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A Review On Sesame Witches - Broom

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ABSTRACT

Phyllody disease, a significant threat to sesame (Sesamum indicum L.) cultivation is caused by phytoplasmas affecting plant phloem leads to severe yield losses is also sometimes called as sesame witches'-broom [47]. Characterized by floral malformations where flowers transform into leaf-like structures, virescence (green pigmentation of floral parts) and sterility, drastically impacting seed production. The disease prevalent in Africa, Asia, and parts of Europe is primarily transmitted by insect vectors, notably leafhoppers (Orosius albicinctus). Phyllody incidence is also found in different districts of Bihar at different crop stage starting from germination, flowering and harvesting during both summer and Kharif season. Phytoplasmas responsible for phyllody belong to various ribosomal groups, predominantly the 16SrII group (peanut witches'-broom phytoplasma). Research gaps persist in understanding vector dynamics, phytoplasma-host interactions, and the development of resistant or tolerant varieties. Early detection is crucial, with diagnostic techniques such as polymerase chain reaction (PCR). The yield contributing characters of sesame plants, i.e. plant height; number of capsules per plant, and test weight were adversely affected due to phyllody. Management strategies emphasize an integrated approach. Cultural practices include the removal of infected plants, use of disease-free seeds, and altering planting dates to avoid peak vector activity. Chemical control, though limited, involves insecticides targeting vectors. Biological control strategies focus on fostering natural predators of vectors. Additionally, breeding for resistant or tolerant sesame varieties offers a promising, sustainable solution, though it remains challenging due to the genetic complexity of resistance traits. This review produces the knowledge on the etiology, transmission, epidemiology, symptomatology, screening and management of phyllody disease in sesame which creates awareness and preparedness prior to onset of disease.

Keywords: *Phyllody, Sesame, Etiology, Epidemiology, Symptomology, Yield, Witches Broom, Bihar*

INTRODUCTION

Sesame is called as the "Queen of oilseeds" because of its excellent qualities of the seed, oil and meal. Sesame is highly nutritive contains protein (20%) and edible oil (50%) and contains high amount of saturated fatty acids (47% oleic acid and 39% linolenic acid) [24] [49] and its oil contains an antioxidant called sesamol which imparts a high degree of resistance against oxidative rancidity. The demand for sesame seeds has increased in the last two decades due to high oil quality, protein content, antioxidant content, and wide adaptability in extreme climatic and edaphic environments [26]. The genus, *Sesamum* comprises 30 "accepted" species and 17 species with "unresolved" status [18]. The basic chromosome numbers for the family, Pedaliaceae are x= 8 or 13, with some tetraploids and octaploids [19]. The growth habit of sesame is indeterminate, although it is considered an annual crop. This sesame genome size is about 350Mb.It is also Known as til (Hindi), tal (Gujarati), til (Panjabi) nuvvulu (Telugu) ellu (Tamil) and ragi (Oriya) in different til growing in parts of India. Sesame is one of the earliest domesticated crops, and the crop is still essential, particularly for farmers in Africa and Asia. Africa as the only place of origin has been debated, and the Indian subcontinent has been suggested as the first place of sesame domestication. Sesame is ranked ninth among the top 13 oilseed crops which make up 90% of the world production of edible oil [2]. The top producing countries of sesame are Tanzania, Sudan, Myanmar, India, and China. In Indian states sesame is grown in Rajasthan, Madhya Pradesh, Uttar Pradesh Andhra Pradesh, Gujarat, Maharashtra, Tamil Nadu, Orissa and Bihar. By 2030, sesame oil consumption is estimated to be approximately 100 MMT globally [47]. The branched root system in sesame contributes significantly to its soil improving properties and is the reason for its ability to act as a super drought-tolerant crop. Sesame is a low yielding crop, which is mainly due to its common problem with capsule shattering. The chemical composition of the white sesame cultivar showed relatively high protein content (25.18%). The sesame is rich in tryptophan and methionine. Sesame seed consumption will increase plasma tocopherol and enhances vitamin E activity, which is reported to prevent cancer and heart diseases. Chlorosesamone extracted from roots of sesame used as a source for biodiesel. It is also used in paint formulation due to its unique semidrying property [6]. The meal after oil extraction contains 30–35% protein that makes a rich feed for poultry and livestock. The presence of natural antioxidants such as sesamin, sesamolin, gamma tocopherol and sesamol, prevent the rancidity of oil.

A serious and devastating disease affecting sesame (*Sesamum indicum* L.), a crucial oilseed crop cultivated mostly in tropical and subtropical areas is phyllody. Phyllody associated with phytoplasma is the major limiting factor affecting cultivation, described more than 100 years ago, first recorded in 1908 at

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Mirpur Khas, Pakistan [50]. Phyllody disease has also been reported in the Asian and African countries, including Burkina Faso, Ethiopia, and India, Iraq, Israel, Mexico,and Myanmar, Nigeria, Oman, Pakistan, Sudan, and Taiwan, Tanzania, Thailand, and Turkey, and Venezuela and Uganda [38]. Phyllody disease is not restricted to the cultivated species of *Sesamum*, but it has been also observed in *S. alatyun*, *S. indicatum* [33], *S.occidentale* and *S.radiatum* [23]. In Phyllody, flower virescence was recorded in all the species of *Sesamum* existing in India with varying degrees of susceptibility. *S. alatum* is the least susceptible among the different species. The phytoplasma strain associated with phyllody of *S.indicum* was identified as*'Ca.Pasteris' where as in other species such as S. malabaricum, S. mulayanum, S. prostratum, S. laciniatum, S. alatum and S. radiatum,* a strain of *'Ca. Paustralasia'* was identifed [44].

A disease of plants that causes aberrant development of flowers by the conversion of floral components into structures resembling leaves. This disease harm sesame which can negatively influence the quality and productivity in several areas, including Bihar. Phyllody also reported indifferent sesame growing districts of Bihar and vary in intensity based on a number of factors including the local environment, farming practices, and vector population. Since sesame phyllody is a destructive disease and it is transmitted by leafhoppers it is important to know the suitable time for cultivation of sesame and the effect of meteorological parameters on disease incidence for planning management strategies to get the optimum yield. Different researchers attempted intra-and inter-specific crosses in sesame for phyllody- resistance and it revealed that disease resistance is governed by one dominant (wild species) and one recessive (cultivated species) gene [38]. The decreased leaf relative water content and chlorophyll content, as well as the limited photosynthetic capacity, and consequently hindered growth of sesame. The leaves on crop plants are well-known source organs because of their photosynthetic functions; however, the leaves on witch's broom shoots have limited photosynthetic capacities [43]. This could be the main reason for the weakened seed and oil yield and could contribute to the attributes of phytoplasma-infected sesame crop plants. Other reasons could include the flower deformation (abnormal zygomorphic flowers forming instead of normal actinomorphic flowers), the irreversible loss of flower fertility, and the presence of seedless capsules induced by hormonal imbalance and the damage caused by the effectors secreted by pathogenic phytoplasma cells [48]. The yield contributing characters of sesame plants, i.e. plant height; number of capsules per plant, test weight was adversely affected due to phyllody. There was reduction in number of capsules, plant height, and yield and test weight in infected plant in comparison to healthy plants due to the phyllody disease [41]. 18 per cent reduction in oil content in case of phyllody affected sesame plants [52] [20]. Sesame phyllody reduced plant yield, test weight, germination percentage and oil content of seeds [52]. The 25 percent transformation of the productive growth of plant into phyllody, it caused 39.73 per cent loss in seed yield of infected sesame plants [21].

Phyllody and witches'- broom in diferent species of Sesamum depicted with healthy plants. a. *S. alatum*; b. *S. indicum*; c. *S. malabaricum*; d. *S. mulayanum*; e. *S. radiatum*; f. *S. laciniatum*; g. *S. prostratum* [44].

ETIOLOGY AND TRANSMISSION

Phyllody disease is caused by phytoplasmas, which belong to the class Mollicutes. In *S. indicum*, four phytoplasma ribosomal groups,16SrI,16SrII,16SrVIand16SrIX have been reported in association with phyllody [39]. This disease is associated with the presence of sesame phyllody phytoplasma transmitted by the leaf hopper *Orosius albicinctus* that been reported as vector from Iran [12]. Recently also the leafhopper *Hishimonus phycitis* has been reported from India as a vector of the disease [27] [31]. Three known mechanisms introduce phytoplasmas into the vulnerable tissue of host plants:

(a) vegetative propagation or grafting of infected plant material, (b) vascular connections made between infected and non-infected host plants by parasitic plants such as dodder (*Cuscuta spp.)* [10] [16], and (c) vector insects feeding on non-infected host plants. These phytoplasmas are obligate parasites of plant phloem tissue and are transmitted by sap-feeding insect vectors, primarily leafhoppers. The transmission cycle involves the insect vector acquiring the phytoplasma from infected plants and subsequently spreading it to healthy plants during feeding. When insects bite diseased plants, phytoplasmas proliferate in the salivary glands of the vector insects and then spread into the phloem of healthy plants by biting them [44]. Phytoplasmas are classified into various groups based on their 16S rRNA gene sequences. With molecular tools based on nested polymerase chain reaction (PCR)assays, sequencing, Restriction profiling, and phylogenetic analysis, phyllody-affected sesame plants collected from nine different states of India were found to be infected by phytoplasmas belonging to two 16Sr groups, namely 16SrI and II. Two subgroups of phytoplasma –16SrI-B and 16SrII-D— were prevalent in symptomatic sesame samples collected from North India, whereas phytoplasma of only the 16SrII group was found in South India [39]. The phytoplasma associated with sesame phyllody disease is part of the 16SrII group, commonly referred to as the peanut witches'-broom group. *Catharanthus roseus* is a model perennial herbaceous horticultural ornamental and medicinal plant of the genus *Catharanthus* in the *Apocynaceae* family used to study the pathogenesis of phytoplasma diseases and the interaction between phytoplasma and plants. Phytoplasma titers can accumulate very high in *C. roseus*, where the pathogen can be easily maintained. Therefore, it is suitable as an alternative host to preserve phytoplasmas from different plant host [8]. Screening was done after making an effort to transmit the disease from periwinkle maintained nearby as an alternate host to the healthy sesame plants through dodder (*Cuscuta campestris*) transmission [36]. Dodders were grown from seeds and placed on periwinkle, a donor as well as reservoir of phytoplasma. The dodders were used as the bridge between the recipient host (healthy sesame) and the donor plant. In the laboratory, most phytoplasmas are transmitted from the original host plants to *C.roseus* through dodders and then transmitted between *C.roseus* by grafting [8]. The transmission of sesamum phyllody by grafting was reported [36]. For grafting inoculation four weeks old sesamum plants were used for the graft inoculation of phytoplasma inoculum under insect proof greenhouse conditions [3]. The symptoms were minced using a mortar and pestle in 0.02M phosphate buffer (pH-7.4) to create the phytoplasmal inoculum for sap transfer. The sap was purified using a two-fold muslin cloth, and the young seedling leaves were injected with it after being previously abraded with 500 mesh carborandum powder. The extra inoculums were immediately removed from the infected leaves by gently washing them with stream water. Up to the onset of symptoms, every infected plant was kept in an insect-proof cage house with appropriate labelling [34].

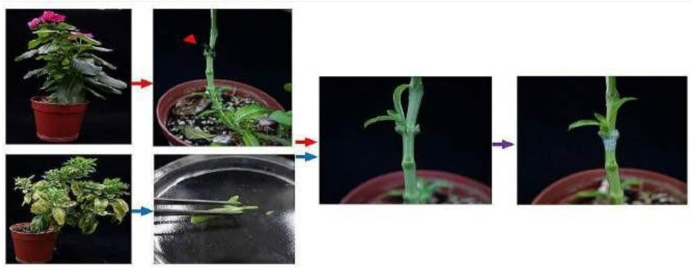


Diagram of grafting technique- The disease scions from phytoplasma-infected plants were cut into a 'V' shape and inserted into the slanting cut made on the healthy stock plants of periwinkle. The red arrow head indicates the grafting site of the plant [7].

Symptoms of sesame phyllody after inoculation of phytoplasma using dodder as bridge and periwinkle as donor [38].

EPIDEMIOLOGY

The epidemiology of phyllody disease is influenced by several factors, including the prevalence and activity of insect vectors, environmental conditions, and the presence of alternative host plants. Warm and humid conditions typically favor the proliferation of both phytoplasmas and their vectors. Consequently, regions with such climatic conditions often experience higher incidences of phyllody disease.

During the *"kharif"* season, maximum temperature and diurnal variation were positively correlated while wind speed, total rainfall and number of rainy days were negatively correlated with the disease incidence. Considering various parameters, the disease could be predicted up to 97% during summer season. And up to 95% during the *"kharif"* season. The disease adversely affected the growth and yield attributes of sesame, reduced the oil content and deteriorated the oil quality. In earlier studies the highest incidence of sesame phyllody disease was observed in crops sown in mid-July and the lowest in crops sown towards the end of August [23] [29] [49]. The sesame crop sown during end of May to mid of June always exhibited higher incidence as compared to that sown from June or early July in India [30]. Phyllody can be caused by several factors, including:

1. Warm and Humid Climate: Phyllody is often associated with areas that have warm temperatures and high humidity, which can favor the growth and transmission of pathogens responsible for the disorder. In the summer season, the population of *H. phycitis* and maximum and minimum temperature, day and night temperature, relative humidity (morning) were positively correlated whereas wind speed and sunshine hours were negatively correlated with the disease incidence [31].

2. Presence of Vector Insects: Some phytoplasmas that cause phyllody are transmitted by insect vectors such as leafhoppers. The lowest leafhopper population was registered on the crops sown in February, the population increased in the crops sown on the first week of August and then started decreasing [31]. Maximum temperature and relative humidity were positively correlated with the insect vector population [9]. The influence of weather variables on vector borne virus diseases stated that the vector population and activity were highly influenced by the weather [15].

3. Genetic Factors: Some plant varieties may be more susceptible to phyllody due to genetic predispositions. All seven species of sesame is found to be susceptible. The lowest incidence of phyllody was found in *S.alatum* (0-6%),followed by S. laciniatum (11-17%) and *S. prostratum* (16-27%).The incidence of phyllody in *S.indicum*, *S.malabaricum*, *S.mulayanum* and *S. radiatum* was between 44-68% [43].

4. Crop Cultivation Patterns: The specific cropping patterns in Bihar, including the types of crops grown and their susceptibility to phyllody, can also influence the prevalence of the disorder. Likewise, during *kharif* season which is the peak season for cultivation of rice which ultimately in creases leaf hopper population.

5. Growing Season: Phyllody can manifest at different stages of crop growth majorly after initiation of flowering, depending on when the crop is exposed to the pathogens and environmental conditions conducive to disease development especially in mid *Kharif* season where the humidity and temperature favours the incidence of leafhopper, the vector of Phytoplasma. Highest phyllody incidence in second fortnight of December and fairly high rate in second fortnight of october to march [35].

SYMPTOMOLOGY

The sesame plants infected by sesame phyllody phytoplasma at earlier growth stages developed symptoms like, yellowing of the leaves, stunting and reduction in leaf size, whereas infection in the later stages resulted in the development of symptoms like virescence, flower proliferation, phyllody and cracking of pods. Some plants infected at a later stage also produced pods which were shriveled and smaller in size. The variations in symptom development with the age of the plant at infection stage were also reported earlier [4] [30]. The symptoms start with vein clearing of leaves. The disease manifests itself mostly during flowering stage, when the floral parts are, transformed into green leafy structures, which grow profusely. The flower is rendered sterile [34]. Symptoms of diseased plants may vary with the phytoplasma, host plant, stage of the disease, age of the plant at the time of infection and environmental conditions [22]. Phyllody, an important disease of sesame is caused by a pleomorphic mycoplasma-like organism (phytoplasma) and transmitted by leaf hopper [50]. The affected plants become stunted and the floral parts being modified in to leafy structures bearing no fruits and seeds causing yield loss up to 33.9 per cent [1]. The symptoms of phyllody disease in sesame are distinct and often easily recognizable. Key symptoms include:

1. Floral Abnormalities: The primary indicator is the conversion of flowers into leafy structures. Petals, stamens, and pistils may transform into green leaf-like structures, rendering the flowers sterile.

2. Stunted Growth: Infected plants often exhibit reduced growth and vigor compared to healthy plants.

3. Leaf Chlorosis: Leaves may turn yellow and show signs of chlorosis.

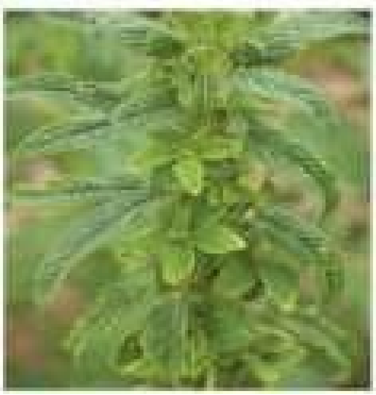
4. Proliferation of Axillary Shoots: There may be an abnormal increase in the number of axillary shoots, giving the plant a bushy appearance.

5. Reduced Pod Formation: Due to the sterility of flowers, pod formation is significantly decreased, leading to a substantial drop in seed yield.

Diagnosis of phyllody disease can be achieved through visual inspection of symptoms. However, for definitive identification, molecular techniques such as polymerase chain reaction (PCR) are employed to detect the presence of phytoplasma DNA.

PHYLLODY SYMPTOMS

Floral Virescence



Witches Broom

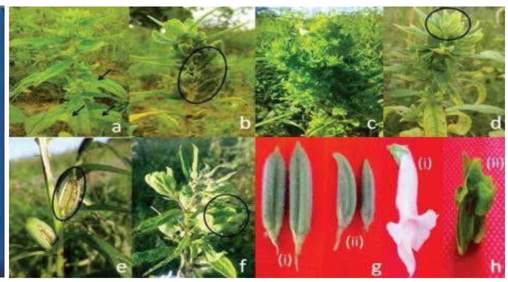
Floral Proliferation

Germinationofs eedsincracked capsule

Dark Exudate Foliage Floral Parts

Short Internodes With Yellow Twisted reduced leaves

Shoot Apex Fasciation



Akhtar et al.,2009

a)Yellowing of leaves, b) flower virescence, c) flower proliferation, d) phyllody, e) cracking of pods, f) shoot like the structure of ovary; g): healthy pods (i) and infected pods (ii); h) healthy flowers (i) and infected flowers (ii)[31].

SCREENING METHOD

Phyllody disease is screened by using the Disease scoring scale (0-6). The scale is available for scoring of phyllody disease [3]. The Formula of percent disease incidence is the ratio of number of plants infected to the total number of plants multiplied by hundred [3].

DISEASESCALE FOR SESAMUM PHYLLODY

Rating	PercentDiseaseIncidence	DiseaseReaction
0	NoSymptomsinanyplant	HighlyResistant
1	0.1-10%	Resistant
2	10.1-20%	ModeratelyResistant
3	20.1-30%	Tolerant
4	30.1-40%	ModeratelySusceptible
5	40.1-50%	Susceptible
6	Morethan 50%	HighlySusceptible

$$\text{Per cent Disease Incidence (PDI)} = \frac{\text{Number of infected plants}}{\text{Number of plants observed}} \times 100$$

Akhtar et al.,2013

STRATEGIES TO MITIGATE PHYLLODY INFECTION

Sesame phyllody pathogen against insecticides, combination of phytoextract + insecticides and combination of antibiotic+ insecticides as seed treatment and foliar spray have been proved. Seed treatment with Imidacloprid 17.8% SL @ 3 mL kg-1 seed + spray of Imidacloprid 17.8% SL @ 2 mL 10 L-1 and Thiomethoxam 25% WG @ 2g 10 L-1 were found most effective by recording minimum per cent disease incidence and maximum yield of sesame and recommended to farmer community for the management of sesame phyllody [37].

Controlling phyllody can be challenging once it has occurred, but several strategies can help manage and prevent its spread:

1. Use of Disease-Free Seeds: Start with certified disease-free seeds and healthy seedlings to reduce the risk of introducing phytoplasma or viruses.

2. Crop Rotation: Avoid planting sesame in the same location year after year to minimize the buildup of pathogens in nearby collateral host where it persists during non-crop season.

3. Sanitation: Remove and destroy infected plants promptly to prevent the spread of the disease to healthy plants. This includes weeds, as they can harbor phytoplasmas.

4. Vector Control: Some phytoplasmas are transmitted by insect vectors such as leafhoppers. Use appropriate insecticides to control these vectors. Minimum leaf hopper population (0.70 "percent") was observed in seed treatment followed by spray (ST imidacloprid+ spray of imidacloprid + spray of tetracycline HCL) [52].

5. Resistant Varieties: Where available, choose sesame varieties that are known to have some resistance or tolerance to phyllody and which falls under 0-10% and 10- 20%. Resistant and moderately resistant respectively. Use of resistant genotype is considered as an economical and durable method for controlling this disease apart from chemical application.

6. Environmental Management: Ensure optimal growing conditions for sesame plants, including balanced nutrition and adequate water supply, to minimize stress factors that can contribute to phyllody.

7. Monitoring and Early Detection: Regularly inspect plants for symptoms. Early detection can help in implementing control measures before the disease spreads. Earlier stage at the flower initiation stage leaf virescence and leaf curling symptoms can be identified and phyllody incidence can be declared at molecular level testing.

8. Natural host reservoirs: Phytoplasma have many hosts range. The most commercially significant disease affecting sesame is phyllody, which was once thought to be brought on by a virus but was later identified as mycoplasma-like organisms (MLO) and, more recently, as phytoplasma [11] A new report of a phytoplasma with phyllody and little leaf disease of periwinkle in Madhya Pradesh [13] and parthenium (*Parthenium hysterophorus*) [14].

9. Chemical treatment -Seed treatment with Imidacloprid 17.8%SL@3 mLkg^{-1} seed followed by its two foliar sprays of @150m Lha-1 were most effective [37]. Seed treatment with Imidacloprid 70WS (7.5gkg-1seed) +foliar spray of Imidacloprid 17.8SL (0.25 mL L^{-1}) gave a minimum incidence of leaf hopper, mirid bug, white fly and sesame phyllody [28].

CONCLUSION

The production of sesame is seriously threatened by phyllody disease, which makes it imperative to have a thorough grasp of its signs, causes, modes of transmission, and preventative measures. Overall, phyllody's management can influence on the expense of cultivating sesame which emphasizes the significance of early control measures where combined with cultural methods, the use of disease-resistant cultivars where available, varying date of sowing of crop with other *kharif* crops which act as host for the phytoplasma vector, increased vicinity of cropped area, vector control measures can help minimize these expenses and lessen the overall financial strain on farmers. Future developments in molecular technology and continued research on phyllody disease is crucial for developing effective management strategies which include understanding the genetic makeup of phytoplasmas can provide insights into their pathogenicity and interactions with host plants and vectors, studying the biology and ecology of insect vectors can help in developing targeted control measures, identifying and characterizing resistance genes in sesame can facilitate the development of resistant varieties through conventional breeding and biotechnological approaches and improving diagnostic techniques for early and accurate detection of phytoplasmas can enhance disease management efforts lead to more sustainable production of sesame and more efficient management.

FUTURE PROSPECTS

Sesame resistance-related genes offer a fresh example of how genes interact with diseases. Compared to sesame cultivars, wild relatives of sesame are far more resistant to disease. Sesame phyllody is a serious disease, but research on it is difficult due to the huge genome size and high level of polyploidy in wild relatives [53]. On the other hand, sesame (*S. indicum*) is a promising model plant for research on oil production and disease resistance due to its tiny diploid genome, increased oil content, and fewer connected genes. More genetic variety would be revealed by the creation of sesame hybrids with prospective features. Therefore, in order to enhance the yield of sesame, hybrid development initiatives should be intensified. It is necessary to search through the vast amounts of sesame germplasm found in various gene and seed banks for characteristics or genes that would enhance seed quality and boost sustainability under challenging environmental circumstances. Sesame research is required to enhance plant design, disease & pest resistance, and yields. Breeders should utilize the unique characteristics that many wild sesame species possess, such as resilience to biotic and abiotic stress and other significant agronomic qualities, to create sesame cultivars. At the national and international levels, a clear program for dispersing sesame seeds created via such intensely coordinated activities ought to be considered.

Conflict of interest: The authors declare that they have no conflict of interest.

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