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Bean common mosaic virus of legumes with special emphasis on mungbean [*Vigna radiata* (L.) Wilczek]: An overview

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Abstract
Mungbean is one of the most important pulse crops for protein supplement in subtropical zones of the world. Looking the productivity of mungbean in India, there are several production constraints in the mungbean growing areas among which diseases and pests plays a prominent role. Bean common mosaic Virus (BCMV) is a most destructive disease and one of the earliest seed borne, which belongs to the Potyvirus group. The group constitutes the largest group having large number of plant viruses which cause heavy yield losses in crops. Symptoms of downward leaf rolling, thickening of leaves, mosaic, leaf deformation, necrosis of tissues of abaxial side of leaves, necrosis of apical stem portion, etc. It is seed borne disease and can be transmitted in the non-persistent manner by several aphid species. Bean common mosaic virus has a wide host range.BCMV as flexuous particles of 823 nm long in mungbean capsid protein of 34 KDa and predicted ~1300 bp product. The virus was found to survive in seed coat, cotyledons and embryo as well as in pollen. The relative humidity, bright sun shine, rainfall positively, vapour pressure correlated with per cent disease intensity of BCMV. The information regarding the symptoms, host, transmissions, location of virus, ELISA, RT-PCR, SDS-PAGE, Epidemiology and management of BCMV disease has been reviewed in this article.

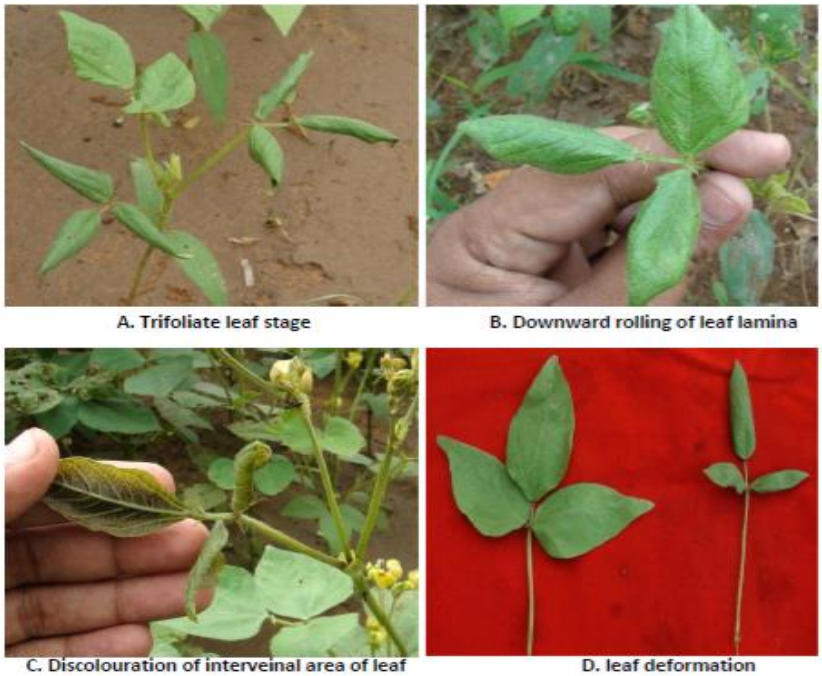
Keywords: BCMV, mungbean, detection, epidemiology and management

Introduction
Mungbean [*Vigna radiata* (L.) Wilczek] is third most important pulse crop of India after chickpea and pigeonpea. A number of the viruses are reported to cause considerable yield losses in legumes including mungbean (Biswas 2017) [6]. Around 45 viruses are reported to infect legumes (Bos *et al.,* 1988) [7] worldwide. The important groups of viruses infecting mungbean are the Luteoviruses, Nanoviruses, Carlaviruses, Furoviruses and Potyviruses. The Potyviruses are the most important causing economically important diseases in grain legumes. Many of the viruses are seed borne in legume hosts and worldwide in distribution. The viruses can infect the crop at any growth stages which is the most important factors for severe losses in yield and quality. Mungbean is infected by more than eight viruses under field conditions the important one are *Mungbean yellow mosaic virus*, Bean common mosaic virus, *Cucumber mosaic virus, Leaf crinkle virus, Leaf curl virus, Mosaic mottle virus* and *Alfalfa mosaic virus* (Nene, 1973; Kaiser *et al*., 1971) [52, 34]. Almost 50% of viruses affecting leguminous crops are seed-borne (Bos *et al*., 1988) [7]. Among the seed borne viruses, Bean common mosaic virus (BCMV) and *Mungbean yellow mosaic virus*, are the major constraints in cultivation and production of green gram. BCMV is one of the most serious and widespread virus in beans world area (Drijfhout *et al*., 1978) [15]. BCMV belongs to the Potyvirus group, which is largest group of plant viruses (Shukla *et al*., 1994). BCMV was first isolated from mungbean (*Vigna radiata*) in Iran by Kaiser *et al*., (1968) [33] with the name mungbean mosaic virus. In Thailand, a virus was isolated from mungbean plants showing mosaic symptoms and identified as a strain of BCMV (Tsuchizaki *et al*., 1989) [68]. The BCMV in India was reported in 1963 simultaneously by Yaraguntaiah and Nariani, (1963) [77]. The Bean Common Mosaic Virus (BCMV) is a widely distributed destructive pathogen on *Phaseolus vulgaris* L. (Nalini *et al*., 2006) [50]. Many Potyviruses have been reported to infect large-seeded legumes and are economically important because they are transmitted at a high frequency through seeds i.e. about 83% in *Phaseolus vulgaris* and 7-22 % in tepary bean. Besides, these are spread naturally by aphid in a non-persistent manner (Puttaraju *et al*., 1999) [58] Seed transmission rate of the virus is reported up to 25% in green gram by Kaiser *et al.,* (1968) [33] and as high as 93 % by (Schmidt, 1992) [62]. Pod yieldlosses in mungbean were reported to be 50 to 64% and seed yield 53–68% (Bashir *et al*., 2000) [3].

Similarly, 8-10 % seed transmission of BCMV was reported in T_9 variety of urdbean with15-20% incidence of disease during July to September (Pathania *et al.*, 2012) [55]. BCMV is economically important disease in Africa, Europe, North America and Latin America. However, infection levels may reach 100% with yield losses ranging from 35-98% (Galvez, 1980) [20]. Yield reductions in bean crop due to BCMV ranged from 53 to 68% in Oregon, USA, depending on disease severity (Hampton, 1975) [25], whereas, Up to 98% yield losses have been reported due to BCMV infection by Varma, (1988) [71] and Hampton *et al*, (1982) [26]. Incidence of BCMV has been observed in considerable form in mungbean growing areas of South-Eastern Rajasthan during *kharif* season. Curiously some of the wild host's plants were also found showing the symptoms of BCMV during the crop season.

Symptomatology

Pierce (1934) [82] for the first time reported the characteristic foliar symptom induced by BCMV. The symptom consists of a mosaic of well defined dark green areas, often observed in a vein banding pattern and consists of top necrosis and subsequent plant death. However, in addition the virus can induce other symptoms viz. mosaic, leaf curl, blistering, dwarfing, and chlorosis (Morales and Bos, 1988) [7]. The type of symptom produced is associated with the strain of BCMV infecting the plants which could be common mosaic with leaf rolling or blistering, light and dark-green patches on the leaf (green mosaic), chlorotic vein banding, yellow mosaic and growth reduction (Galvez, 1980) [20]. Kaiser and Mossahebi, (1974) [32] observed mosaic in the primary leaves of the virus infected seedlings which usually became more discernible in the trifoliate leaves. Drijfhout in 1978 [16] reported two main types of symptom in *Phaseolus vulgaris*, depending on virus strain and host genotype i.e. 'Common mosaic' which often associated with leaf malformation and 'Black root' characterized by systemic necrosis and plant death. Ben-Moshe *et al.*, (1991) [4] observed chlorotic leaf mottling and yellowing, chlorotic depressions, systemic necrosis and bronzing which resulted in killing of the plant. Saiz, *et al*., (1995) [59] observed green yellow, vein banding mosaic, leaf malformation, rolling and stunting symptoms of BCMV in Spanish bean field. Verhoeven *et al.*, (2003) [72] reported varied symptoms among bean varieties. They reported that the pods showing mosaic patterns resulted in reduction in number and size of the seeds. Mukeshimana *et al*., (2003) [48] studied the symptoms of BCMV and bean common mosaic necrosis virus (BCMNV), where both showed a light green or yellow and dark green mosaic pattern on leaves, usually accompanied by puckering, distortion and rolling of the leaves. Other symptoms seen on susceptible hosts include mottling, curling and malformation of leaves, as well as general stunting of the plant. Plants infected early in the growing season or grown from infected seed may suffer a delay in maturity and have fewer pods and seeds per pod than healthy plants. Saqib *et al*., (2005) [60] reported first the occurrence of BCMV from Western Australia on the *Phaseolus vulgaris* plants with the symptoms as mottle, leaf deformation, severe mosaic, malformation of leaves and pods, downward curling of leaves and reduction in leaf size under field conditions. Hong-Soo Choi *et al*., (2006) [29] described BCMV of mungbean showing symptoms of chlorotic, yellow mosaic and vein clearing. Kapoor *et al*., (2009) [35] described symptoms such as leaf rolling, leaf distortion, mottling, puckering, vein banding, stunted growth, etc. in French bean due to BCMV. Bhadramurthy and Bhat, (2009) [5] described mosaic, leaf and stem necrosis, leaf distortion and stunting as the characteristic disease symptoms associated with BCMV infection in vanilla crop. Deepti and Chalam, (2009) [35] reported that out of forty germplasm lines of Faba bean subjected to Growing-on test (GOT) under controlled conditions, 38 lines showed symptoms of leaf rolling, mosaic, leaf narrowing and stunting of plants. However, systemic mosaic, mottling, and downward cupping of leaf margin with reduced leaf lamina were observed in variety T_9 of urdbean (Pathania *et al*., 2012) [55]. Yadav (2013) [76] revealed that symptoms of BCMV vary with mungbean variety, virus strain, environmental conditions and stage of plant growth at the time of infection. The first symptom of the disease was observed at trifoliate leaf stage. The plants infected by BCMV showed reduction and downward rolling of leaf lamina, necrosis of veins, leaf deformation and discolouration of interveinal area of leaf. The diseased plants produced less pods with necrosis which were shriveled and produced a few light weight small and discolored seeds.



E. Mungbean Plant severity infected by BCMV

F. Necrosis of inter venial area of lamina

Transmission

Sap Transmission

Ben-Moshe *et al.*, (1991) [4] reported that *Glycine max*, *Lycopersicon esculentum*, *Phaseolus vulgaris*, *Vicia faba* and *Vigna unguiculata* have expressed the disease by mechanical inoculation of the virus. Udayashankar *et al.*, (2010) [69] did differential host tests, where primary leaves of the cowpea were inoculated with sap from the Bean common mosaic virus- Black eye cowpea mosaic and CABMV-positive seedlings. The inoculated seedlings were evaluated for possible latent infection by DAC-ELISA. Verma and Gupta, (2010) [73] did differential sap inoculation with BCMV at cotyledonary, trifoliate leaf stage and pre-flowering stage of French bean. They found that cotyledonary leaf infection favored maximum disease expression. Saqib *et al*., (2010) [61] reported that the BCMV infecting common leguminous weed, *Macroptilium atropurpureum* and *Phaseolus vulgaris* when sap inoculated onto *Nicotiana benthamiana*, *Chenopodium amaranticolor* and *C. quinoa* gave typical symptoms as in the primary host. Yadav (2013) [76] reported that inoculated plants showed downward rolling of leaves lamina in all inoculated plants after 28 days.

Seed Transmission

Morales and Bos, (1988b) [47] reported that the rate of BCMV transmission through seed varies due to genotypes of common bean and virus strains and ranged from 0 to 83%. Seed Transmission of BCMV in 12 mungbean lines infected at seedling stage ranged from 8 to 32 per cent (Kaiser and Mossahebi, 1974) [32]. However, the seed transmission rate had been reported as high as 93 % (Schmidt, 1992) [62]. Hong-Soo Choi *et al*., (2006) [29] reported in the range of 1.0 to 4.9% in mungbean cultivar Soseon, while in Gyeongseon 1% seed transmission rate was obtained. Kumar *et al.*, (2011) [39] revealed a seed-transmission rate of 3.37 to 9.18% of BCMV in mungbean. Ben-Moshe *et al*., (1991) [4] reported that the seeds appearing healthy from infected pods did not show any symptoms at germination inspite of virus infection. The virus was detected from such seeds by ELISA with BCMV antiserum. They observed Georgia isolate of BCMV to be seed transmissible at a rate of about 94% in guar line PI 340385. Sengooba *et al.*, (1994) [63] reported that necrotic strain-type isolates of BCMV obtained from wild legumes were seed-transmitted in bean and wild legumes. Hormozi-Nejad *et al*., (2010) [30] reported that BCMV is a major seed transmitted virus in common bean and use of virus-free germplasm is a prerequisite for production of certified seeds. Seed transmission of BCMV was observed up to 8-10% in T_9 variety of urdbean by Pathania *et al.*, (2012) [55]. Peyambari *et al.*, (2011) [53] reported that seed transmission rates in butter bean (ks-21478), kidney bean (ks-31170) and navy bean (ks-41235) genotypes were 78.3%, 79.8% and 54.9%, respectively. Yadav (2013) [76] reported 24.0, 26.0 and 22.0 per cent of seed transmission in IR-16, K-851 and Meha varieties of mungbean, respectively. Genotype LGG 460 did not express any symptoms of BCMV.

Insect Transmission

Insect-vectors are the means of secondary spread of BCMV from infected plants within a crop. Different species of Aphid have been reported to transmit BCMV which includes *Aphis gossypii*, *A. medicaginis*, *A. rumicis*, *Hayhurstia atriplicis*, *Uroleucon ambrosiae*, *Macrosiphum euphorbiae* and *Acyrthosiphon pisum* (Zaumeyer and Thomas, 1957) [78]. BCMV can be transmitted in the non-persistent manner by several aphid species *viz*., *Acyrthosiphon pisum*, *Aphis fabae* and *Myzus persicae* which do not normally colonize *P. vulgaris* but transmit the virus as winged migrants (Kennedy *et al.*, 1962; Zettler and Wilkinson, 1966) [36, 81]. The efficacy of BCMV transmission is determined by the pre- and post-feeding behaviour of *Myzus persicae* (Zettler and Wilkinson, 1966). Zettler, (1969) [80, 81] reported that the transmission of virus by aphids was dependent on symptom expression and better sources of virus acquisition. The younger leaves were better sources for virus acquisition than older leaves. Kaiser *et al.*, (1971) [34] reported *A. craccivora*, *A. fabae*, *A. gossypii*, *A. pisum*, *A. sesbaniae* and *Myzus persicae* as the important insect vector in the spread of the virus and varied greatly in their efficiency and acquisition-feeding period from less than 1 min to 72 hrs and inoculation- feeding periods from 18-72 hrs. Kaiser and Mossahebi, (1974) [32] reported that the BCMV is transmitted in a stylet-borne manner by several aphid species, including *A. craccivora*, *A. pisum* and *A. sesbaniae* for natural infection of mungbean. Losses in vegetative growth and seed yield of bean by the black bean aphid (*A. fabae*) transmitting BCMV was significant when aphid infestation occurred during the early stages of plant development, and to a lesser extent during anthesis (Khaemba and Latigo, 1985) [37]. Similarly, more damage occurred at higher levels of infestation. In India, younger bean plants were found to be more susceptible to BCMV transmission by *M. persicae* than older plants; nymphs and apterous aphids were more efficient at transmission of the virus than winged adults (Gupta and Chowfla, 1990) [24]. Bashir and Hampton, (1994) [2] recorded aphid transmission rates of 24-55% in experiments using three *Aphis craccivora* per plant. Gray (1996) reported that Potyviruses are spread primarily by seeds and secondarily by aphid vectors which transmit the virus in a non-persistent manner. Yadav (2013) [76] reported that sixty minutes of acquisition access period *A. craccivora* leads to 80 percent transmission of the virus with 17 days of incubation periods and 3 hrs inoculation feeding.

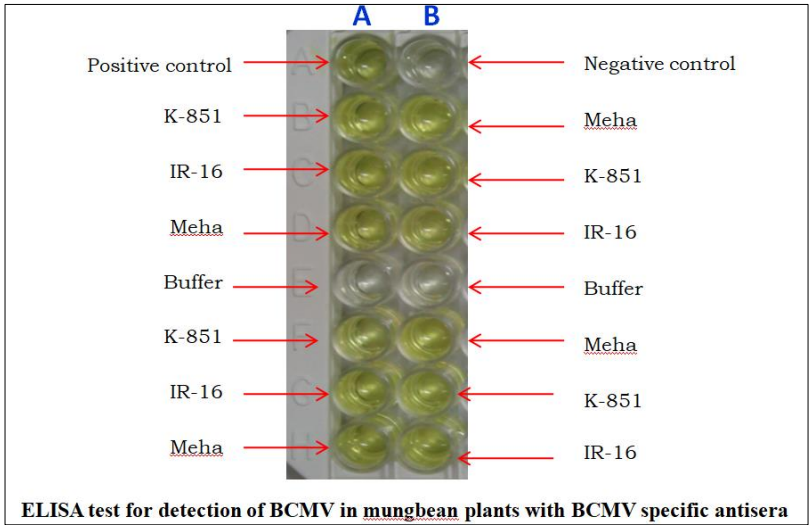
Host range

Bean common mosaic virus has a wide host range. Natural

hosts of BCMV are mainly restricted to *Phaseolus* spp., especially *P. vulgaris* (Drijfhout, 1978) [16]. However, BCMV has been isolated naturally from other leguminous species including *Vigna unguiculata* (Zaumeyer and Thomas, 1957) [79], *V. radiata* (Kaiser and Mossahebi, 1974) [32], *Rhynchosia minima* (Meiners *et al*., 1977) [42] and *Lupinus luteus* (Frencel and Pospieszny, 1979) [19]. There are also reports of the incidence of potyviruses which resemble, or have a close serological relationship with BCMV. Sharare and Raychaudhuri, (1963) described a virus which resembled BCMV infecting black gram. Potyviruses with a close serological relationship to BCMV have also been isolated from mung bean. The range of botanical families infected by BCMV is fairly narrow as compared to other potyviruses and consists mainly of legume species. Experimental leguminous hosts and non-hosts are described by Galvez, (1980) [20]; Boswell and Gibbs, (1983) [8]; Morales and Bos, (1988a) [46]. Non-leguminous hosts include *Chenopodium album var. centrorubrum*, *C. quinoa* and *C. amaranticolor*, which only develop local lesions and *Nicotiana clevelandii*, which develops systemic infection (Drijfhout and Bos, 1977) [14]. Christie and Crawford, (1978) [11] reported that *N. benthamiana* was successfully infected with the American type culture collection (ATCC) strain pv25 of BCMV. Spence and Walkey, (1995) [66] tested 29 legume species for susceptibility to six isolates of BCMV. Five species i.e. *Cassia didymobotrya*, *Crotalaria laburnifolia*, *Desmodium heterocarpon*, *D. triflorum* and *Rhynchosia sublobata* were resistant by all strains tested. Whereas, five species *i.e. Centrosema pubescens*, *Crotalaria anagyroides*, *C. lanceolata*, *C. ochroleuca* and *Rhynchosia minima* were susceptible to infection by five of the six isolates tested. Zaumeyer (1957) [78] reported that BCMV is mainly found in *Phaseolus* species. Hollings (1957) [28] proved the usefulness of clusterbean as a host for identifying plant viruses as the red lesions were specific, uniform and unlike those induced by other viruses on *Chenopodium amarantiocolor*. Other susceptible legumes included *Phaseolus lunatus* var. Small White, *Phaseolus multiflora*, *Vicia sativa*, *Pisum sativum*, *Pisum arvense*, *Vigna sinensis*, *Cyamopsis sporaloides*, *Melilotus indica*, *Crotolaria intermedia* and *Chrysolopus spectabilis* (Le Beau, 1947) [40]. Verma *et al*., (1962) reported systemic necrosis, starting at tips and margins of leaves and spreading to whole plant in BCMV infected *Glycine max*. They also observed systemic chlorotic mottling in *Phaseolus vulgaris*, systemic leaf curling and tip necrosis in *Vigna radiate* and chlorotic local lesions in *V. unguiculata*. They also observed *Datura stramonium*, *Nicotiana tabacum cv*. White Burley and *Solanum nigrum* as diagnostically susceptible host species. Bhadramurthy and Bhat (2009) [5] reported vanilla as a new host of BCMV and observed mosaic, leaf and stem necrosis, leaf distortion and stunting. Prachi *et al*., (2009) reported that BCMV was restricted to *Phaseolus vulgaris*, *Vigna umbelleta* and *Vigna angularis*. Yadav (2013) [76] studied twenty various hosts of BCMV and revealed that urdbean (*V. mungo*) and marigold (*Calendula officinalis*) gave strongly positive reaction to BCMV with O.D. value of 3.890 and 3.513, respectively with BCMV antisera. Whereas, urdbean (*V. mungo*), pomegranate (*Punicum granatum*), cowpea (*V. unguiculata*) and castor (*Ricinis communis*) gave positive reaction as compared to positive control to potyvirus antisera. However, other host with their O.D. values were soybean (*Glycine max*)(2.268), *S. lycopersicum* (2.886), *V. unguiculata* (2.678),*C.album* (2.672), *A. viridis (2.873), P. vulgaris* (2.984) and *R. communis* (2.872) which detected positively to BCMV as compared to positive control.

Detection of BCMV through Enzyme-linked immunosorbent assay (ELISA) technique.

ELISA appears to be the most suitable seed health testing procedure, especially for viruses, which are highly antigenic because of the presence of capsid protein. Species-specific monoclonal antibodies are available for the identification and differentiation of serotype A and serotype B isolates (Mink *et al.,* 1994) [43]. A number of monoclonal antibodies and polyclonal antisera can be used in ELISA for identification of BCMV isolates (Spence and Walkey, 1995) [66]. Hobbs *et al*., (1987) [27] used polyclonal antibodies to detect *Black eye cowpea mosaic* strain of BCMV. They recorded high ELISA values in comparison to the negative control and on par values with the positive control. Polyclonal antiserum of Potato virus Y (PVY) has also been used for the detection of BCMV (Mishra *et al.,* 1997). Gillaspie *et al.,* (1998) [44, 21] reported serological relationship of these two viruses with BCMV in guar with several BCMV antisera and with BYMV antiserum. Monoclonal antibodies possessing three epitopes located on the coat protein amino terminus of viruses of the BCMV group have been found to differentiate some group members (Mink *et al*., 1994) [43]. BCMV is also detected by DAS-ELISA in green gram and french bean **(**Khetarpal *et al*., 1994; Puttaraju, *et al*., 1999) [38, 58]. Gnutova *et al*., (2000) developed indirect and “sandwich"variants of ELISA to detect Bean common mosaic virus. Puttaraju *et al*., (2004) [57] identified BCMV serologically by Direct Antigen Coating- ELISA (DAC-ELISA) technique. Yadav (2013) [76] found that infected leaves of IR-16, Meha and K-851 gave strong positive reaction with BCMV specific antisera with an O.D. value of 3.99, 3.91 and 3.37, respectively as compared to positive control with an OD value of 2.20.



ELISA test for detection of BCMV in mungbean plants with BCMV specific antisera

Location of BCMV in seed parts of Mungbean

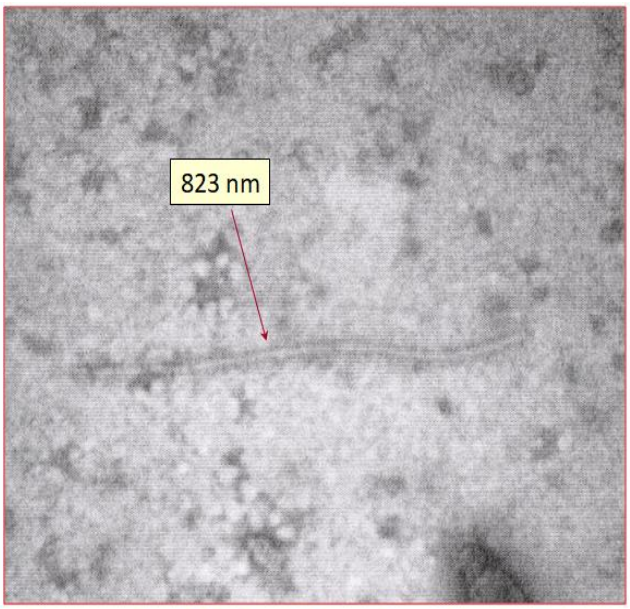
Bean Common Mosaic Virus particles are reported to survive in bean seed for at least 30 years (Zaumeyer and Thomas, 1957) [78]. BCMV was detected internally in cotyledons and embryos, but not in seed coats. Seed maturation (drying) had little effect on the virus distribution in cotyledons and embryos (Ekpo and Saettler, 1974) [17]. Due to its high seed transmissibility, BCMV can be widely dispersed in the field by planting infected seeds (Mavri and Sustar-Vozli, 2004) [41]. Therefore, planting certified healthy seed is one of the main practical and economical step towards the effective control of BCMV and production of good quality crop. Yadav (2013) [76] reported that BCMV presence in complete seed as well as seed coat, cotyledons and embryo parts of the seed which was detected with BCMV antisera under ELISA.

Infection of BCMV in different parts of mungbean plant

Bean common mosaic virus is transmitted by seed and, occasionally, by pollen from one generation to the next. Virus particles can be transmitted through pollen, grains, ovules and flowers of infected plants (Wilson and Dean, 1964) [74]. However, Irena and Jelka, (2004) [31] reported that the virus could be transmitted to offspring from healthy plant through the pollen of infected plant. Yadav (2013) [76] reported that infected leaves, pollen and seeds gave strong positive reaction with O.D. value of 3.231, 3.243 and 3.362, respectively. However, root, pods and root nodules gave negative reaction.

Detection BCMV under Transmission Electron Microscope

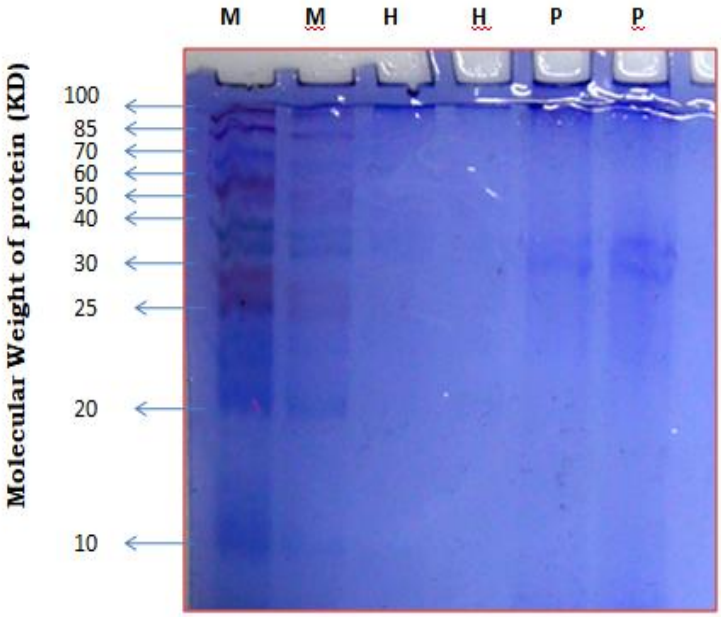
Sacchindanand *et al.*, (1973) reported that the particles of bean common mosaic virus infecting cowpea were flexuous rods measuring 750 – 925 x 15 nm. Kaiser and Mossahebi, (1974) [32] observed rod shaped and flexuous particles of BCMV in mungbean which was approximately 750 nm in length. Potyvirus group of viruses were having flexuous filamentous particles of 765 nm (Drijfhout, 1978 [15]; Morales and Bos, 1988 [7]). Damayanti *et al.*, (2008) [12] studied BCMV in yam bean [*Pachyrhizus erosus* (L.) Urban] in Indonesia and observed that the virus was flexuous filamentous about 700 nm in length. Under Immunosorbent electron microscopy (ISEM) the virus particles were of filamentous structure having a diameter of 750 nm (l) and 15 nm (w) (Verma and Gupta, 2010) [73]. Udayashankar *et al.*, (2012) [69] studied BCMV by electron microscopy flexuous rod shaped particles 750 nm long. Yadav (2013) [76] detected 823 nm long virus as flexuous particles under transmission electron microscopy.



Microphotograph of BCMV particle as observed under Electron Transmission Microscope

Detection of BCMV protein through Sodium Dodecyl Sulphate Polyacrylamide Gel Electrophoresis (SDS-PAGE)

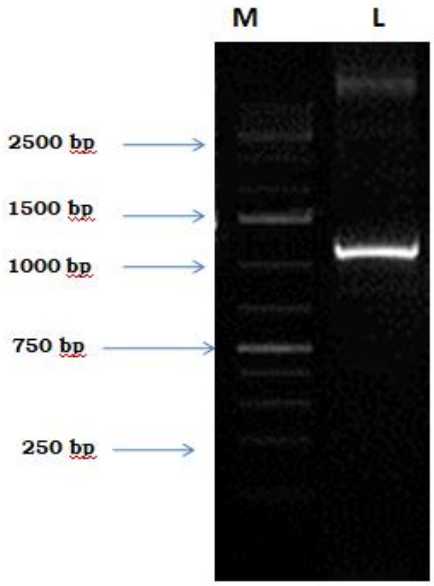
Molecular weight of the BCMV virus coat protein was determined approximately 34x103 KDa by SDS-PAGE. The virus RNA was approximately 9.5 kb in size, as estimated by denaturing agarose gel electrophoresis (Hu *et al*., 1995). The partially purified BCMV virus upon electrophoresis on SDS-PAGE revealed major band corresponding to 34 kDa (Bhadramurthy and Bhat, 2009) [5]. Yadav (2013) [76] observed that capsid protein of Bean Common Mosaic virus was of 34 KDa, whereas, no band was observed in healthy leaf sample wells.



Samples
M = Protein molecular weight marker
H= Standard Healthy leaf sample of plant
P= Purified sample of BCMV

Detection of BCMV through Polymerase Chain Reaction (PCR) using family specific universal primers

The sensitivity of nucleic acid-based detection systems has greatly improved following the development of the Polymerase Chain Reaction (PCR) procedure (Mullis *et al*., 1986). By a combination of reverse transcription RT-PCR and restriction enzyme analyses, it is possible to differentiate both viruses, two pathogroups of BCMNV and one pathogroup of BCMV from the others (Xu *et al*., 1991). Abdullah *et al*., (1995) [1] reported that about 39% of ELISA negative samples tested positive for BCMV by PCR. Total RNA was used as a template for rt-PCR (reverse transcription followed by polymerase chain reactions) using specific primers directed toward the coat protein cistron to obtain products of 890 bp and 740 bp for BCMV and BCMNV, respectively (Flores-Estevez *et al*., 2003) [18]. The nucleotide sequences of the coat protein (CP) for four BCMV strains (NL-1, NL-2, Nl-4 and NL-7) were aligned and primers were chosen to amplify a 404 bp fragment (Trajkova and Khristova, 2008). Sharma *et al*., (2009) [67, 35] have isolated viral RNA from infected leaves by trizol reagent. RT-PCR amplification of total genomic RNA using BCMV degenerate primers generated an amplicon of ~1000bp, which was cloned in pGEMT-Easy vector and custom sequenced.The presence of BCMV in 3 of the samples was confirmed using specific RT-PCR. Comparison of the amplifiable fragments of the tested samples and used marker (M) for determining the presence of the expected size of fragment of about 1456 bp, which allowed by the amplification of primers. Whereas, amplification did not occur in the negative control (Dragana *et al*., 2010) [13]. The sequences of the four BCMV and BCMV-BICM isolates each consisted of 583-622 and 550-577 nucleotides (Udayashankar *et al*., 2012) [70]. Yadav (2013) [76] studied under RT-PCR amplified product when run on 1 per cent agarose revealed the presence of predicted ~1300 bp product of BCMV in the symptomatic mungbean plants.



RT-PCR amplification for *Bean common mosaic virus* (BCMV) coat protein.

M: 1000 bp plus DNA ladder (Fermentas)
Lane1: RT-PCR of BCMV coat protein after cDNA synthesis using oligodT10-18.

Epidemiology of the BCMV

Early plantings of cultivars at the time when the incidence of the aphid vectors of legume viruses is low, could give good seed yields (Burke, 1964) [10]. Tu (1989) revealed a positive correlation of aphid population on 20 to 30 days crop and disease incidence at 45 days old crop with maximum temperatures, in soybean infected by soybean mosaic virus in Canada. Nariani and Costa, (1960) [51], analyzed the aphid population and rainfall in cowpea infected with blackeye cowpea mosaic virus in Tamil Nadu. At 30 days period, aphid populations were recorded as 45 aphids per plant with 85.96 percent disease incidence. Rainfall of 3 mm between 30 to 35 days reduced the population of aphid to 10 to 12 stage with decrease in percent disease incidence up to 32.3 percent. Prasad *et al*., (2007) [56] reported that aphid population was found to be negatively correlated with maximum temperature. Yadav (2013) [76] revealed that minimum disease intensity *i.e*. 25.5, 28.8 and 31.5 % observed in first date of sowing crop of Meha, IR-16 and K-851, respectively. The disease intensity was correlated with the weather parameter which revealed that relative humidity of 80.4 to 90.2% as well as bright sun shine of 4.31 to 5.3 hrs had positive correlation with disease intensity in all the three dates of sown crop. The rainfall about 46.0 mm was positively correlated with PDI of BCMV in first date of sown crops. Minimum temperature *i.e.* 25.5 to 27.5^{o}C and vapour pressure 24.9-25.52 were positively correlated in first date of sowing and negatively correlated in second and third date. Aphid population was positively correlated with the weather factors i.e. minimum temperature 24.9-27.2^{o}C, vapour pressure 24.4 to 26.0 and relative humidity 82.2 to 90.5%. Among these RH of 82.2 to 90.5% has very positive correlation as the aphid population increased with increase in relative humidity.

Management of the disease by vector control

Brunt and Kenten, (1971) [9] reported that application of Dimethoate in the soil had affected the spread of aphid transmitted viruses from infected to healthy plants in potato crop. Foliar sprays of imidacloprid 70 WS and Acephate 0.07 per cent were significantly effective at 15 days after first spray and ten days after second spray in controlling the tobacco aphid than other foliar sprays (Anon., 1992). Yadav (2013) [76] revealed that minimum disease intensity with two sprays of thiamethoxam 25WG @ 4g/10 lit of water followed two sprays of dimethoate 30 EC @10ml/10 lit of water, two sprays of imidacloprid 70 WG @2 g/10 lit.

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