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Viruses of spices and their managemente

This article presents a comprehensive overview of viruses affecting vegetatively propagated spice crops, particularly black pepper, small cardamom, and large cardamom. It examines the biology of each causal virus, their geographic distribution, economic significance, characteristic symptoms, and modes of transmission including through infected planting material and insect vectors. Given the challenges posed by vegetative propagation, the article emphasizes the importance of integrated management approaches, including early detection using molecular diagnostics, production of virus-free planting material, vector control, and cultural practices. These strategies are critical for ensuring sustainable spice cultivation and mitigating the impact of viral diseases on crop yield and quality.

SPICE crops such as black pepper, small cardamom, and large cardamom play a crucial role in the agricultural economies of tropical regions. However, their sustainable production is increasingly challenged by viral diseases that cause significant yield losses and quality deterioration. These viruses are primarily spread through infected planting materials and insect vectors, making disease management particularly complex due to the crops' vegetative mode of propagation. Addressing these challenges requires an integrated approach that combines early detection, clean planting material, vector control, and farmer awareness. Strengthening these measures is essential to ensure the long-term health and productivity of spice crops.

Black pepper *(Piper nigrum)*

Mottle/Stunt disease (Piper yellow mottle virus, cucumber mosaic virus, black pepper virus F, black pepper virus E, and black pepper virus B)

Aetiology: The disease, reported from all black pepper-growing regions, is caused by piper yellow mottle virus (PYMoV), a member of the genus *Badnavirus* in the family *Caulimoviridae*. PYMoV is a bacilliform-shaped, double-stranded DNA virus. In addition to PYMoV, a few black pepper plants have been found co-infected with cucumber mosaic virus (CMV) (*Cucumovirus*) and black pepper virus F (BPVF) (*Fabavirus*). Furthermore, two additional viruses–black pepper virus E (BPVE) (*Enamovirus*) and black pepper virus B (BPVB) (*Badnavirus*)–have been reported to infect black pepper in China. CMV is characterized by isometric particles and possesses a tripartite, positive-sense single-stranded RNA genome. BPVF is an isometric bipartite RNA virus. Molecular diagnostic tools such as PCR, real-time PCR, loop-mediated isothermal amplification (LAMP), and recombinase polymerase amplification (RPA) have been developed and validated for the detection of CMV and PYMoV in black pepper and related species.

Distribution and economic importance: Stunt disease has been reported from all major black pepper-growing countries, including Brazil, China, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand, and Vietnam. BPVF has been detected in China, Brazil, and India, whereas BPVE and BPVB have so far been reported only from China. Yield losses associated with the disease range from negligible to as high as 85%, depending on the severity of infection.

Symptoms of viral disease affecting black pepper

Symptoms: Symptoms on leaves include mosaic patterns, yellow mottling, distortion, and a reduction in leaf size. In advanced stages, the leaves become deformed and narrow, often assuming a sickle-like appearance. Infected plants exhibit stunting due to a reduction in internodal length. Studies have shown that symptom expression is influenced by environmental conditions and soil nutrition. Severe symptoms are more pronounced under high temperature and relative humidity.

Disease cycle: The primary mode of disease spread is through the use of virus-infected planting material. In addition, PYMoV is transmitted by mealybug vectors–*Ferrisia virgata, Planococcus citri,* and *Planococcus elisae*–as well as the black pepper lace bug *(Diconocoris distanti)* in a semi-persistent manner. The vectors responsible for the transmission of CMV, BPVB, BPVE, and BPVF are currently unknown. Among these viruses, PYMoV, BPVF, and BPVB primarily infect black pepper and its related species, whereas CMV has a broad host range.

Sustainable management: Currently, there are no resistant varieties of black pepper available against viral infections. Therefore, efforts must focus on reducing sources of infection, limiting vector-mediated spread, and minimizing the impact of viruses on yield. The identification and propagation of virus-free planting material are critical to breaking the infection cycle. Since visual symptoms are unreliable for detecting virus-free plants, sensitive molecular diagnostics–such as PCR, real-time PCR, LAMP, and RPA–should be employed to screen mother plants.

Virus-free planting stocks of black pepper have been successfully generated from PYMoV-infected plants using meristem-tip culture and somatic embryogenesis. Virus-free plants obtained through such techniques may be established in a designated mother block and maintained in a virus-free state through regular monitoring and testing. Planting materials from this mother block should be multiplied in protected nursery conditions and subsequently used for commercial cultivation.

Additional measures to eliminate sources of infection include rouging and destruction of infected plants, removal of alternative virus hosts, and implementation of phytosanitary practices. To prevent vector-mediated transmission, the control of insect vectors through environmentally safe insecticides and biopesticides is recommended. In the absence of natural resistance to viruses in black pepper, the development of virus-resistant plants through transgenic approaches or gene-editing technologies may provide a promising long-term solution.

Integrated management in the field

Infections in black pepper plants may be asymptomatic or manifest with mild, moderate, or severe symptoms. Symptom expression is largely influenced by environmental factors such as high temperature, humidity, and soil nutrient status. Severely infected plants should be uprooted and destroyed–either by burning or by deep burial–to prevent further spread of the virus. For plants exhibiting mild to moderate symptoms, the following management practices are recommended to support recovery and maintain plant health and yield:

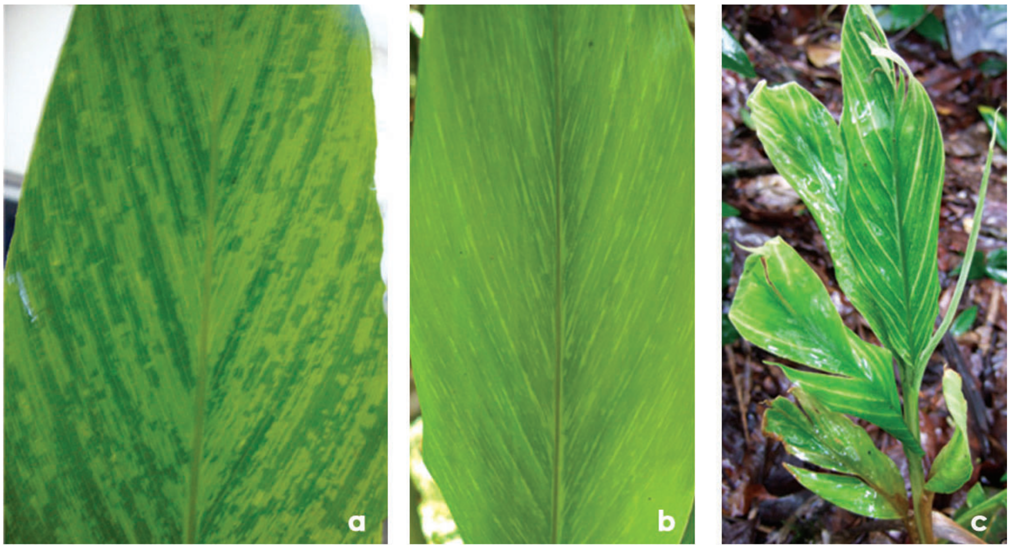
- Soil amendment with lime or dolomite to correct pH, along with the application of NPK fertilizers to ensure optimal nutrient availability.
- Application of plant growth-promoting rhizobacteria (PGPR) consortia and Trichoderma twice a year–pre- and post-monsoon–either by mixing with well-decomposed farmyard manure (FYM) and applying at 10–15 kg per plant or by soil drenching at a rate of 2–3 litres per plant.
- Foliar spraying of a micronutrient mixture at a concentration of 5 g/litre, applied twice–once after spike emergence and again after spike set.

Small cardamom (*Elettaria cardamomum*)

Mosaic (katte or marble) (cardamom mosaic virus)

Aetiology: Cardamom mosaic disease is caused by cardamom mosaic virus (CdMV), a member of the genus Macluravirus within the family Potyviridae. The virions of CdMV are flexuous rod-shaped particles measuring approximately 700–800 nm in length and 15 nm in width. Viral isolates display considerable variability in both symptom expression and nucleotide sequence. Diagnostic assays such as reverse transcription PCR (RT-PCR) and SYBR Green-based real-time RT-PCR and RPA-LFA have been developed for the detection of CdMV.

Distribution and economic importance: Mosaic disease has been reported from India, Guatemala, and Sri Lanka, with incidence rates ranging from 0% to 85%. Yield loss varies significantly depending on the stage of crop growth at the time of infection. Infection at an



Symptoms caused in cardamom by different viruses. (a) cardamom mosaic virus (b) banana bract mosaic virus, and (c) cardamom vein clearing virus early stage often results in total crop failure, whereas late infections lead to a gradual decline in productivity. In cardamom intercropped with arecanut, yield losses of 10–60%, 26–91%, and 82–92% have been recorded in the first, second, and third years of infection, respectively. In contrast, when cardamom is cultivated as a sole crop, losses of 38%, 62%, and 69% were observed over the same time period.

Symptoms: Infected plants can be diagnosed by the presence of interveinal mosaic or stripe mosaic symptoms, which typically originate from the midrib and extend toward the leaf margins. In advanced stages, leaf size is reduced, resulting in stunted plant growth. Mottling is also observed on the leaf sheaths of affected plants. As the disease progresses, it spreads to all tillers within the clump, leading to the development of fewer, smaller tillers and the production of short, sparse panicles.

Disease cycle: The major spread of the virus occurs through infected planting material, volunteer plants, and alternate hosts. In-field transmission primarily takes place via non-persistent transmission by the aphid Pentalonia caladii. Both nymphal and adult stages of the aphid are capable of transmitting the virus, with the winged and wingless adult forms being the most efficient vectors. Aphid populations persist year-round in plantations, with the abundance of winged vectors peaking between November and May. The primary spread of the disease is typically random, whereas secondary spread follows a circular pattern around the initial infection source. The latent period for symptom expression ranges from 20 to 114 days, depending on the plant's growth stage and prevailing environmental conditions. Symptom expression tends to occur earlier in younger plants and during the May to November period.

Chlorotic streak (banana bract mosaic virus)

Aetiology: The disease is caused by a strain of banana bract mosaic virus (BBrMV), which belongs to the genus Potyvirus in the family Potyviridae. BBrMV particles are flexuous and rod-shaped, measuring approximately 700 nm in length and 14 nm in diameter. Several diagnostic assays are available for the detection of BBrMV, including ELISA, lateral flow immunoassay (LFIA), RT-PCR, real-time RT-PCR, and RT-LAMP.

Distribution and economic importance: Chlorotic streak disease has been reported from all major cardamom-growing regions of India, with prevalence levels varying from 0 to 15%. The highest incidence is observed in plantations where banana is grown in close proximity to or intercropped with cardamom.

Symptoms: The initial symptoms of the disease appear as spindle-shaped yellow or light green streaks along the veins. These streaks gradually coalesce, resulting in a yellow or light green discoloration of the veins. In some infected plants, yellow or light green mottling also becomes evident on the petiole and leaf sheath. As the disease progresses, it spreads to the tillers within the clump, significantly impairing their growth and productivity.

Disease cycle: The infected cardamom and banana plants serve as the primary source of the virus. The secondary spread of BBrMV occurs non-persistently through aphids.

Vein clearing (*Kokke kandu*) (cardamom vein clearing virus)

Aetiology: The disease is caused by cardamom vein-clearing virus (CdVCV), which belongs to the genus Betanucleorhabdovirus in the family Rhabdoviridae. The virions are bacilliform in shape, and the viral genome comprises a single molecule of linear, negative-sense single-stranded RNA (ssRNA) approximately 13 kb in length. Several molecular assays are available for the detection of CdVCV, including reverse transcription PCR (RT-PCR), real-time RT-PCR, reverse transcription loop-mediated isothermal amplification (RT-LAMP), and reverse transcription recombinase polymerase amplification (RT-RPA).

Distribution and economic importance: The disease was first reported in 1993 in the Indian state of Karnataka and is now considered endemic to the Hassan and Uttara Kannada districts of the state. Notably, the disease has not been reported from Kerala, which is the principal cardamom-growing region of India. The infection may occur either alone or in association with CdMV. In contrast to mosaic disease, plants affected by CdVCV deteriorate rapidly, with yield losses reaching up to 84% within the first year of infection. Due to the severity and rapid progression of the disease, many farmers in the endemic regions have abandoned cardamom cultivation altogether.

Symptoms: The initial symptoms of the disease are characterized by uninterrupted or intermittent vein clearing. As the disease progresses, additional symptoms such as rosetting, loosening of the leaf sheath, and tearing of the leaves become evident. A distinctive symptom is the intertwining of newly emerging leaves with older ones, resulting in a hook-like appearance–commonly referred to as kokke kandu in local parlance.

Disease cycle: The primary source of infection is the use of virus-infected planting material or clones, while secondary spread occurs through the cardamom aphid, Pentalonia caladii. The incubation period of the virus within the plant ranges from 22 to 128 days, depending on environmental conditions and plant growth stage.

Sustainable management of viral diseases of cardamom

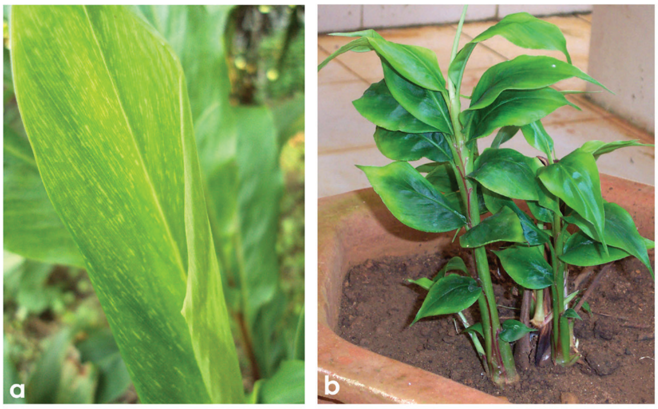
The variety IISR-*Vijetha,* which is resistant to CdMV, is recommended for cultivation in regions where mosaic disease is prevalent. However, in the absence of resistant varieties against BBrMV and CdVCV, the production and use of virus-free planting material becomes a critical component of integrated disease management. For this purpose, nurseries should be established in isolated locations using indexed, virus-free suckers. Molecular diagnostic tools such as RT-PCR, real-time RT-PCR, and RT-LAMP are effective in identifying virus-free mother plants for propagation.

In established plantations, regular monitoring and removal of infected plants, including collateral hosts such as *Colocasia* and *Caladium*–which serve as aphid breeding sites–are essential. Trashing of old and senile leaves, followed by application of recommended insecticides or biopesticides, helps in reducing vector populations. Additionally, the use of entomopathogenic fungi such as *Verticillium chlamydosporium*, *Beauveria bassiana*, and *Paecilomyces lilacinus* can further aid in suppressing aphid vectors and minimizing disease spread.

Large cardamom (*Amomum subulatum*)

Chirke or mosaic streak

Large cardamom chirke disease is caused by large cardamom chirke virus (LCCV), a member of the genus Macluravirus within the family Potyviridae. LCCV is a flexuous, rod-shaped virus measuring approximately 625–650 × 12.5 nm and contains a positive-sense single-stranded RNA (ssRNA) genome. Yield losses due to the disease can be as high as 85%. Infected plants exhibit mosaic streaks along the veins, which gradually coalesce and turn brown and necrotic, ultimately resulting in leaf desiccation. In addition to being propagated through vegetative means, LCCV is transmitted in a non-persistent manner by aphid vectors, predominantly Myzus persicae and Rhopalosiphum maidis. Diagnostic tools for LCCV detection include ELISA ,LFIA), and RT-PCR.



Symptoms of chirke
(a) foorkey, and (b) infected large cardamom

Foorkey

The disease is caused by cardamom bushy dwarf virus (CBDV), which belongs to the genus Nanovirus in the family Nanoviridae. CBDV is a spherical virus, 18–20 nm in diameter, with a multipartite genome consisting of nine single-stranded DNA (ssDNA) segments, each approximately 1.0 kb in length. Infected plants exhibit severe stunting, producing sterile shoots, and within two to three years, the entire clump is reduced to a mass of stunted shoots that fail to flower. Leaves are reduced in size, and the shoots gradually dry out, ultimately leading to the death of the entire clump. Leaf tips exhibit necrosis, and flowering spikes become leaf-like and fruitless. The weed Acorus calamus is also susceptible to CBDV, serving as a potential reservoir. Besides vegetative propagation, the virus is transmitted by aphid vectors, Pentalonia nigronervosa and Micromyzus kalimpongensis. Detection of CBDV is facilitated by diagnostic assays such as ELISA, dot-immunobinding assay, and PCR-based methods.

Sustainable management of viral diseases of large cardamom

In the absence of resistant varieties against LCCV and CBDV, the production and deployment of virus-free planting material is a key component of the integrated disease management strategy. To ensure the availability of healthy planting stock, nurseries should be established in isolated locations using indexed virus-free suckers. Within plantations, regular monitoring and prompt removal of infected plants, including collateral hosts that serve as aphid breeding sites, are essential to limit disease spread. Management of vector populations should include trashing of old and senile leaves, followed by application of recommended insecticides or biopesticides.

CONCLUSION

Virus-induced diseases are among the most significant constraints limiting the yield and quality of spice crops. The challenge of managing these viral diseases is compounded by the vegetative mode of propagation, vector-mediated transmission, and the presence of weeds that act as reservoir hosts. However, significant progress has been made in the identification of viruses infecting various spice crops, and sensitive diagnostic tools are now available for the detection of virus-free mother plants. These can be utilized for the production of healthy planting materials through vegetative propagation or tissue culture techniques. An integrated approach involving the use of resistant varieties, virus-free planting material, and the timely implementation of phytosanitary measures—along with the sustainable management of insect vectors—can substantially reduce the impact of viral diseases and enable spice growers to mitigate biotic stresses caused by viruses.

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Organic fertigation system

An organic fertigation unit was developed for use of cowdung and vermicompost filtrates as a nutrient source for crops. A power-operated agitator was also fabricated for the organic fertigation unit for large-scale vegetable cultivation. The proportion of manure and water, duration of agitation, and settling time of manure solution were optimized to improve the nutrient content of supernatant and filtrate using the power-operated agitator. Vermicompost filtrate prepared by mixing vermicompost and water in a ratio of 1:5 followed by agitation for 10 min and settling for 6 hr showed increased nutrient content (K, P, Ca and Mg) in the filtrate. It was recommended that organic manure filtrate along with a 50% recommended dose of fertilizer should be applied to get a higher yield of okra and improve the nutrient and microbial status of the soil.

Source: ICAR Annual Report 2022-23