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Studies on bean common mosaic virus of French bean (*Phaseolus vulgare* Linn.)

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Abstract
Worldwide, french bean (*Phaseolus vulgare* Linn.) is one of the most important pulse crops, but having very low production due to biotic or abiotic stresses. Diseases are one of the most important causes for low production from biotic point of view. This crop is attacked by many viral diseases *viz*., Bean Common Mosaic Virus (BCMV), Bean Yellow Mosaic Virus (BYMV), Broad Bean Mosaic Virus, Bean Leaf Roll Virus (BLRV), Bean Distortion Dwarf Virus (BDDV), Mung Bean Mosaic Virus (MBMV), Bean Seed Borne Mosaic Virus, Dendrobium Mosaic Potyvirus (DeMV), Bean Southern Mosaic Virus (BSMV), Bean Pod Mottle Virus and Bean Mild Mosaic Virus (BMMV). Amongst all viral diseases, Bean Common Mosaic is an important disease. Hence, the present studies on Bean Common Mosaic Virus of french bean were proposed and carried out during the year 2018 to 2020. The experiments were carried out at the Department of Plant Pathology and Agricultural Microbiology, College of Agriculture, Pune (Maharashtra, India) and the screening of french bean germplasm against BCMV was carried out at Zonal Agricultural Research Station (Plain Zone), Regional Fruit Research Station, Ganeshkhind, Pune (Maharashtra, India). Results of the study clearly revealed that, the virus was mechanically/sap transmissible. It was also transmissible by insect and through seeds and pollens. The insect vectors, *Myzus persicae*, *Aphis craccivora* and *Bemisia tabaci* transmitted the virus in non-persistent manner. The host range study showed that, the BCMV virus was mainly confined to plants belonging to family Leguminosae, and symptoms observed on them included mosaic, mottling, blistering and puckering, necrosis, vein banding, reduction in pod size, overall stunting of plant, bending of leaf margins, downward curling of leaves as well as cupping of leaves. Physical properties *viz*., TIP, DEP and LIV of the virus under study were 60 ºC, between 10^{-3} to 10^{-4} and 48 h (at room temperature), respectively. Based on these observations, virus infecting french bean (*Phaseolus vulgare* Linn.) was identified as Bean Common Mosaic Virus belonging to Potyvirus group (Family-Potyviridae). Appraisal of french bean germplasm under field conditions revealed that, out of 60 germplasm screened, none of the germplasm was found disease free. Eleven germplasm showed 1-10 % disease incidence, thirteen germplasm showed 11-40 % disease incidence, twenty-five germplasm showed 41-75 % disease incidence, eight germplasm showed 76-90 % disease incidence and three germplasm showed 91-100 % disease incidence.

Keywords: Bean common mosaic virus, French bean (*Phaseolus vulgare*), Thermal inactivation point (TIP), Dilution end point (DEP), Longevity *in vitro* (LIV), Sap transmission, Insect transmission, Pollen transmission, Germplasm screening

Introduction
Common bean (2n=22) is a self-pollinated crop, originated in Central and South America. The dry seed type varieties are called as 'Rajmash'. French bean is also called as 'grain of hope'. Common names given to this crop in different regions are rajmah, haricot bean, runner bean, kindey bean, salad bean, snap bean, string bean, bush bean, white bean, frijoles, garden bean, navy bean, field bean, dry bean, pole bean etc. In Indian languages, it is dubbed as farasbi (Marathi), Tingal Avre Kai (Kannada), Barigalu (Telgu), Tingal Avro (Konkani), Phansi (Gujrati), Babri (Punjabi) and Avaricica (Malayalam). It is also called as Bohne in German, Boon in Dutch, Havebonnon in Danish, Heblohuela or Judis frijol in Spanish, Feijao in Portuguese and Green Bean in English.

French bean is mainly cultivated in America, England, Poland, Brazil, Mexico, China and India. According to the demand for french bean in India, there is only 10 per cent production and 90 per cent french bean is imported. This crop is traditionally a crop of temperate region and can be grown on wide range of soil but thrives well in well drained, loamy and light alluvial soil with pH 6.0 to 7.0.

French bean pod contains carbohydrates 61 g, dietary fibers 14 g, sugars 2 g, protein 21 g, fat 1 g, saturated fatty acid 0 g, cholesterol 0 mg, vitamin C 4.5 mg, calcium 83 mg, iron 6.7 mg

and energy 337 kcal per 100 g.

Worldwide, french bean is one of the most important pulse crops, but having very low production due to biotic or abiotic stresses. Diseases are one of the most important causes for low production from biotic point of view. This crop is attacked by many viral diseases *viz*., Bean Common Mosaic Virus (BCMV), Bean Yellow Mosaic Virus (BYMV), Broad Bean Mosaic Virus, Bean Leaf Roll Virus (BLRV), Bean Distortion Dwarf Virus (BDDV), Mung Bean Mosaic Virus (MBMV), Bean Seed Borne Mosaic Virus, Dendrobium Mosaic Potyvirus (DeMV), Bean Southern Mosaic Virus (BSMV), Bean Pod Mottle Virus and Bean Mild Mosaic Virus (BMMV). Amongst all viral diseases, Bean Common Mosaic is an important disease causing severe losses in yield. Currently, no any resistant variety to this disease is available. Considering the importance of this disease, the present study was undertaken to study various aspects of the pathogen including transmission of the virus, host range of the virus, screening of germplasm for disease resistance and physical properties. Moreover, being a serious disease, an attempt was also made to screen available germplasm to find out resistant cultivar of french bean to this disease.

Methodology

Present investigation on bean common mosaic virus (BCMV) of french bean was carried out during the year 2018 to 2020. The experiments were carried out at the Department of Plant Pathology and Agricultural Microbiology, College of Agriculture, Pune (Maharashtra, India). Screening of french bean germplasm against BCMV was done under field conditions at the experimental farm of Zonal Agricultural Research Station (Plain Zone), Regional Fruit Research Station, Ganeshkhind, Pune (Maharashtra, India).

Collection of disease samples

The fields of french bean from various locations such as Satara, Nashik, Junnar, College of Agriculture, Pune as well as ZARS, Ganeshkhind, Pune were surveyed and plants showing characteristics symptoms of bean common mosaic virus (BCMV), such as mottling, blistering, downward curling of leaves, vein clearing followed by chlorotic vein banding and characteristic mosaic symptoms were collected. These diseased samples of BCMV were used for extracting crude sap. Diseased plants of french bean in the plots were identified and tagged. After maturity the seeds were collected, dried and stored in paper bags. The shriveled, deformed and small sized seeds were separated and sown separately in pots. After 20 days, plants showing typical symptoms of BCMV were used to maintain the virus culture on healthy french bean plants.

Raising of seedlings

Healthy seeds of french bean var. Varun were used for raising experimental plants. The earthen pots were filled with sterilized mixture of medium black soil and well decomposed farmyard manure (3:1). Three seeds were sown in each pot and the sap inoculations were done on 8 days-old seedlings.

Maintenance of virus culture

Leaves showing characteristics symptoms of bean common mosaic virus (BCMV) were macerated using sterilized, pre-chilled mortar and pestle by adding chilled 0.01 M phosphate buffer (pH 6.3) in the ratio 1:1 w/v. Crude sap, thus, obtained was used for inoculating healthy french bean plants. Fifteen days after inoculation, these plants exhibited BCMV symptoms. Thus, the BCMV was maintained on french bean plants. Similar procedure was repeated six times for maintaining virus.

Transmission study of BCMV

1. Mechanical transmission

Preparation of inoculum

Young infected leaves showing prominent symptoms of bean common mosaic virus (BCMV) were collected and then washed thoroughly with running tap water, in order to remove the dirt associated with the leaves, and dried with blotting paper. The inoculum was prepared in a sterilized and pre-chilled mortar and pestle by macerating young infected leaves in chilled 0.01 M phosphate buffer (pH 6.3) in the ratio 1:1 w/v. Crude sap was obtained by squeezing the pulp through double layered muslin cloth. This extract was used as a standard inoculum for further studies.

Inoculation

Healthy french bean seedlings were inoculated 8-10 days after sowing, when the first pair of the cotyledonary leaves opened. Prior to inoculation, a pinch of 600-mesh celite powder (carborundum powder) was added to the standard inoculum, as an abrasive. Inoculation was done by gently rubbing sterilized cotton swab dipped in the inoculum on the upper surface of the cotyledonary leaves. The inoculated leaves were washed gently with water to remove excess inoculum, 3 min. after inoculation. Inoculated plants were labelled indicating date and maintained in insect proof glasshouse. Observations were taken regularly and recorded.

2. Insect transmission

Transmission by aphids

The aphid species were reared on their respective host *i.e. Myzus persicae* Sulz. on cabbage, *Aphis craccivora* Koch. on cowpea, *Rhophalosiphum maidis* Fitch. on maize and *Aphis gossypii* Glov. on cotton. Aphids were collected in a test tube, with its mouth covered with muslin cloth, from colonies maintained on healthy host plant and given a pre-acquisition fasting of 2 hours. These aphids were then transferred to virus infected leaves, kept in a Petridish, for acquisition feeding for 20 min. Later, the aphids were transferred to healthy young test plants for inoculation feeding for 1 h. The test plants were sprayed with 0.05 per cent acephate to kill the aphids. Experiment was carried out in insect proof glasshouse condition.

Transmission by thrips

Thrips species were reared on their respective host *i.e*., *Thrips tabaci* on onion and *Thrips palmi* on watermelon and then collected from their respective host. Thrips at nymphal stage were collected from their host plants with the help of moistened tip of a camel hair brush No.1. Young infected leaves of french bean were placed in a Petridish, on which the nymphs are transferred for acquisition feeding for 5 days. The nymphs were then transferred to healthy french bean plants for inoculation feeding for 10 days. Then, the plants were sprayed with 0.05 per cent acephate to kill the thrips. Experiment was carried out in insect proof glasshouse condition.

Transmission by white flies

The whiteflies species *Bemisia tabaci* were reared on

Nicotiana tabacum for transmission studies. Healthy whiteflies were collected in a glass globe covered with black paper. The mouth of the glass globe was tied with muslin cloth. A fasting period of 4 hours was given to collected whiteflies. Virus infected french bean leaves were inserted in the glass globe for acquisition feeding by whiteflies for 24 h. Later, the white flies were transferred to healthy french bean plant kept inside a glass globe for inoculation feeding for duration of 24 h. After 24 h, the plants were sprayed with 0.05 per cent acephate to kill the whiteflies. The plants were kept under condition of insect proof glasshouse condition.

3. Seed transmission
Seeds from the infected plants were collected. These seeds were sown separately in pots containing mixture of soil and farm yard manure in 3:1 ratio. The germinated seedlings were observed for symptoms and observations were recorded.

4. Pollen transmission
Pollens from the infected plants were collected and transferred on stigma of healthy plants. Infected plants were labeled properly and observed periodically.

Host range study
Host range study was carried out to find the host range of the virus under study. Host plant species were raised in insect proof glasshouse. These plants were mechanically inoculated and observed for reaction with the virus. The host plants included red gram (*Cajanus cajan*), mung (*Vigna radiata*), pea (*Pisum sativum*), cowpea (*Vigna unguiculata*) and soybean (*Glycine max*).

Screening of germplasm for disease resistance
To find out the source of resistance in french bean, french bean germplasm was appraised in open field conditions against bean common mosaic virus (BCMV). Sixty germplasm lines were selected for the screening. Observations on BCMV per cent disease incidence was recorded after 15 days of sowing.

Physical properties of BCMV
1. Dilution end point (DEP)
Crude sap was extracted by macerating the infected leaves of french bean and filtered through double layered muslin cloth. A series of dilutions *viz*., 1:10, 1:100, 1:500, 1:1000, 1:5000 and 1:10000 were prepared from the crude sap using distilled water. The leaves were mechanically inoculated with each dilution by adding a pinch of celite powder (carborundum powder) as abrasive. In order to avoid contamination, inoculation was carried out starting from highest dilution i.e., 1:10000 (10^{-4}) to 1:10 (10^{-1}) and finally the undiluted sap served as control. Inoculated plants were labeled properly and observed periodically.

2. Thermal inactivation point (TIP)
Crude sap was obtained by the method described in the foregoing section. For determination of thermal inactivation point, 1 ml undiluted crude sap was added separately in 5 ml test tubes and the test tubes were subjected to different temperatures, starting from 40 ºC to 65 ºC with a difference of 5 ºC, for 10 min. for each treatment in hot water bath. Immediately after the heating period, the test tubes were cooled under running tap water. The untreated sap served as control. Sap from each tube was then mechanically inoculated in healthy french bean plants. Inoculations were done from highest to lowest temperature *i.e.* 65 ºC to 40 ºC so as to avoid contamination. The inoculated plants were labeled and maintained in glasshouse and were observed periodically.

3. Longevity *in-vitro* (LIV)
Crude sap was extracted by the method described in the foregoing text. One ml of undiluted crude sap was transferred separately to each of the glass vial with rubber stopper. Sap samples were taken out at periodic intervals and were inoculated on healthy french bean plants. Freshly extracted sap served as control. The inoculated plants were labeled properly and were observed periodically.

Research findings
Transmission study of BCMV
Mechanical / sap transmission
The results of mechanical transmission experimentation indicated that the virus was sap transmissible as the inoculated healthy plants exhibited typical symptoms of bean common mosaic virus (BCMV) (Plate 1).

Insect transmission
Study conducted on transmission of bean common mosaic virus (BCMV) by insect vectors explicitly indicated that the aphid species, *Myzus persicae* and *Aphis craccivora*, transmitted the virus in non-persistent manner. However, other aphid species *viz*., *Aphis gossypii* and *Aphis fabae* transmitted the virus in non-persistent manner. These results are in conformity with those of Singh (1976) [21], Walkey and Marilyn (1979) [26], Gupta and Chowfla (1986) [9], Behl (1993) [1], Ronalli and Parisi (1997) [18] and, Tolkach and Gnutova (2001) [23].

Seed transmission
An experiment conducted to study transmission of bean common mosaic virus (BCMV) through seeds, clearly indicated that the seeds collected from diseased plants exhibited symptoms of BCMV on seedlings at 1st and 2nd trifoliate leaf stage (15 days after inoculation). Thus, the results explicitly unveiled that the virus transmitted through seeds collected from diseased plants. The virus transmission through seed was 20-32 % (Table 1). Similar results have also been reported by Singh (1976) [21], Walkey and Marilyn (1979) [26], Putturaju *et al*. (1999) [17] and, Vishwa-Dhar *et al.* (1990) [25].

Table 1: Seed transmission of bean common mosaic virus

Sr. No.	No. of seeds sown	No. of seeds germinated	No. of seedlings showing infection	Seed transmission (%)
1	30	28	6	21.43
2	30	21	5	23.80
3	30	25	8	32.00
4	30	23	5	21.74
5	30	25	7	28.00

Pollen transmission
An experiment conducted on pollen transmission of common bean mosaic virus (BCMV) indicated that the plants showed symptoms identical to BCMV 15 days after pollen transfer. The results proved that diseased pollens are responsible for spread of the disease from plant-to-plant. In field conditions,

the diseased pollens may spread the disease through wind as well as insects. Results obtained in this experiment are in agreement with those of Das and Milbrath (1961) [5], George and Davidson (1963) [8], Bennett (1969) [2], Mandahar (1981) [11], Shepherd (1972) [20] and, Mink (1992) [12].

Host range

Host range study was conducted using the plants belonging to family leguminosae. In this study, it was clearly discerned that the virus initially induced faint chlorotic local lesions which later turned necrotic. Host plants under study exhibited varied reactions to bean common mosaic virus (BCMV) (Table 2). The inoculated leaves of cowpea (*Vigna unguiculata*) showed systemic mosaic symptoms. The leaves of soybean (*Glycine max*) exhibited chlorotic as well as necrotic local lesion. The inoculated leaves of mothbean (*Vigna radiata*) showed systemic mosaic symptoms. The inoculated leaves of pea (*Pisum sativum*) exhibited systemic mosaic symptoms, whereas the leaves of french bean (*Phaseolus vulgaris*) showed mosaic, vein banding and downward curling of leaves. Singh (1976) [21], Behl (1993) [1], Chailani *et al.* (1994) [3], Njau and Lyimo (2000) [13], Tolkach and Gnutova (2001) [23] have reported similar results.

Table 2: Host range of bean common mosaic virus

Species	Symptomatic / non-symptomatic	Symptoms
Glycine max	+	Chlorotic local lesion and necrotic local lesion
Vigna radiata	+	Mosaic
Pisum sativum	+	Mosaic
Phaseolus vulgaris	+	Mosaic, vein banding, downward curling of leaves
Cajanus cajan	-	No symptoms
Vigna unguiculata	+	Mosaic

Symptomatology

To study symptomatology of BCMV, the french bean plants grown in the field of Agronomy Section of College of Agriculture, Pune and from the screening trial plots were observed and recorded the symptoms. The french bean plants showed mosaic, mottling, vein banding and downward curling of leaves (Plate 2 to 9). The symptoms appeared on the inoculated french bean plants 15-20 days after inoculation. Symptoms recorded are described below:

Mosaic

Leaves were mottled with yellow, white and light or dark spots and streaks.

Mottling

A pattern of irregular marks, spots, streaks, blotches or patches of different shades or colours usually yellowish spots were observed on plants. Green to yellow mottling of younger leaves were noticed in the upper canopy. In severe cases leaves showed puckering and distortion and, plants were stunted. Pods were misshaped with mottling and reduced in size.

Vein banding

Yellow mottling or chrome yellow bands along the principal veins of leaves were noticed. Bands of lighter or darker colour along the main veins of leaf were recorded.

Blistering and puckering

Raised, oval to round shaped blisters similar in appearance to that of bubbling. Raised light green to yellow blisters appeared on upper leaf surface.

Downward curling of leaves

Upward curling of leaf margins, yellowing of veins and reduction of leaf size were common. Additionally, leaf veins were swollen with shortening of internodes and petioles. Older leaves were leathery and brittle.

Symptoms on seeds

Shrivelled, deformed and small sized seeds were harvested from the infected plants.

Bending of leaf margins and cupping of leaves.

Leaf margins were deformed and bending of margins and cupping of leaves was observed.

The above disease symptoms have earlier been reported by Singh (1976) [21], Behl (1993) [1], Chailani *et al.* (1994) [3], Njau and Lyimo (2000) [13], Tolkach and Gnutova (2001) [23], Yaraguntaiah and Nariani (1963) [27], Singh (1976) [21], Behl (1993) [1], Spence and Walkey (1994) [22], Putturaju *et al.* (1999) [17], Pierce (1934) [16], Dean and Wilson, (1959) [6], Drijfhout and Bos (1977) [7], Behl, (1993) [1].

Screening of germplasm

Results pertaining to reactions of different germplasm lines to bean common mosaic virus (BCMV) are presented in Table 3.

Table 3: Reactions of different germplasm lines to bean common mosaic of French bean caused by bean common mosaic virus

Sr. No.	Name of germplasm	Per cent Disease incidence	Sr. No	Name of germplasm	Per cent Disease incidence
1.	Phule Surekha	30 %	31.	Phalguni	80 %
2.	Contender	38 %	32.	Vaishnavi	5 %
3.	GK 06	45 %	33.	Selection 9	60 %
4.	EC 500377	50 %	34.	Dharwad selection	75 %
5.	Kanpur 1	33 %	35.	New contender-1	95 %
6.	Kanpur 2	62 %	36.	EC 28304	7 %
7.	GK 13	35 %	37.	ACPR-19	43 %
8.	GK 03-06	72 %	38.	SVM	55 %
9.	HPR 35	76 %	39.	PRJ 125	20 %
10.	EC 530909	55 %	40.	RII-GRB	90 %
11.	IC 039081	60 %	41.	GK 5	73 %

12.	3-2-701	70 %	42.	Kashmiri	69 %
13.	GRB 9901	83 %	43.	Arka Komal	23 %
14.	ACPB 11	74 %	44.	Kashmiri selection1	42 %
15.	Jampa Improved	30 %	45.	Arka Sharath	83 %
16.	IC 28008	63 %	46.	Laxmi	7 %
17.	GRB 9410	35 %	47.	Junner 1	15 %
18.	UHEB-30	70 %	48.	Parner 1	10 %
19.	GK 5-1	32 %	49.	Junner 2	63 %
20.	Kanpur 3	25 %	50.	Junner 3	70 %
21.	GK 1	10 %	51.	Junner 4	77 %
22.	EC 500354	65 %	52.	Junner 5	89 %
23.	958	50 %	53.	Junner 6	62 %
24.	GK 2	8 %	54.	Junner 7	40 %
25.	PDR 14 (R-952)	4 %	55.	Junner 8	91 %
26.	ACPR 94040	60 %	56.	Junner 9	28 %
27.	Phule Suyash	65 %	57.	Parner 2	85 %
28.	Jampa improved type	9 %	58.	Junner 10	73 %
29.	Arka Suvidha	10 %	59.	Akole 2	93 %
30.	Sevil	14 %	60.	Akole 3	5 %

Out of sixty french bean germplasm, none of the germplasm was found free from bean common mosaic virus (BCMV). Eleven germplasm lines *viz*., GK-1, GK-2, PDR-14 (R-952), Jampa improved type, Arka Suvidha, Sevil, Vaishnavi, EC-28304, Laxmi, Parner-1 and Akole-3 showed 1-10 % disease incidence; thirteen germplasm *viz.*, Phule Surekha, Contender, Kanpur-1, GK-13, Jampa Improved, GRB-9410, GK-5-1, Kanpur-3, PRJ-125, Arka Komal, Junner-1, Junner-7 and Junner-9 showed 11-40 % disease incidence; twenty-five germplasm *viz*. GK-06, EC-500377, Kanpur-2, GK-03-06, EC-530909, IC-039081, 3-2-701, ACPB-11, IC-28008, UHE-B-30, EC-500354, 958, ACPR-94040, Phule Suyash, Selection-9, Dharwad selection, ACPR-19, SVM, GK-5, Kashmiri, Kashmiri selection-1, Junner-2, Junner-3, Junner-6 and Junner-10 showed 41-75 % disease incidence; eight germplasm *viz*. HPR-35, GRB-990, Phalguni, R-II-GRB, Arka Sharath, Junner-4, Junner-5 and Parner-2 showed 76-90 % disease incidence and, three germplasm *viz*. New contender-1, Junner-8 and Akole-2 showed 91-100 % disease incidence. Earlier researchers Noordam (1973) [14], Lapidot *et al*. (2000) [10], Pico *et al*. (1998) [15] and Vidavsky *et al*. (1998) [24] had screened French bean germplasm lines against BCMV.

Physical properties

Dilution end point

The dilution end point of bean common mosaic virus (BCMV) was found between 10^{-3} and 10^{-4}. The number of local lesions was found to decrease with increase in dilution of the sap (Table 4).

Table 4: Dilution End Point (DEP) of bean common mosaic virus

Dilution	No. of leaves inoculated	Average number of lesions
Crude sap (Control)	10	6.7
1:10	10	5.4
1:100	10	4.2
1:500	10	3.6
1:1000	10	2.0
1:5000	10	0.7
1:100000	10	0

Thermal inactivation point (TIP)

Thermal inactivation point (TIP) indicates the infectivity of the virus present in the sap after heating the sap at particular temperature for specific time period. In the present study, BCMV virus remained infective after heating at 55 ºC for 10 min. However, the number of lesions decreased gradually after heating the crude sap to successive higher temperatures from 40 ºC to 55 ºC. Moreover, the virus lost its infectivity when the sap was heated to 60 ºC (Table 5).

Table 5: Thermal inactivation point (TIP) of bean common mosaic virus

Temperature (ºC)	No. of leaves inoculated	Average no. of lesions
Crude sap (Control)	10	7.6
40	10	5.0
45	10	4.5
50	10	3.2
55	10	1.2
60	10	0
65	10	0

Longevity *in vitro* (LIV)

Longevity *in vitro* indicates how long the virus present in the sap remains infective after storing it for particular period. In the present investigation, BCMV present in the sap was found infective up to 48 hours. After 60 hours, the infectivity of the sap was lost (Table 6).

Table 6: Longevity *in vitro* (LIV) of bean common mosaic virus

Storage period in h	No. of leaves inoculated	Average no. of lesions
0	10	8.0
2	10	6.6
4	10	5.2
8	10	4.8
12	10	3.0
24	10	2.8
36	10	1.5
48	10	0.7
60	10	0

The physical properties of the virus under investigation were: DEP 10^{-3} to 10^{-4}, TIP 60 ^{0}C and LIV 48 h at room temperature. The similar physical properties of bean common mosaic virus have earlier been reported by Chowfla *et al*. (1990) [4], Chailani *et al*. (1994) [3], Saiz *et al*. (1995) [19], Spence and Walkey (1994) [22], Ronalli and Pariasi (1997) [18] and, Tolkach and Gnutova, (2001) [23].

Plate 1: Mechanical / Sap transmission

Plate 2: Mottling

Plate 3: Vein banding

Plate 4: Downward curling of leaves

Plate 5: Curling of leaves

Plate 6: Bending of leaf margin

Plate 7: Blistering and puckering

Plate 8: Healthy and diseased pods

Plate 9: Overall stunting

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