

Sterility Mosaic Disease: A Silent Threat to Pigeonpea and the Search for Resistant Varieties

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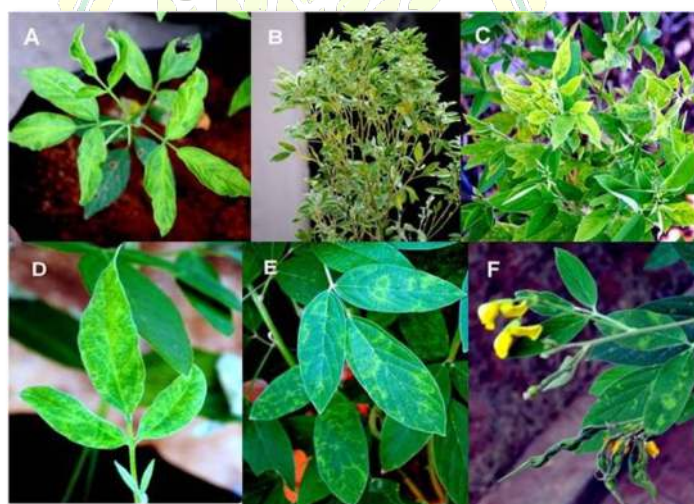
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Pigeonpea [*Cajanus cajan* (L.) Millsp.] is an important pulse crop that contributes significantly to food security and farmers' livelihoods. However, its productivity is severely affected by sterility mosaic disease (SMD), one of the most destructive viral diseases of pigeonpea. Commonly known as the "Green Plague", SMD is caused by *Pigeonpea sterility mosaic virus-1* (PPSMV-1) and *Pigeonpea sterility mosaic virus-2* (PPSMV-2), transmitted by the eriophyid mite *Aceria cajani*. Owing to the absence of an effective curative treatment, the development of resistant varieties remains the most reliable and economical strategy for disease management. This article highlights the importance of pigeonpea, major features of SMD, challenges associated with its management, and the role of conventional and molecular breeding approaches in developing resistant cultivars.

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is one of the most important pulse crops cultivated in tropical and subtropical regions worldwide, particularly in India. Commonly known as tur, red gram or arhar, pigeonpea plays a significant role in the livelihoods of resource-poor farmers because of its relatively low input requirements. It is a highly valued multipurpose food legume. Its protein-rich seeds are widely consumed, while immature green pods are utilized as vegetables. The foliage serves as livestock fodder, whereas dried stems are used as fuel and thatching material.

From a nutritional standpoint, pigeonpea is a rich source of essential minerals such as calcium, phosphorus, magnesium, iron, sulphur and potassium, along with water-soluble vitamins including thiamine,



riboflavin and niacin. The seeds contain approximately 20–22% protein and are consumed in various forms, including green peas, whole grains and split pulses. Besides its nutritional importance, pigeonpea contributes to sustainable agriculture through biological nitrogen fixation, improvement of soil fertility and adaptation to rainfed conditions.

Despite its importance, pigeonpea productivity remains considerably below its potential because of several biotic and abiotic constraints, among which diseases pose a major challenge.

Among these diseases, sterility mosaic disease (SMD), often referred to as the "Green Plague" of pigeonpea, is considered one of the most destructive. Unlike many plant diseases that primarily affect leaves or stems, SMD severely affects the reproductive development of the crop. Infected plants remain green and exhibit excessive vegetative growth, but flowering is greatly reduced or completely absent, resulting in little or no pod formation. Consequently, severe infection can cause substantial yield losses and significant economic hardship for farmers.

The disease is caused by *Pigeonpea sterility mosaic virus* (PPSMV-1 and PPSMV-2) and is transmitted by the eriophyid mite *Aceria cajani*. The microscopic size of the vector, coupled with the complex nature of virus transmission, makes effective disease management extremely challenging. Chemical control of viral diseases is generally ineffective, while management of the mite alone seldom provides complete protection against the disease. Consequently, sterility mosaic disease continues to threaten pigeonpea production across major growing regions.

Over the past few decades, considerable research has focused on understanding the disease, identifying resistant sources and developing improved pigeonpea cultivars capable of withstanding infection. Conventional breeding, supported by molecular markers and modern genomic tools, has accelerated the development of resistant varieties and offers one of the most sustainable approaches to disease management. Such advances not only reduce dependence on pesticides but also contribute to stable yields and improved food security.

This article explores the biology and impact of sterility mosaic disease, discusses the factors that make the disease difficult to manage, and highlights scientific efforts aimed at developing disease-resistant pigeonpea varieties for sustainable agriculture.

The Silent Threat: Sterility Mosaic Disease

Sterility mosaic disease (SMD) was first reported by Mitra in 1931 from Bihar, India. Since then, it has emerged as one of the most destructive diseases of pigeonpea in the Indian subcontinent, causing substantial economic losses. The disease is endemic to India and has also been reported from Bangladesh, Nepal, Myanmar, Sri Lanka, Thailand and China. In India, SMD occurs in almost all major pigeonpea-growing states, including Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Karnataka, Maharashtra, Punjab, Tamil Nadu, Telangana, Uttar Pradesh and West Bengal.

The characteristic symptoms of SMD include mosaic patterns, bushy and pale-green plants with excessive vegetative growth, smaller leaves, stunting, leaf distortion and reduced flowering or complete

cessation of flowering. Infected plants may also exhibit reduced plant height, fewer branches, fewer flowers and shorter pods.

The term "Green Plague" reflects the striking appearance of infected plants. Although the plants remain green and continue producing vegetative growth, they fail to produce normal flowers and pods. The severity of symptoms depends largely on the pigeonpea genotype and the stage of infection.

In susceptible plants infected at an early stage, particularly before approximately 45 days after sowing, symptoms are generally severe and flowering may cease completely, resulting in complete sterility. Infections occurring at later stages tend to produce milder symptoms, including mosaic symptoms on only a few branches, reduced flowering and partial sterility. Based on symptom expression, SMD symptoms can broadly be categorized into three types:

1. Severe mosaic with complete sterility
2. Mild mosaic with partial sterility
3. Chlorotic ring spots without sterility

The disease can spread rapidly under favourable environmental conditions, making early detection and timely management essential.

The Culprit Behind the Disease

For several decades after sterility mosaic disease was first reported in 1931, its exact causal agent remained uncertain. A major breakthrough came with the identification of *Pigeonpea sterility mosaic virus* (PPSMV) as the causal agent. Subsequent molecular studies revealed that SMD is associated with two distinct viruses, namely *Pigeonpea sterility mosaic virus-1* (PPSMV-1) and *Pigeonpea sterility mosaic*

virus-2 (PPSMV-2), both belonging to the genus *Emaravirus*.

Field observations and molecular investigations have indicated differences in symptom expression associated with the two viruses. PPSMV-1 is mainly associated with chlorotic ring spots and line patterns, whereas PPSMV-2 is associated with mosaic symptoms, stunting and sterility. Mixed infections involving both viruses can result in more severe disease symptoms under field conditions.

Unlike many plant viruses that are transmitted by insects such as aphids or whiteflies, PPSMVs are transmitted by the microscopic eriophyid mite *Aceria cajani*. The mite has a relatively narrow host range and is primarily associated with pigeonpea and certain wild relatives. It is the principal known vector responsible for the transmission of SMD.

During feeding, the mite acquires the virus from infected plants and subsequently transmits it to healthy plants, thereby facilitating disease spread within and between fields.

Why Is SMD Difficult to Manage?

1. Efficient Vector-Mediated Spread

The disease is transmitted by the microscopic eriophyid mite *Aceria cajani*. Because of their extremely small size, these mites can remain unnoticed during field scouting and may be disseminated to nearby plants and fields, facilitating rapid disease spread.

2. Carryover Through Volunteer and Ratoon Plants

The virus-vector system depends on living host plants for survival and multiplication. Volunteer pigeonpea

plants, ratoon crops and susceptible wild relatives may act as sources of inoculum and vector populations during the off-season. Their presence can make it difficult to break the disease cycle.

3. Protected Microhabitats on the Plant

The eriophyid mites can survive in protected microhabitats, including areas associated with leaf trichomes and young plant tissues. Their microscopic size and protected location make complete exposure to acaricide sprays difficult.

4. Lack of a Direct Curative Treatment

Once a plant becomes infected, there is no effective chemical treatment capable of eliminating the virus from the plant. Management therefore primarily focuses on reducing vector populations, removing sources of inoculum and preventing further disease spread.

5. Delayed Recognition of Symptoms

Early symptoms may be inconspicuous and can easily be overlooked during routine field observations. By the time characteristic symptoms such as excessive branching, mosaic patterns and cessation of flowering become prominent, the infection may already be well established and may have spread to neighbouring plants.

Management Strategies

Although no curative treatment is available for plants already infected with sterility mosaic disease, an integrated disease management approach can help reduce disease incidence and delay its spread.

Chemical Management

Acaricides can be used to suppress populations of the eriophyid mite *Aceria cajani*, thereby reducing the

transmission of PPSMV. However, repeated chemical applications may increase production costs and are often impractical for resource-poor farmers, particularly because pigeonpea is predominantly cultivated under low-input production systems.

Therefore, acaricides should be used judiciously and as a component of an integrated disease management programme rather than as a stand-alone solution.

Cultural Practices

Removal of volunteer pigeonpea plants, ratoon crops and susceptible wild hosts before sowing can help eliminate potential sources of virus inoculum and vector populations. Regular field sanitation and removal of severely infected plants may further reduce disease spread.

Agronomic Practices

Agronomic practices such as modification of sowing dates, plant density, spacing, intercropping and the use of border crops have been investigated for their potential to reduce SMD incidence. However, their effectiveness may vary with location, genotype, environmental conditions and vector pressure. Consequently, these practices alone cannot provide reliable disease control.

Limitations of Existing Management Practices

Despite their potential benefits, cultural and chemical management practices face several limitations, including labour requirements, additional production costs, limited availability of inputs and difficulties in achieving timely implementation.

Therefore, the cultivation of resistant varieties remains the most reliable, economical and environmentally

sustainable strategy for the long-term management of sterility mosaic disease in pigeonpea.

The Search for Resistant Varieties

Breeding for disease-resistant varieties is considered one of the most effective and economical approaches for reducing crop losses and has received high priority in pigeonpea improvement programmes.

The search for resistance begins with germplasm screening, in which large numbers of pigeonpea lines—including cultivated varieties, breeding materials, landraces and wild relatives—are evaluated under natural or artificial disease pressure. Such extensive screening has resulted in the identification of several resistant sources that serve as valuable donors in breeding programmes.

These resistant donor lines are crossed with high-yielding but susceptible cultivars to combine disease resistance with desirable agronomic traits such as high yield, early maturity and good grain quality. The resulting progenies are evaluated over successive generations to identify plants that combine stable resistance with superior agronomic performance.

Traditionally, resistance has been assessed through field screening, in which breeding populations are exposed to disease pressure through the mite vector. Genotypes that remain free from disease symptoms are subsequently evaluated to confirm the stability and nature of their resistance.

Although conventional screening methods are effective, they are labour-intensive and time-consuming. Their effectiveness may also depend on environmental conditions, vector abundance and the availability of virulent virus isolates.

Role of Molecular Breeding in SMD Resistance

The identification of molecular markers associated with SMD resistance has significantly improved the efficiency of resistance breeding. Molecular markers enable breeders to identify plants carrying resistance-associated genomic regions at an early stage, without waiting for disease symptoms to develop.

This approach can reduce the time, labour and resources required for repeated field evaluations. Once validated, molecular markers can be incorporated into marker-assisted selection (MAS) programmes, allowing breeders to select desirable plants at early generations.

The integration of conventional breeding with marker-assisted selection has accelerated the development of SMD-resistant pigeonpea cultivars. Molecular breeding can also facilitate the identification and utilization of diverse resistance sources and support the development of cultivars with broader and more stable resistance.

Improved cultivars must subsequently be evaluated across multiple locations and growing seasons to determine the stability of resistance under diverse environmental conditions and disease pressures.

The development and adoption of SMD-resistant varieties can substantially reduce yield losses and provide farmers with a sustainable and cost-effective approach to disease management.

Future Prospects

Future research on sterility mosaic disease should focus on identifying diverse and durable sources of resistance, understanding the molecular mechanisms

underlying host resistance, and developing reliable molecular markers for efficient selection.

Advances in genomics, transcriptomics, marker-assisted selection, genomic selection and other molecular breeding approaches offer significant opportunities for accelerating the development of resistant pigeonpea cultivars.

Greater emphasis should also be placed on understanding the interactions among pigeonpea genotypes, PPSMV-1, PPSMV-2 and *Aceria cajani*. Such knowledge will be valuable for developing integrated disease management strategies and identifying resistance that remains effective against diverse virus populations and vector pressures.

The combination of resistant cultivars with appropriate cultural practices and judicious vector management is likely to provide the most sustainable strategy for minimizing the impact of SMD.

Conclusion

Sterility mosaic disease continues to pose a major challenge to sustainable pigeonpea production because of its widespread occurrence, complex virus-vector

relationship and the absence of effective curative control measures. The identification of *Pigeonpea sterility mosaic virus-1* and *Pigeonpea sterility mosaic virus-2*, together with improved understanding of their transmission by the eriophyid mite *Aceria cajani*, has significantly advanced research on this disease.

Although cultural practices and vector management can help reduce disease incidence under certain conditions, the development and deployment of resistant varieties remain the most practical, economical and environmentally sustainable strategy for long-term management.

Advances in conventional breeding, supported by molecular markers and other genomic tools, have accelerated the identification and incorporation of resistance into improved pigeonpea cultivars. Continued efforts in resistance breeding, integrated disease management and the application of modern molecular technologies will be essential to minimize yield losses and ensure sustainable pigeonpea production for future generations.

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