruit rind showing reduction in number of epidermal cells/mm

Plate 17. Microplot of bhendi sprayed with metasystox (0.2%) + soil application of carbofuran 3 G (15 kg/ha)

parthenium leaf extract (10%) (R-P-R-P-R) (46.00%). In case of Action 100 (0.2%) (Plate 18), the disease was 51.00 per cent which were on par with each other. The parthenium leaf extract (10%) and unsprayed control plot recorded maximum disease incidence of 72.00 per cent and 91.26 per cent (Plate 19) respectively. Similar trend was observed in previous observations made at 15, 30, 45, 60 and 75 days after planting (Table 10 and Fig. 3).

The soil application of carbofuran 3G (15 kg/ha) twice (Once at the time of sowing and 20 days after sowing) + 5 sprays of metasystox (0.2%) reduced the disease the extent of 73.18 per cent, followed by Rogor (0.2%) 68.38 per cent, soil application of carbofuran 3G (15 kg/ha) twice (once at the time of sowing and next 20 days after sowing) 62.10 per cent, alternate spray of Rogor (0.2%) and parthenium leaf extract (10%) (R-P-R-P-R) 59.03 per cent and Action 100 (0.2%) 54.39 per cent. Parthenium leaf extract (10%) was least effective as it reduced only 23.96 per cent of disease over control.

4.7.1.1 Vector population

Whitefly *Bemisia tabaci* population was recorded in the above experiment at 15, 30, 45, 60, 75 and 90 days after planting and the data are presented in the (Table 11).

The lowest whitefly population average number per leaf (3.46) per plot was observed in soil application of carbofuran 3G (15 kg/ha) twice (Once at the time of sowing and next 20 days after sowing) + metasystox

Plate 18. Microplot of bhendi sprayed with Action 100 (0.2%)

Plate 19. Unsprayed microplot of bhendi (control)

Table 10. Efficacy of insecticides, plant extracts and viricide in the management of BYVMV duirng summer 2001

Treatments		Per cent disease incidence at**						Average	% reduction over control	Yield (q/ha)
		15 DAP*	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP			
T_1	Metasystox (0.2%) + carbofuran 3G (15kg/ha)	4.90	6.35	8.28	12.27	20.31	29.33	13.57	73.18	53.66
		(12.79)***	(14.54)	(16.64)	(20.44)	(26.78)	(32.77)			
T_2	Rogor (0.2%)	5.80	7.54	9.03	16.25	23.07	34.33	16.00	68.38	46.00
		(13.94)	(15.89)	(17.46)	(23.73)	(28.66)	(35.85)			
T_3	Action 100 (0.2%)	6.49	12.47	16.14	20.38	32.02	51.00	23.08	54.89	40.33
		(14.65)	(20.62)	(23.66)	(26.78)	(34.45)	(45.57)			
T_4	Carbofuran 3G (15kg)	5.27	9.48	11.25	17.46	28.51	43.14	19.18	62.10	45.16
		(13.18)	(17.85)	(19.55)	(24.65)	(32.27)	(41.03)			
T_5	Parthenium leaf extract (10%)	4.49	18.48	36.45	38.59	60.91	72.00	38.48	23.96	35.83
		(12.11)	(21.47)	(23.11)	(30.33)	(47.41)	(58.05)			
T_6	R-P-R-P-R	5.00	11.48	12.51	18.49	30.94	46.00	20.73	59.03	42.00
		(12.42)	(19.73)	(20.70)	(25.40)	(33.77)	(42.71)			
T_7	Control	6.33	25.43	45.25	55.36	80.07	91.26	50.61		21.16
		(14.54)	(30.26)	(42.25)	(48.04)	(63.43)	(72.74)			
	S.E.m±	0.615	0.586	0.658	1.094	1.698	1.468	-	-	-
	CD at 5%	(2.014)	(1.692)	(1.988)	(3.329)	(5.229)	(4.482)	-	-	-

* DAP: Days after planting
** Observation recorded 1 day prior to spray
*** Figures in parenthesis indicate arcsine value

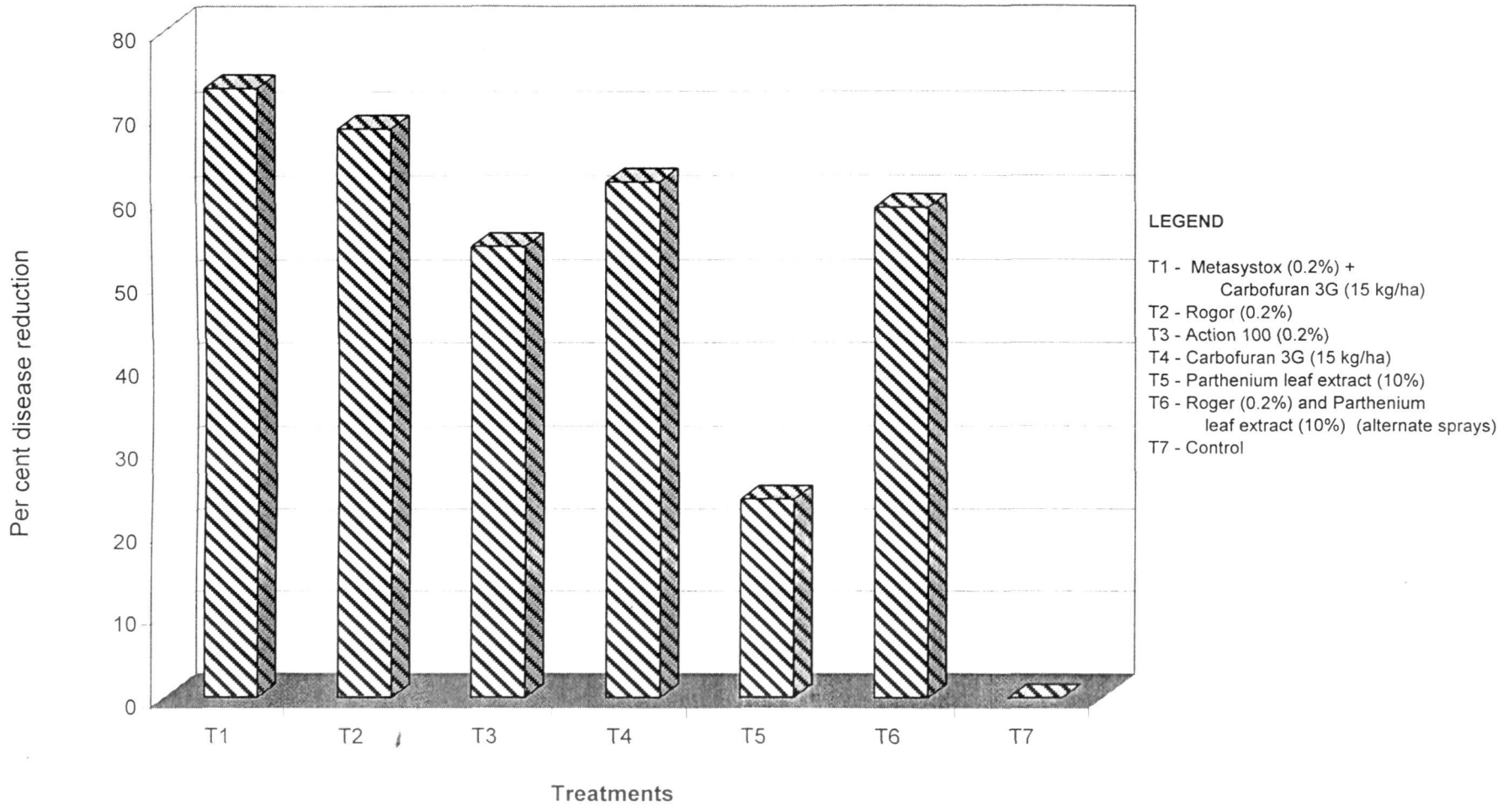

Fig. 3 . Management of Bhendi yellow vein mosaic virus during summer 2001

Table 11. Whitefly population per leaf during summer 2001

Sl. No.	Treatments	Average number of whitefly per leaf per plot at						Mean population
		15 DAP*	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	
T_1	Metasystox (0.2%) + carbofuran 3G (15 kg/ha)	4.43	4.56	5.03	3.36	2.36	1.02	3.46
T_2	Rogor (0.2%)	3.70	5.70	6.50	5.10	4.10	2.50	4.60
T_3	Action 100 (0.2%)	5.58	9.58	10.58	9.06	8.06	5.58	8.07
T_4	Carbofuran 3G (15 kg/ha)	4.86	6.86	7.86	5.26	4.93	3.70	5.57
T_5	Parthenium leaf extract (10%)	4.16	12.50	11.33	11.03	9.03	5.59	8.94
T_6	R-P-R-P-R	6.56	9.20	10.20	7.13	6.16	4.16	7.23
T_7	Control	5.29	20.50	24.66	17.29	12.79	6.56	14.51
	S.E.m±	0.568	0.763	0.867	0.544	0.602	0.510	-
	CD at 5%	2.252	2.352	2.671	1.676	1.854	2.215	-

* DAP: Days after planting

(0.2%) sprayed plots. In case of Rogor (0.2%), soil application of carbofuran 3G (15 kg/ha) twice (once at the time of sowing and next 20 days after sowing), alternate spray of Rogor (0.2%) and parenthium leaf extracts (10%) (R-P-R-P-R) and Action 100 (0.2%) sprayed plots recorded whitefly population per leaf as 4.60, 5.57, 7.23, 8.07 and 8.94 respectively, whereas whitefly population (14.51) was significantly higher in the unsprayed plots.

During *kharif* 2000 there was not much BYVMV incidence in any of the plots (Plate 20) as compared to summer 2001 (Plate 21).

4.7.2 Screening of bhendi genotypes against bhendi yellow vein mosaic disease

Nineteen genotypes were screened for Bhendi yellow vein mosaic disease under field conditions at UAS, Dharwad during *kharif* 2000 and summer 2001 to identify the source of resistance. Bhendi yellow vein mosaic disease incidence was recorded at pre flowering and post flowering stages of the crop by calculating per cent disease incidence.

During summer 2001 the yellow vein mosaic disease incidence varied from 0.80 to 74.99 per cent in Arka Anamika and Pusa sawani respectively (**Table 12**). Among the 19 lines tested least disease incidence and highest yield was observed in Arka Anamika (0.80% and 23.00 t/ha) followed by Hybrid No. 8. (0.96% and 22.09 t/ha), Hybrid No. 10 (0.96 and 22.52 t/ha) (Plate 22), Reshma (2.97% and 21.58 t/ha) and Soumya F_1 (OH-4002) (3.25% and 20.55 t/ha). Highest yellow vein mosaic

Plate 20. During *kharif* 2000 microplot of bhendi was free from BYVMV infection

Plate 21. During summer 2001 microplot showing BYVMV symptoms on bhendi

Table 12 Screening of bhendi genotypes to yellow vein mosaic virus during summer 2001

Sl. No.	Genotype	Pre-flowering incidence (%)	Post flowering incidence (%)	Mean incidence (%)	Yield (t/ha)
1	Pusa Sawani	55.55	94.44	74.99	7.90
2	490327	30.52	73.15	46.83	12.57
3	27930	22.64	72.94	47.73	15.58
4	495458	21.66	71.11	46.88	16.20
5	357995	20.11	76.66	43.88	16.60
6	357996	20.52	72.63	46.57	17.50
7	217922	23.50	73.15	48.32	12.89
8	481999	21.50	70.14	45.82	14.58
9	Harbhajan	20.78	77.89	49.33	12.01
10	496753	21.76	72.58	47.17	14.56
11	496750	23.66	74.29	48.97	14.01
12	40 days bhendi	22.28	77.80	50.04	13.58
13	496667	21.11	76.77	48.94	13.90
14	Arka Abhaya	16.52	56.58	36.55	18.50
15	Arka Anamika	0.10	1.50	0.80	23.00
16	Reshma	0.40	5.55	2.97	21.58
17	Hybrid No.8	0.20	1.76	0.93	22.09
18	Soumya F_1 (OH-4002)	0.50	6.00	3.25	20.55
19	Hybrid No.10	0.20	1.72	0.96	22.52

Plate 22. During summer 2001 microplot showing resistant variety (1) Arka Anamika (2) Hybrid No.8 (3) Hybrid No.10 and highly susceptible variety (4) Pusa Sawani

incidence and lowest yield was recorded in Pusa sawani (74.99% and 7.90 t/ha) followed by 40 days bhendi, Harbhajan, 490327, 217930, 496458, 357995, 357996, 217922, 481999, 496753, 496750, 499667 and Arka Abhay.

Further, these genotypes were grouped into different categories based on 0-9 scale (**Table 13**). None of the genotypes tested was immune. Arka Anamika Hybrid No. 8 and 10 genotypes showed resistant reaction Soumya F_1 (OH-4002) and Reshma were moderately resistant, most of the genotypes (13) showed susceptible and Pusa Sawani genotype was highly susceptible to yellow vein mosaic disease.

During *kharif* 2000, 19 genotypes were screened for Bhendi yellow vein mosaic disease at UAS Dharwad under field conditions. The yellow vein mosaic incidence varied from 0.4 to 3.60 per cent (**Table 14**) on Pusa sawani. So during *kharif* there was no disease pressure (Plate 23) as compared to summer 2001 (Plate 24).

4.6 EFFECT OF YELLOW VEIN MOSAIC INCIDENCE ON GROWTH AND YIELD PARAMETERS OF BHENDI

The effect of yellow vein mosaic disease on growth and yield parameters of bhendi was studied by tagging fifteen plants. Observations were recorded at 35, 45 and 55 DAP on plant height, fruit size (length x breadth), number of fruits per plant.

Table 13 Grouping of genotypes into different categories during summer 2001

Scale	Description	Category	Genotypes
0	No symptoms on plant	Immune	-
1	1% or less plants	Resistant	Hybrid 8 and 10 and Arka Anamika
3	1-10% plants exhibiting symptoms	Moderately resistant	Soumya F_1 (OH-4002), Reshma
5	11-20% Plants exhibiting symptoms	Moderately susceptible	-
7.	21-50% plants exhibiting symptoms	Susceptible	40 days bhendi Harbhajan, 490327, 217930, 496458, 357995, 357996, 217922, 481999, 496753, 496750, 499667 and Arka Abhay
9	51% or more plants exhibiting symptoms	Highly susceptible	Pusa Sawani

Table 14 **Screening of bhendi genotypes to yellow vein mosaic virus during *kharif* 2000**

Sl. No.	Genotype	Pre-flowering incidence (%)	Post flowering incidence (%)	Mean incidence (%)
1	Pusa Sawani	0.40	3.60	2.00
2	490327	0.0	0.0	0.0
3	27930	0.0	0.0	0.0
4	495458	0.0	0.0	0.0
5	357995	0.0	0.0	0.0
6	357996	0.0	0.0	0.0
7	217922	0.0	0.0	0.0
8	481999	0.0	0.0	0.0
9	Harbhajan	0.0	0.0	0.0
10	496753	0.0	0.0	0.0
11	496750	0.0	0.0	0.0
12	40 days bhendi	0.0	0.0	0.0
13	496667	0.0	0.0	0.0
14	Arka Abhaya	0.0	0.0	0.0
15	Arka Anamika	0.0	0.0	0.0
16	Reshma	0.0	0.0	0.0
17	Hybrid No.8	0.0	0.0	0.0
18	Soumya F_1 (OH-4002)	0.0	0.0	0.0
19	Hybrid No.10	0.0	0.0	0.0

Plate 23. During *kharif* 2000 all the genotypes were free from BYVMV infection

Plate 24. During summer 2001 different genotypes showing BYVMV symptom on bhendi

The data presented in Table 15 indicated that yellow vein mosaic disease had its effect on plant height, fruit size and number per plant. The plant height was reduced in infected plants and effect was more in plants infected at 35 DAP (42.43 cm) than at 45 DAP (61.55 cm) and 55 DAP (71.40 cm). The disease also reduced the fruits per plant, the number of fruits (5.0) per plant was recorded in plants infected at 35 DAP (8.3) at 45 DAP and (14) at 55 DAP. The disease also reduced the fruit size, the fruits of infected plants at 35 DAP were small (6.39 x 0.87 cm) at 45 DAP (8.46 x 1.28 cm) and at 55 DAP (11.34 x 1.50 cm).

Table 15. Effect of Bhendi yellow vein mosaic virus on growth and yield parameters of Bhendi

Stage of infection (DAP)*	Plant height (cm)	Fruit size length and breadth (cm)	Number of fruits per plant
35	42.43	6.39 x 0.87	5.0
45	61.55	8.46 x 1.28	8.3
55	71.40	11.34 x 1.50	14.0

* Days after planting

Discussion

V. DISCUSSION

Bhendi yellow vein mosaic (BYVM) is one of the most economically important diseases of bhendi in India. The disease was first reported in Maharashtra (Kulkarni, 1924). Though the disease has been present in India for a long time, no systematic efforts have been made to characterize the virus, know the sources of infection and many other aspects of the disease including management.

In north Karnataka the information on BYVMV is very meagre, therefore the present study was emphasised on survey to know the distribution pattern of the disease in this region. Field and lab experiments were conducted to study the symptomotology, transmission, histopathological changes host range and management aspects at the Department of Plant Pathology, University of Agricultural Sciences, Dharwad.

Roving survey was conducted to know the distribution of yellow vein mosaic virus in Northern parts of Karnataka during *kharif* 2000 and summer 2001 in the major bhendi growing areas of Belgaum, Dharwad, Gadag and Haveri districts. The survey results indicated that the disease incidence varied from season to season and the disease was present in all the bhendi fields surveyed. During the *kharif* season, the incidence varied from 0.0 to 18.5 per cent. Whereas, the incidence was markedly higher in summer months which ranged from 12.6 to 78.60 per cent.

In all the bhendi fields surveyed, infected plants exhibited yellow vein mosaic symptoms, vein clearing, slight curling of infected leaves and reduction in the leaf size.

Manjula Rao during 1985, reported the incidence of BYVMV to the time of 1 to 15 per cent during *kharif* and 11 to 80 per cent during summer in and around Bangalore. Variation in disease incidence in different season might be because of variation in temperature and relative humidity that may have a direct influence on vector population and vector migration. This could also be a major factor why the disease incidence is almost negligible in the *kharif* crop.

To know the appearance and spread of disease a fixed plot survey was conducted at MRS, UAS, Dharwad in both *kharif* 2000 and summer 2001 seasons. During summer the yellow vein mosaic virus appeared on Pusa Sawani early in the crop stage i.e., before 15 DAP, and at 15 DAP, 8.5 per cent of the plants were showing clear symptoms, and then gradually increased to 66.5 per cent at 60 DAP. During the first observation at 15 DAP, vein clearing symptoms on the younger leaves were noticed along with venial chlorosis persisted upto 30 DAP. At 45 DAP, minute enations on the axial side of leaves were observed. At 60 DAP complete yellowing of leaves and fruits were malformed and bleached which were less in number. Invariably 15 DAP whiteflies were found feeding on the bhendi plants in the plot along with jassids, thrips and mites.

During *kharif* the disease incidence on Pusa Sawani ranged form 0.0 to 3.5 per cent. The highest disease incidence of 3.5 per cent was recorded at 60 DAP followed by 1.5 per cent at 45 DAP, 0.5 per cent at 30 DAP and there was no incidence at 15 DAP.

Early infected plants were severely stunted and infected plants produced a few fruits of small size. These symptoms were similar to those described by Fernando and Uduravan (1942) and Kulkarni (1924) and Uppal *et al.* (1940).

In the present investigation, BYVMV was not mechanically transmitted. BYVMV was not transmissible by sap inoculation. Earlier studies also showed that BYVMV was not sap transmissible (Raychaudhuri and Nariani, 1977).

Further, the virus causing BYVMV under study was not seed borne and was not transmitted through seeds as none of the seedlings raised form seeds obtained from diseased plants developed any symptoms even upto 30 days after emergence. Similarly, the BYVM virus was not transmitted thorough dodder from bhendi to bhendi as no symptoms appeared on the test plants even upto 30 days after dodder establishment. The BYVM virus was neither sap transmissible (Capoor and Varma, 1949; Costa, 1969; Uppal *et al.*, 1940; Raychaudhuri and Nariani, 1977) nor transmitted by seed nor through the parasitic activity of dodder (*Cuscuta reflexa*) (Capoor and Verma 1950). It was observed that BYVMV was transmitted by whitefly *Bemisia tabaci* and symptoms

appeared on bhendi within 10-15 days after inoculation. Similar observations were also made by various workers (Singh, 1980; Muniyappa and Veeresh, 1984; Varma, 1952; Summanwar, 1980). It was also observed that BYVMV was transmitted by grafting and symptoms appeared on bhendi 20 days after grafting. Successful graft transmission of BYVMV was reported by Capoor and Varma (1949), Uppal *et al.* (1940), Manjula Rao (1985) showed 87-100 per cent transmission by side grafting. Inoculated plants took 15-20 days to show the symptoms.

In order to know the source of infection to bhendi, several host plants were inoculated with BYVMV by *B. tabaci*. The virus causing BYVM under study had a limited host range. Out of 13 host plants belonging to four different families, *viz.*, leguminaceae, malvaceae, euphorbiaceae and solanaceae, dark green vein and yellow vein clearing symptoms developed on *Croton bonplandianum*, curling and crinkling symptoms on *Althaea rosea*. Capoor and Varma (1950) reported that the host range of the virus was limited to the family Malvaceae, Summanwar (1980) reported that *Altheaea rosea* was infected with BYVMV. Pun *et al.* (1999a) detected BYVMV in five weed plant species, *viz.*, *Acalypha indica, Althaea rosea, Croton bonplandianum, Hibiscus rosa-sinesis* and *Parthenium hysterophorus* through DAC-ELISA using polyclonal anibodies raised against African cassava mosaic virus (ACMV). The reaction of antigen extract from infected okra leaves was stronger with PC Abs to ACMV.

Histopathological changes noticed in leaf tissues due to BYVMV infection. The palisade cells started losing their columnar appearance

with no intercellular spaces. Easu (1933) reported that curly top disease induced pronounced changes in the infected leaves of sugar beet (Sawant and Capoor, 1985 a and b). There was no clear cut differentiation into palisade and spongy layers in contrast to clear differentiation of palisade and spongy layers in healthy leaf. Mishra and Singh (1973) reported that there was no cellular differentiation into palisade and spongy layers due to low concentration or multiplication of virus in leaf tissues of chilli infected by mosaic virus. Similar observation were made by several workers (Sorokin, 1927; Easu, 1933, Shaffield 1938; Esau, 1944; Joshi and Dubey, 1975).

In the infected fruit rind, the number of epidermal cells/mm were 70.20 compared to 98.70 in healthy fruit rind. Thimmaiah (1992) noticed histopathological changes in cotton boll rind, with less number of epidermal cells (63.33 mm) in infected fruit as compared to healthy (93.33 mm).

Attempts were made to develop management strategies by using insecticides i.e. metasystox, rogor, carbofuran 3G (granular insecticide), viricide, i.e. action 100 and parthenium leaf extract. These were evaluated for the efficacy in keeping disease incidence low by controlling vector whitefly *Bemisia tabaci* which are responsible for the spread of disease. Among these insecticides, viricides and leaf extracts sprayed at 15 days interval, soil application of carbofuron 3G @ 15 kg/ha and spraying 0.2 per cent metasystox was the most effective which not only kept the vector population low (2.46), but also helped in reducing incidence (13.57%),

Hybrid No. 8 and 10 showed some resistant reaction to the BYVMV, and two F_1 hybrid i.e. Reshma and Soumya F_1 (OH-4002) showed moderately resistant reaction. In general, overall disease incidence was more and majority of the genotypes tested were susceptible. Similar type of evaluation was reported by several workers (Chauhan *et al.*, 1981; Sharma and Sharma, 1984; Khan and Mukhopadyay, 1986; Dhankhar *et al.*, 1989; Singh and Gupta, 1991; Borah *et al.*, 1992; Arora *et al.*, 1992; Sharma *et al.*, 1993 and Anju Handa and Gupta, 1993; Suresh Kumar, 2000).

The effect of BYVMV on growth and yield parameters of bhendi was studied at different stages. The results clearly indicated that BYVMV had effect on plant height, fruit size and number of fruits per plant. The plant height was reduced in infected plants and effect was more in plants infected at 35 DAP (42.43 cm) compared to (61.55 and 71.40) at 45 and 55 DAP respectively. The number of fruits per plant produced in plants infected at 35 DAP (5.0) as compared to (8.3 and 14) at 45 and 55 DAP respectively. The fruits of infected plants (at 35 DAP) were small (6.39 x 0.87 cm) compared to (8.46 x 1.28 cm) and (11.34 x 1.50 cm) at 45 and 55 DAP respectively. Similar effects of BYVMV on growth and yield parameters of bhendi was reported by several workers (Chellaiah and Murugesan, 1976b; Sinha and Chakrabarti, 1978; Sastry and Singh 1974; Nath and Saikia, 1995; Suresh Kumar, 2000).

rogor spray (0.2%) was the next best (16.00%) followed by soil application of carbofuran 3G @ 15 kg/ha alone (19.18%). Alternate sprays of rogor and parthenium leaf extract showed (20.73%) and action 100 (23.08%) as compared to control (50.61%). Similarly several workers (Sastry and Singh, 1973a; Palaniswamy *et al.,* 1973; Chakrabarthi and Mukhopadyay, 1977; Chelliah, 1976, Khan and Mukhopadhyay, 1985b) have reported the control of whiteflies by spraying systemic insecticides like metasystox, roger, dimecron, phosphomidon, monocrotophos, along with Granular insecticides carbofuran 3G and phorate 10G. These insecticides reduced the incidence and spread of BYVMV. Parthenium leaf extract was least effective (30.78%) as compared to control. Least disease reduction (29.53%) was recorded with parthenium leaf extract sprays as against highest disease reduction (76.60%) with treatment of soil application of carbofuran 3G + sprays of metasystox over control. Effect of plant extracts on virus disease in successful inhibition of BYVMV had been reported by several workers (Chaudhary *et al.*, 1995; Pun *et al.*, 1999a; Okuyama *et al.*, 1978).

Identification of resistant genotypes is one of the most important aspects in the management of virus diseases which will be the best possible solution to the viral disease problems. In the present study, 19 different genotypes were screened for BYVMV under natural conditions. The per cent disease incidence ranged from 0.80 to 74.99 per cent. None of the genotype tested was immune. Only 3 genotypes i.e. Arka Anamika,

Conclusions

BYVMV is one of the main constraints in the cultivation of bhendi in Karnataka. The spread of the disease was dependent on the activities of vector whitefly. Therefore, the disease incidence was severe during summer than *kharif* seasons in Karnataka.

BYVMV produces yellow vein mosaic symptoms, vein clearing, slight curling of infected leaves and reduction in the leaf size. Early infected plants were severely stunted. Infected plants produced a few fruits of small size.

BYVMV was not transmissible by sap inoculation, seed or dodder, but it was transmissible by whitefly *Bemisia tabaci* and also by graft transmission.

BYVMV has narrow host range and produced symptoms on *Croton bonplandianum* (Euphorbiaceae) and *Althaea rosea* (Malvaceae) 20-35 days after inoculation.

BYVMV infected leaves showed that palisade tissues start loosing their columnar appearance with no intercellular spaces in leaf tissue and there was reduction in number of epidermal cells in fruit rind as compared to healthy ones.

BYVMV was controlled by applying soil application of carbofuran 3G (15 kg/ha) + metasystox (0.2%) or rogor (0.2%). Hybrids/varieties like Arka Anamika, Hybrid bhendi No.-8, Hybrid bhendi No-10, Reshma

Soumya F_1 (OH-4002) showed resistant reaction, whereas Pusa Sawani showed highly susceptible reaction to BYVMV.

Future line of work

1. Detailed survey has to be undertaken throughout Karnataka to know the distribution and severity of disease according to seasons.

2. More emphasis should be given for the characterization of virus.

3. Attempts should be made to develop serodiagnostic techniques for quick detection of the disease.

4. More attention should be given for studies on virus-vector relationships.

5. Detailed studies on the epidemilogy of Bhendi YVMV should be undertaken.

6. Efficacy of insecticides, viricides and plant extracts in managing the BYVMV should be further evaluated in hot spots with susceptible cultivars over seasons.

Summary

VI. SUMMARY

Bhendi, or lady's finger, also called okra (*Abelmoschus esculentus* (L.) Moench) is one of the important vegetable crops grown extensively throughout the tropical, subtropical and warm regions of the temperate zones of the world. Bhendi suffers from several diseases with substantial losses in yields. Of all the diseases, BYVM is one of the most severe diseases which takes a heavy toll in India. BYVMV infected plants exhibit yellow vein mosaic, vein clearing, curling of infected leaves and reduction in the leaf size. The present investigation was carried out on different aspects of BYVMV, *viz.*, distribution, symptomatology, transmission, histopathology, host range and management.

A roving survey revealed that the occurrence of BYVM disease in almost all parts of Belgaum, Dharwad, Gadag and Haveri districts. The appearance of BYVM was more during summer season as compared to *kharif* season. The incidence of BYVM ranged from 12.6 per cent (Kubihal) to 78.60 per cent (Dhundshi). The cultivar Pusa sawani was more susceptible to BYVMV. Whiteflies, jassids, thrips and mites were the most common insects observed in almost all the fields.

Fixed plot survey for BYVMV showed that the disease appeared during second fortnight of March and increased gradually by the end of May. The highest disease incidence of 66.5 per cent was recorded at 60

DAP and minimum disease incidence was recorded at 15 DAP. Whiteflies, jassids, thrips and mites were the insects recorded on the crop.

BYVMV was not mechanically transmissible nor through seed, or dodder but was transmitted by grafting and whiteflies *Bemisia tabaci* of 62 to 88 per cent.

The BYVMV has narrow host range and produced symptoms litre crinkling, curling and vein clearing 20 to 35 days after inoculation on *Croton bonplandianum* and *Althaea rosea.*

Histopathology studies of BYVMV infected samples showed that there was shortening of palisade cells lacking intercellular spaces. There was no clear cut differentiation into palisade and spongy layers. The epidermal cells per unit length on the fruit rinds of healthy were more compared to the infected.

Studies on management aspects indicated that the crop could be protected from incidence of disease by soil application of carbofuran 3G (15 kg/ha) once at the time of sowing and next 20 days after sowing and by spraying systemic insecticides metasystox (0.2%) or Roger (0.2%) at 15, 30, 45, 60 and 75 DAP which reduced vector population and also disease incidence.

Among the 19 genotypes screened against BYVMV under natural field conditions, none of the genotypes was found to be immune.

Genotypes Arka Anamika, Hybrid No-8 and 10 showed resistant and genotypes Reshma and Soumya F_1 (OH-4002) showed moderately resistant reaction. Most of the genotypes showed susceptible reaction and Pusa Sawani was highly susceptible.

Studies on effect of BYVMV on growth and yield parameter of bhendi was studied at different stages. The result clearly indicated that BYVMV has effect on plant height, fruit size and number of fruit per plant.

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STUDIES ON OKRA (BHENDI) YELLOW VEIN MOSAIC VIRUS

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ABSTRACT

Okra (Bhendi) is one of the important vegetable crops grown extensively throughout the tropical, subtropical and warm regions of the temperate zones of the world. Bhendi suffers from several diseases with substantial losses in yield. Of all the diseases, BYVM is one of the most of severe disease which takes a heavy toll in India.

The survey was conducted to know the distribution of BYVMV in Northern parts of Karnataka during *kharif* 2000 and summer 2001 in the bhendi growing areas of Belgaum, Dharwad, Gadag and Haveri districts. During *kharif* season, the incidence varied from 0.0 per cent to 18.5 per cent (Hukkeri). Whereas, the incidence was markedly higher in summer months which ranged from 12.6 per cent (Kubihal) to 78.6 per cent (Dhundshi).

The infected plants were characterised by production of yellow vein mosaic symptoms, vein clearing, slight curling and reduction in the leaf size. The virus was not transmissible by sap inoculation, seed or dodder, but it was transmissible by whitefly *Bemisia tabaci* and by graft transmission.

The virus has narrow host range and produced symptoms like crinkling, curling and vein clearing on *Croton bonplandianum* and *Althaea rosea* 20-35 days after inoculation. Histopathology studies of BYVMV infected leaves showed that palisade tissues start loosing their coloumnar appearance with the intercellular spaces in leaf tissue and there was reduction in number of epidermal cells in fruit rind as compared to healthy ones.

Among the different insecticides, viricides and plant extracts tested soil application of carbofuran 3G (15 kg/ha) + metasystox (0.2%) or rogor (0.2%) reduced vector population and also disease incidence.

Among 19 genotypes screened against BYVMV none of the genotypes were found to be immune. Arka Anamika, Hybrid No. 8 and 10 genotypes showed resistant reaction. Soumya F_1 (OH-4002) and Reshma were moderately resistant, most of the genotypes (13) showed susceptible reaction and Pusa Sawani genotype was highly susceptible to yellow vein mosaic disease.