



REVIEW ARTICLE

Gummy stem blight in cucurbits: Pathogen biology, host range and management strategies

Ganaparapu Radhika¹, Murugavel Kavitha^{1*}, Thangamani Chinnusamy¹, Sudha Appusami², Vanitha Shanmugam², Manivannan Narayana³ & Indu Rani Chandrasekaran¹

¹Department of Vegetable Science, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

²Department of Plant pathology, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

³Department of Genetics and Plant Breeding, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

*Correspondence email - kavitha.m@tnau.ac.in

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Abstract

Gummy stem blight (GSB) is an emerging and serious disease affecting cucurbitaceous crops. It is caused by three closely related fungal pathogens: *Stagonosporopsis cucurbitacearum*, *S. citruli* and *S. caricae*. GSB has a wide host range among the cucurbitaceous family across the world. About 50-80 % yield losses were reported where the continuous cultivation of cucurbits is undertaken. Symptoms include water-soaked lesions on young leaves, chlorosis, splitting of cortical stem tissues and dark brown discoloration in mature fruits. The pathogen also forms chlamydospores-brown, unicellular and spherical in shape. Molecular techniques involving microsatellite markers and internal transcribed spacer (ITS) regions were used for molecular characterization of *Stagonosporopsis* spp. Management of GSB is still in a primitive stage; even when integrated methods are followed, they are still ineffective, specifically during rainy seasons. So, development of genetic resistance in the plants can be a good approach for minimal incidence. This review will provide insights on diversity, host range, life cycle and spread of *Stagonosporopsis* spp.; it also gives an emphasis on development of resistant cultivars. Genomic and molecular approaches (i.e., marker-assisted selection) will be the quick and accurate ways for selection and improvement of resistant lines.

Keywords: ascospores; conidia; Didymellaceae; integrated management; molecular characterization; resistant breeding; *Stagonosporopsis* spp.

Introduction

Cucurbitaceous crops represent a significant group of vegetable worldwide, which include cucumber, watermelon, muskmelon, pumpkin and various gourds (1, 2). About 95 genera with 1000 species are present in the cucurbitaceous family (3). According to FAO (2021), global production includes 101.6 million tonnes (Mt) of watermelon, 91.3 Mt of cucumber, 28.5 Mt of melons and 28 Mt of squashes and pumpkin (4).

Cucurbitaceous crops are nutritious because they provide beneficial vitamins and minerals (5). Beyond their nutritional value, cucurbit crops have long been used in traditional medicine due to their rich phytochemical content (6). Both cultivated and wild species exhibit therapeutic properties, including anti-inflammatory, anti-diabetic, anti-diarrheal and diuretic effects (7).

Cucurbit crops are susceptible to wide range of pathogens, including fungi, oomycetes, bacteria, phytoplasmas, viruses, viroids and nematodes (8). Among these, fungal infections cause significant economic losses due to yield and quality reduction (8, 9). Emerging fungal diseases

in cucurbits include GSB, Downy mildew, Cercospora leaf spot, Anthracnose, Fusarium wilt and fruit rot (10). GSB is particularly severe and widespread and when it affects fruits, it is commonly referred to as black rot (1).

GSB is caused by three closely related species of *Stagonosporopsis*: *S. citruli*, *S. caricae* and *S. cucurbitacearum* formerly classified under *Didymella bryoniae* and later changed to *Stagonosporopsis* spp. (4, 11-13). The pathogen produces reproductive structures (pycnidia and pseudothecia) on infected leaves and other aerial plant parts, including petioles, vines, stems, tendrils and pedicels (14). Favourable environmental conditions, particularly high temperatures and rainfall, significantly promote GSB development and resulting in about a 17-43 % decrease in yield and fruit quality. The pathogen can survive in the absence of the host by persisting in soil, weeds and seeds (4, 15).

Contact fungicides such as mancozeb and chlorothalonil, along with other systemic fungicides, have been used to manage GSB (16). There are significant concerns about practicality of fungicides regarding environmental safety and acquired resistance of the

pathogen to fungicides (17, 18). Sole reliance on chemical control, particularly during the rainy season, has proven insufficient (15). Under these circumstances, breeding for resistant cultivars presents a sustainable and effective alternative (19).

This review discusses emerging GSB disease in cucurbits. It is one of the most devastating diseases affecting cucurbits worldwide, causing significant yield losses and quality reduction. Despite numerous studies, the complex interactions between different *Stagonosporopsis* species and cucurbit hosts, as well as recent advances in molecular characterization and disease management, are scattered across various publications. Therefore, a comprehensive review is needed to consolidate the current understanding of the pathogen biology, host range, molecular identification, resistance mechanisms and management practices. To conduct this review, a comprehensive literature search was performed using Google Scholar. Keywords such as “gummy stem blight,” “cucurbits resistance,” specific cucurbit crop names, “*Stagonosporopsis*,” and “molecular characterization” were used to retrieve relevant articles. Studies were selected that focused on the pathogen’s biology, host range, disease resistance and management strategies. Priority was given to recent research to ensure up-to-date coverage of the topic. Duplicate and irrelevant articles were excluded. This approach enabled a focused and thorough review of the existing knowledge on gummy stem blight in cucurbits.

Impact of the GSB on production

Gummy stem blight (GSB) affects cucurbitaceous crops globally and has been documented in India across several species, including wax gourd, bitter gourd, chayote, cucumber, muskmelon and ridge gourd (20). In watermelon it was first reported at IIHR Bengaluru, India, where the year-round cultivation of watermelon (*Citrullus lanatus*) is being done. Previously it has not been documented in this location, but in recent days GSB has become a hazard to watermelon production (20). Since evolving seed-borne diseases are major limiting factors in the seed production system of vegetables, GSB is a major problem in cucurbit seed production as it is transmitted through seeds and increasing the cost of production in terms of control measures (10, 21). Severe disease outbreaks cause plant drying, which leads to

Table 1. Yield/economic losses due to GSB in cucurbits

Crop	Economic/yield loss (%)	References
Watermelon	40 %	(23)
Musk melon	30-60 %	(24)
Cucumber	80 %	(25)

sudden death of the plants results significant decrease in production (22) (Table 1).

The incidence of GSB was more prevalent than that of other foliar diseases in the field. It was also stated that between 2013 and 2016, the Percent Disease Index nearly reached 75 % during the wet season. The dry season reached around 68 %, which is less than the rainy season (22).

Geographical distribution and economic importance

Gummy stem blight (GSB) is a globally distributed and economically significant disease of cucurbits (11). It was first recorded in 1823 on an unidentified cucurbit in Sweden and later reported in India on chayote in Mysore (26). Since then, it has spread to other cucurbit crops such as cucumber, bitter gourd, ash gourd, muskmelon and ridge gourd, which collectively contribute significantly to the country’s vegetable production (13). Table 2 lists initial country - level reports of GSB on various cucurbit hosts. At present the disease (GSB) is said to be noticed in 37 different species of cucurbits with 21 different genera on every continent where cucurbits are grown (27). *S. citrulli* was the most common species with broad geographic distribution and *S. caricae* was also

Table 2. Incidence of GSB in different countries

Country	Year	Name of the crop	References
Germany	1869	White bryony	(29)
Italy	1885	Musk melon	(29)
Usa (Delaware)	1891	Watermelon	(29)
France	1891	Cucumber	(29)
India	1967	Chayote	(26)

similarly widespread. However, *S. cucurbitacearum* has only been noticed in temperate areas (28).

Host range

Stagonosporopsis spp. occurs across the world and infects 21 genera with 37 species of the Cucurbitaceae (27). But, as per 2011 report by Keinath the host range was about 12 genera with 23 species, this indicates the significant extension in host range of the pathogen to 14 new species (27, 30). Among all cucurbit hosts disease severity was found to be highest in watermelon than cucumber, musk melon and squash (21) and watermelon and musk melon are most susceptible (27).

While bottle gourd was historically considered resistant or unaffected, recent outbreaks have been reported in India from Uttar Pradesh, Karnataka and Andhra Pradesh, indicating an emerging threat to this crop (18, 20, 30, 31).

Three species of *Stagonosporopsis*: *S. citrulli*, *S. caricae* and *S. cucurbitacearum* overlaps in host range and geographical distribution (4). *S. cucurbitacearum* and *S. citrulli* were more aggressive on cucurbits, but *S. caricae* pathogenic to cucurbits but aggressively infects the papaya (32).

Symptoms

Stagonosporopsis spp. infects cucurbit crops at all growth stages, with visible symptoms typically 3 to 12 days after infection (14, 16). Symptoms may appear before and after transplantation in the field. Early symptoms on seedlings include discoloration to yellow with tissue decay on the seed leaves (cotyledons) and prior to the development of chlorosis or necrosis, the tissue may appear as water-soaked lesions on leaves (16). The disease spread from the leaf margin to inside the leaf lamina and invaded the entire leaf (20). On stem initial symptoms appeared as brown to dark brown spots that grew about 1 to 20 (mm) in length with an oval to elongated shape (33). GSB infections produce a wide range of symptoms and it is referred to as black rot on cucurbit fruits. Infections occur both on the internal and external surfaces of the fruit. Rotting of fruit starts from the inside of the blossom



Fig. 1. Symptoms of GSB on different plant parts.

end and becomes more pronounced as it moves to the fruit exterior, in some cases, malformed tapering at the fruit tip is observed (34) (Fig. 1).

In muskmelon, symptoms start as water-soaked lesions that turn into brown or greenish yellow; eventually forming blighted patches as spots merge. In watermelon, angular water-soaked lesions are typical on leaves, while necrosis and gummy exudates may be observed on stems (21) (Table 3).

Pathogen

Gummy stem blight (GSB) is caused by a complex of three phylogenetically distinct fungal species: *S. cucurbitacearum*, *S. citrulli* and *S. caricae*. These species belong to the phylum Ascomycota, class Dothideomycetes and family Didymellaceae. Despite their genetic differences, all three exhibit indistinguishable morphological features (11).

Historically, the pathogen was classified under the genus *Didymella*, that established by Pier Andrea Saccardo in 1880, with the species later named *Didymella bryoniae* by Heinrich Rehm in 1881 (4). This name is now considered as a synonym for the current *Stagonosporopsis* classification. Among the three, *S. citrulli* is the most widespread and

aggressive species (30) (Table 4).

Molecular characterization

Pathogen profiling and molecular tests have become crucial for developing effective management strategies (35). Also, *Stagonosporopsis* spp. have undistinguishable morphology but are genetically distinct, thus, employing microsatellite markers based on polymerase chain reaction can be an accurate way for identification of the pathogen (11). Microsatellite markers of Db01, Db05 and Db06 DNA regions, ITS-1, ITS-4 primers and TUB_T1_F, TUB_T22_R primers of β -tubulin (TUB) DNA region; DNA sequence data help to distinguish *Stagonosporopsis* spp. ITS-1, ITS-4 primers are of widely used and considered to be universal primers (28, 33, 38) (Table 5).

Life cycle

Stagonosporopsis spp. endures high temperatures by growing on crop residues (18). The species of *Stagonosporopsis* yield both asexual fruiting bodies called pycnidia and sexual fruiting bodies called pseudothecia (8). Asexual spores (conidia) move short distances by rain and runoff, while sexual spores (ascospores) are airborne and may move far (36). Ascospores have the ability to travel about 366 m. Thus,

Table 3. Symptoms of GSB on different plant parts

Plant part	Symptoms	References
Leaf	Dark discolouration on leaf margin	(16, 20)
	Water-soaked lesions	
	Development of necrosis	
Stem	Initial symptoms brown to dark brown spots on stem	(33)
	Waxy water-soaked lesions on cortical tissue	
	Gummy exudates and presence of fruiting bodies on lesions	
Fruit	Fruit rot at blossom end with brown discolouration and moves towards fruit tip exterior	(34)
	Development of fruiting bodies	
	Dried and blackened tissue	

Table 4. Morphological characterization of *Stagonosporopsis* spp.

Morphological parameter	Characteristics	References
Mycelium	• White and hairy aerial mycelium • Black in colour	(35)
Pycnidia	• Globose to sub globose in shape • Ostiolate • 120-180 µm in diameter	(33, 35)
Conidia	• Smooth, round ended and cylindrical in shape • Aseptate/septate (mono or di septate) with slight constriction • Average length and width of conidia was 8 × 3 µm	(21, 35, 33)
Chlamydospores	• Unicellular • Spherical or ellipsoid in shape • Light brown in colour • 7.7-13 × 6-12 µm in size • Single or 5-10 in chain	(33)

Table 5. Different primers used for molecular characterization

Primers			DNA sequence	References
Microsatellite marker primers	Db01 (DNA regions)	Db01_F	CGGTCCGGTCAACCTACTAC	(28)
		Db01_R	CACGCCAGCAAATCTCACTA	
	Db05 (DNA regions)	Db05_F	TATGACGTTGGGCAAGTGAG	
		Db05_R	TTTGCTGGGATGGTGTGTA	
	Db06 (DNA regions)	Db06_F	GGTGACATCTTGCCTGAATG	
		Db06_R	TGGTTGTTTGGTTGTTTGA	
ITS primers	ITS-1		5'-TCC GTA GGT GAA CCT GCG G-3'	(33, 38)
	ITS-4		5'-TCC TCC GCT TAT TGA TAT GC-3'	
(TUB)	TUB_T1_F		5'-TCTGGATGTTGTGGGAATCC-3'	(28, 33)
	TUB_T22_R		5'-ACCCGCTGAACCTAAGC-3'	

ascospores are considered to be the primary inoculum for diseases and rapidly spread to the other fields (37). Large masses of conidia are released by black pycnidia (33). Upon infection, pseudothecia may grow before pycnidia and within the 7 days, ascospores were released from pseudothecia (37). Germination of the spores forms the appressoria; help to penetrate the host plant through the intact leaf surface (cuticle); later the pathogen spreads in the host plants and damages the plant tissue (38).

Survival and spread

GSB spreads via air, soil and seed, with wind and splashing water facilitating rapid transmission in cucurbit-growing regions (18, 31). Ascospores, the primary inoculum, are airborne and capable of traveling long distances, while conidia, embedded in sticky matrices, are suited for short-range dissemination through rain splash (16) (Fig. 2).

In India, *D. bryoniae* was discovered in muskmelon crops as a seed-borne disease that spreads from seed to seedling; again, inoculum gets transmitted from plant to seed (39). With the advent of the free trade regime during the last two decades, there is an increased movement and exchange of seed material. This has probably led to the arrival of this new disease in Bengaluru, India, where the vegetable seed business is active (20). Field-grown cucurbits were also

infected by GSB from grafted cucurbits. Both the scion and the rootstock are infected by GSB, as the wounds would encourage the growth of GSB, as the grafted plants are frequently misted or maintained at high humidity levels to encourage graft union repair (40).

Management

Effective management of GSB requires an integrated approach that combines cultural, biological and chemical practices to minimize disease incidence and severity (15) (Fig. 3).

Cultural methods

Collection and destruction of diseased material from the fields immediately after noticing the disease incidence was the first most important measure to control the disease spread (22). Soil amendments, such as chicken litter and mustard oilcake applied during the early growth stages, have been shown to reduce GSB incidence (41). Since, it can spread through seeds, purchasing seeds from trustworthy companies with a track record of producing GSB-free seeds was advisable. Also, seed treatment is a mandatory measure to limiting the source of inoculum through seed (16).

Biological methods

Biological control, involving the use of beneficial microorganisms, presents a sustainable and cost-effective

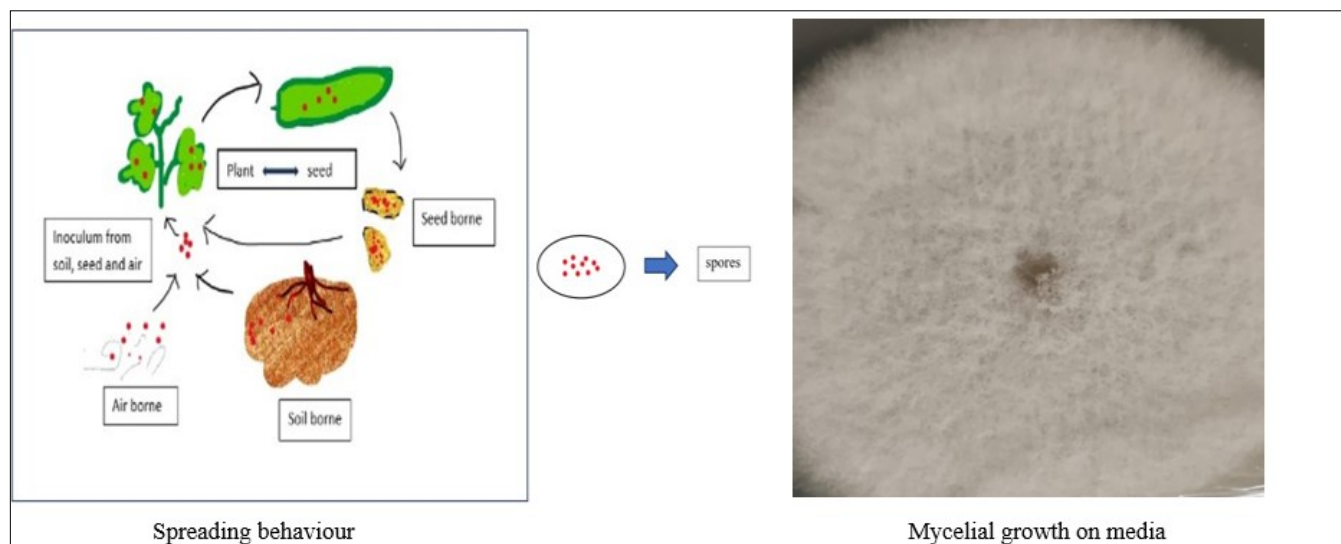


Fig. 2. Growth and spread of *Stagonosporopsis* spp.

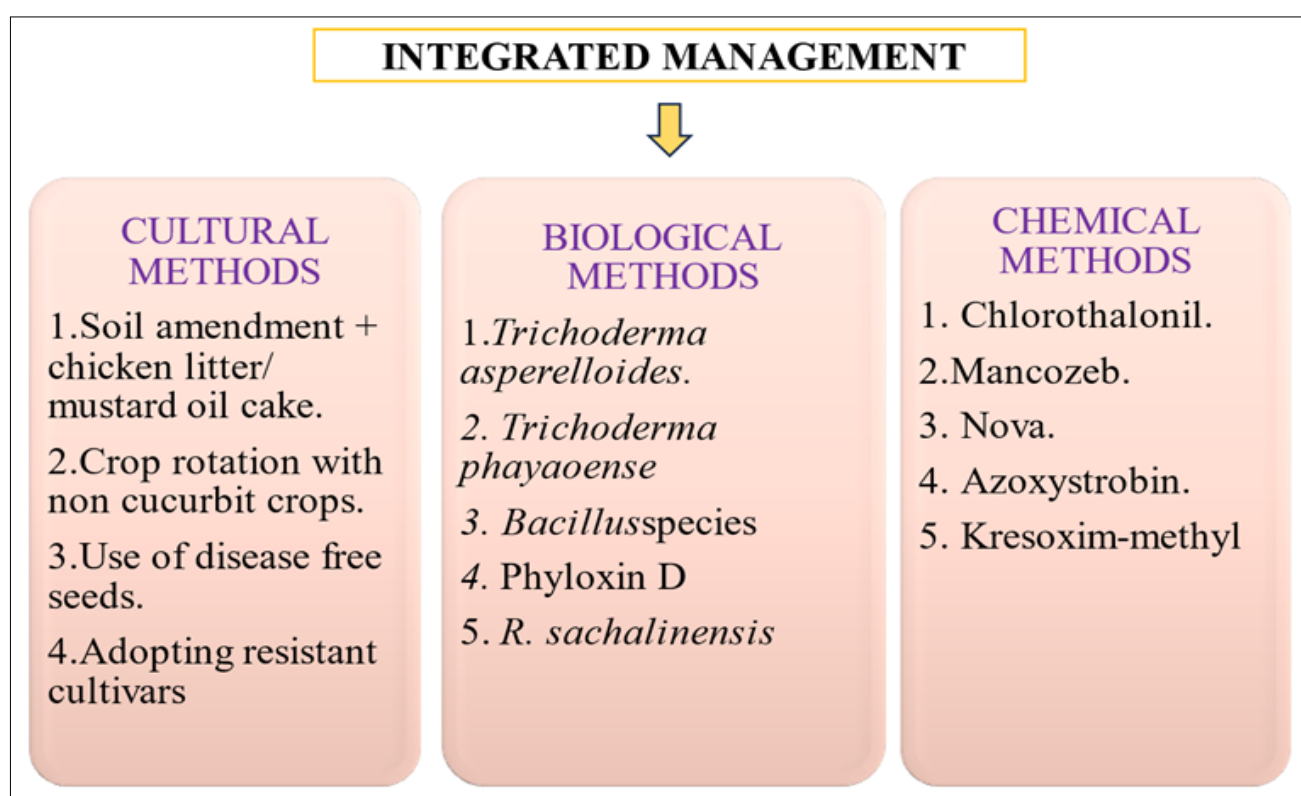


Fig. 3. Integrated management methods to control the gummy stem blight disease in cucurbits.

alternative to synthetic pesticides, offering environmental safety along with disease suppression (42).

Trichoderma

Trichoderma asperelloides PSU-P1 is a biological control agent (BCA) that has higher antifungal properties against *S. cucurbitacearum*. It also showed the lowest disease severity during the seedling stage. A novel *Trichoderma phayaoense* species was found to effectively control GSB and promote plant growth in muskmelon (43), by inhibiting the mycelial growth of *S. cucurbitacearum* (44). Formulations of *Trichoderma* are used as seed treatments or soil applications in solid and liquid forms (45). Dry powder formulations are better for seed coating and effective methods against soil-borne fungi (46). Powder formulation @ 3-10 g/kg of seed used for treating the seeds (47). For soil treatment, *Trichoderma* can be added in the soil before sowing (48).

Bacillus

As bio-control agents, *Bacillus* species have their prime role in managing plant diseases. *Bacillus* species were found to have antagonistic effects against *D. bryoniae* as they inhibit the hyphal growth of *D. bryoniae* (49).

Bio-pesticides

Bio-pesticides such as polyoxin D and *Reynoutria sachalinensis* extracts have demonstrated effectiveness as alternatives to chemical fungicides like chlorothalonil in managing GSB (42).

Chemical methods

Non-systemic fungicides such as chlorothalonil and mancozeb are commonly used for GSB control. Foliar application of mancozeb @ 0.2 % effectively suppressing disease development (41, 50). In addition, silicon applications not only help reduce disease severity but also enhance fruit quality and yield (51). Three foliar sprays of Nativio 75 WG @

0.1 %, Aimstar Top 325 SC @ 0.1 % and Bordeaux combination (1:1:100) @ 0.1 %, with a 10-day interval, were observed to lower Percent Disease Index (PDI) by 8.50-9.0 % and improving yield by 14.72-17.89 t/ha (52). Cyprodinil 0.37 kg/ha + Fludioxonil 0.25 kg/ha and Cyprodinil 0.29 kg/ha + 0.10 kg/ha difenoconazole have been reported to decrease disease severity. It was also reported that interaction result of these chemicals, more effective in reducing severity than application alone (53).

Host-plant resistance

The increasing resistance of the pathogen to chemicals (4) and the presence of inoculum in the soil, makes it is difficult to prevent GSB disease through chemical control methods alone, specifically under open field conditions (18, 19, 54). In addition, pesticide application has hazardous effects on the environment.

Therefore, developing GSB-resistant varieties has become important approaches for the crops severely affected by GSB (25). So, the choice of the breeders is to select and create disease-resistant types (55). In recent decades, it has become possible to identify distinct kinds and genera of cucurbitaceous crops that are less susceptible to GSB (56). Although, genetic resistance mechanisms associated with resistant genes in Cucurbitaceae crops have been documented, the underlying molecular mechanisms need further attention (35).

Grafting through employing the rootstocks, which are enduring the hostile situations, also helps to manage GSB and it is extensively exploited for managing geophilic pathogens (14). Here is the example: squash hybrid Shelper, resistant to *D. bryoniae*, can be utilized as muskmelon rootstock (57).

Molecular breeding tools (i.e., marker-assisted selection) are more efficient than those of conventional breeding methods for developing the GSB-resistant cultivars because molecular breeding tools are accurate and take less time than conventional breeding methods (58). Transcriptome-based gene mining may assist in identifying host genes, infection-associated metabolic processes, signal transduction pathways and molecular control networks in plant-pathogen interplay; such knowledge would assist in understanding cucurbit molecular pathways that drive host resistance to *Stagonosporopsis* (59).

Metabolites such as oxalic acid and eriodictyol act as marker metabolites in melon resistance against GSB (60). BLAST analysis of the genomic areas carrying the significant QTLs of *gsb-s6.1* and *gsb-s6.2* identified 117 genes, 14 of which were disease resistance-related (25). Adding numerous GSB-resistant genes to cultivars improves resistance and longevity (61) (Table 6).

Conclusion

India has reported cases of this biotic stress in a number of cucurbits, including chayote, cucumber, muskmelon, ridge

gourd, wax gourd and bitter gourd by *S. cucurbitacearum*, *S. citruli* and *S. caricae*. GSB leads to severe yield losses with increasing severity and in recent years GSB incidence has become severe in crops like bottle gourd to which this disease was initially negligible. The *Stagonosporopsis* spp. are morphologically indistinguishable but can be identified through molecular characterization. The major symptoms of the disease include irregular brown spots that coalesce and develop as blight and gummy exudates appear on the stem. On leaf symptoms appear as dark discolouration and necrosis of leaf margin. All cultural, biological and chemical methods are used to control the disease. Since the pathogen is air-borne, seed-borne and soil-borne, making it difficult to control the disease only through these methods. Hence, the host plant resistance plays a key role in minimizing the disease incidence. Genomic and molecular-based approaches offer the advantage of speed and accuracy in identifying resistance traits, which are essential in combating future outbreaks of GSB in cucurbit crops - one of India's major vegetable groups. Moving forward, enhancing research and development efforts in this area will be vital in safeguarding crop yields and ensuring the sustainability of cucurbit production in India.

Authors' contributions

GR and MK wrote the original draft and performed the tables. VS and SA performed the figures. TC, MN and IC reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Luo Q, Tan GF, Ma YQ, Meng PH, Zhang J. Cucurbitaceous vegetables' gummy stem blight research. *Agronomy*. 2022;12(6):1283. <https://doi.org/10.3390/agronomy12061283>
2. McCreight JD. Cultivation and uses of cucurbits. In: Grumet R, Katzir N, Garcia-Mas J, editors. *Genetics and genomics of Cucurbitaceae*. Plant genetics and genomics: crops and models. Springer, Cham; 2017. p. 1-12. <https://doi.org/10.1007/739720162>
3. Yu J, Wu S, Sun H, Wang X, Tang X, Guo S, et al. CuGenDBv2: an updated database for cucurbit genomics. *Nucleic acids Res*. 2023;51(D1):D1457-64. <https://doi.org/10.1093/nar/gkac921>
4. Seblani R, Keinath AP, Munkvold G. Gummy stem blight: One disease, three pathogens. *Mol Plant Pathol*. 2023;24(8):825-37. <https://doi.org/10.1111/mp.13339>
5. Yiblet Y. Overview of Cucurbitaceae families. In: *Biological and abiotic stress in Cucurbitaceae crops*. IntechOpen; 2023. <https://doi.org/10.5772/intechopen.1001306>

Table 6. Resistant genes/QTLs of major cucurbits against *Stagonosporopsis*

Crop	Resistant genes	References
Muskmelon	<i>gsb-4</i> and <i>gsb-6</i>	(61)
Cucumber	<i>gsb-s1.1</i> , <i>gsbs2.1</i> , <i>gsb-s6.1</i> , <i>gsb-s6.2</i> , <i>gsb-s6.3</i>	(25)
Watermelon	<i>ClGSB3.1</i> , <i>ClGSB5.1</i> and <i>ClGSB7.1</i> , <i>Qgsb8.1</i> locus	(58, 62)

6. Rolnik A, Olas B. Vegetables from the Cucurbitaceae family and their products: Positive effect on human health. Nutrition. 2020;78:110788. <https://doi.org/10.1016/j.nut.2020.110788>
7. Shrivastava A, Roy S. Cucurbitaceae: A ethnomedicinally important vegetable family. J Med Plants Stud. 2013;1(4):16-20.
8. Keinath AP, Wintermantel WM, Zitter TA. Compendium of cucurbit diseases and pests, 2nd edition. APS Publication; 2017. <https://doi.org/10.1094/9780890545744>
9. Garampalli RH, Gapalkrishna MK, Li HX, Brewer MT. Two *Stagonosporopsis* species identified as causal agents of gummy stem blight epidemics of gherkin cucumber (*Cucumis sativus*) in Karnataka, India. Eur J Plant Pathol. 2016;145:507-12. <https://doi.org/10.1007/s10658-015-0841-2>
10. Tripathi AN, Maurya S, Pandey KK, Behera TK. Global scenario of vegetable fungal diseases. Veg Sci. 2024;51:54-65. <https://doi.org/10.61180/vegsci.2024.v51.spl.06>
11. Brewer MT, Rath M, Li HX. Genetic diversity and population structure of cucurbit gummy stem blight fungi based on microsatellite markers. Phytopathol. 2015;105(6):815-24. <https://doi.org/10.1094/PHYTO-10-14-0282-R>
12. Aveskamp MM, de Gruyter J, Woudenberg JH, Verkley GJ, Crous PW. Highlights of the Didymellaceae: a polyphasic approach to characterise *Phoma* and related pleosporalean genera. Stud mycol. 2010;65(1):1-60. <https://doi.org/10.3114/sim.2010.65.01>
13. Bhat ZA, Bhat MA, Ahanger MA, Badri ZA, Mir GH, Mohi-u-Din FA. Survival of *Didymella bryoniae* incitant of ridge gourd blight under temperate conditions. Int J Curr Microbiol App Sci. 2018;7:2632-8. <https://doi.org/10.20546/ijcmas.2018.705.305>
14. Keinath AP. Diagnostic guide for gummy stem blight and black rot on cucurbits. Plant Health Prog. 2013;14(1):35. <https://doi.org/10.1094/PHP-2013-1024-01-DG>
15. Dalcin MS, Tschoeke PH, Aguiar RW, Fidelis RR, Didonet J, Santos GR. Severity of gummy stem blight on melon in relation to cultivars, use of fungicides and growing season. Horti Bras. 2017;35(4):483-9. <https://doi.org/10.1590/S0102-053620170403>
16. Newark M, Paret ML, Dufault NS, Freeman JH. Management of gummy stem blight (black rot) on cucurbits in Florida. UF/IFAS Extension, University of Florida, Gainesville; 2014.
17. Gusmini G, Song R, Wehner TC. New sources of resistance to gummy stem blight in watermelon. Crop Sci. 2005;45(2):582-8. <https://doi.org/10.2135/cropsci2005.0582>
18. Bhardwaj DR, Gautam KK, Saha S, Nagendran K, Pandey KK, Singh AK, et al. Mining the source of resistance for downy mildew and gummy stem blight in bottle gourd (*Lagenaria siceraria*) accessions. Indian J Agric Sci. 2018;88:746-50. <https://doi.org/10.56093/ijas.v88i5.80071>
19. Parakkunnel R, Varalakshmi B, Sanna MK. Identification of sources of multiple disease resistance in advanced breeding lines of bottle gourd (*Lagenaria siceraria* (Molina) Standley). Int J Curr Microbiol Appl Sci. 2021;10(1):2511-20. <https://doi.org/10.20546/ijcmas.2021.1001.291>
20. Mahapatra S, Rao ES, Sandeepkumar GM, Sriram S. *Stagonosporopsis cucurbitacearum* the causal agent of gummy stem blight of watermelon in India. Australas Plant Dis Notes. 2020;15:7. <https://doi.org/10.1007/s13314-020-0376-z>
21. Basim E, Basim H, Abdulai M, Baki D, Öztürk N. Identification and characterization of *Didymella bryoniae* causing gummy stem blight disease of watermelon (*Citrullus lanatus*) in Turkey. Crop Prot. 2016;90:150-6. <https://doi.org/10.1016/j.cropro.2016.08.026>
22. Ramsoondar J, Da Silva C, Ramkissoon A, Chinnadurai C, Ramsuhag A, Jayaraman J. Gummy stem blight: an emerging epiphytotic disease of pumpkin in Trinidad, West Indies. Trop Agric. 2018;95(2).
23. Dos Santos GR, Rodrigues Sousa SC, Juliatti FC, Rodrigues AC, Dalcin MS, Bonifacio A. Control of gummy stem blight in watermelon through different management systems. Biosci J. 2016;32(2):371-7. <https://doi.org/10.14393/BJ-v32n2a2016-30035>
24. Frantz JD, Jahn MM. Five independent loci each control monogenic resistance to gummy stem blight in melon (*Cucumis melo* L.). Theor Appl Genet. 2004;108:1033-8. <https://doi.org/10.1007/s00122-003-1519-2>
25. Zhang S, Liu S, Miao H, Shi Y, Wang M, Wang Y, et al. Inheritance and QTL mapping of resistance to gummy stem blight in cucumber stem. Mol Breed. 2017;37:1-8. <https://doi.org/10.1007/s11032-017-0623-y>
26. Sohi HS. New records of fungal disease from India part 1. Indian J Mycol Plant Pathol. 1972;2:139-42.
27. Rennberger G, Keinath AP. Susceptibility of fourteen new cucurbit species to gummy stem blight caused by *Stagonosporopsis citrulli* under field conditions. Plant Dis. 2018;102(7):1365-75. <https://doi.org/10.1094/PDIS-12-17-1953-RE>
28. Jeong YJ, Kwon OK, Jeong AR, Lee H, Moon H, Lee ON, et al. Population structure of *Stagonosporopsis* species associated with cucurbit gummy stem blight in Korea. Plant Pathol J. 2022;38(5):522. <https://doi.org/10.5423/PPJA.OA.07.2022.0102>
29. Chiu WF, Walker JC. Physiology and pathogenicity of the Cucurbit black-rot fungus. J Agri Res. 1949;78(12):589-615.
30. Keinath AP. From native plants in central Europe to cultivated crops worldwide: the emergence of *Didymella bryoniae* as a cucurbit pathogen. HortScience. 2011;46(4):532-5. <https://doi.org/10.21273/HORTSCI.46.4.532>
31. Sushma K, Nagalakshmi T, Arunodhayam K, Sadarunnisa S, Ramaiah M. Survey on incidence of gummy stem blight on ridge gourd (*Luffa acutangula* (L.) Roxb.) in Andhra Pradesh. Pharma Innovation. 2021;10(12):1198-200.
32. Stewart JE, Turner AN, Brewer MT. Evolutionary history and variation in host range of three *Stagonosporopsis* species causing gummy stem blight of cucurbits. Fungal Biol. 2015;119(5):370-82. <https://doi.org/10.1016/j.funbio.2014.12.008>
33. Nuangmek W, Aiduang W, Suwannarach N, Kumla J, Lumyong S. First report of gummy stem blight caused by *Stagonosporopsis cucurbitacearum* on cantaloupe in Thailand. Can J Plant Pathol. 2018;40(2):306-11. <https://doi.org/10.1080/07060661.2018.1424038>
34. McPherson M, O'Neill T, Kennedy R, Wakeham A, Wright K, Goodson M, et al. Cucumber: improving control of gummy stem blight caused by *Mycosphaerella melonis* (*Didymella bryoniae*). AHDB Horticulture Project PE. 2011;1.
35. Li PF, Ren RS, Yao XF, Xu JH, Babu B, Paret ML, et al. Identification and characterization of the causal agent of gummy stem blight from muskmelon and watermelon in East China. J Phytopathol. 2015;163(4):314-9. <https://doi.org/10.1111/jph.12277>
36. Damicone J, Brandenberger L. Watermelon diseases. Oklahoma Cooperative Extension Service. 2020; FS EPP-7679.
37. Rennberger G, Turecek WW, Keinath AP. Dynamics of the ascospore dispersal of *Stagonosporopsis citrulli*, a causal agent of gummy stem blight of cucurbits. Plant Pathol. 2021;70(8):1908-19. <https://doi.org/https://doi.org/10.1111/ppa.13424>
38. Nga NT, de Neergaard E, Jørgensen HJ. Infection biology of *Stagonosporopsis cucurbitacearum* in watermelon and defence responses in the host. Agriculture. 2024;14(3):380. <https://doi.org/10.3390/agriculture14030380>
39. Sudisha J, Niranjana SR, Umesha S, Prakash HS, Shetty HS. Transmission of seed-borne infection of muskmelon by *Didymella bryoniae* and effect of seed treatments on disease incidence and fruit yield. Biol Control. 2006;37(2):196-205. <https://doi.org/10.1016/j.biocontrol.2005.11.018>

40. Keinath AP, DuBose VB. Disinfectant treatments that reduce transmission of *Stagonosporopsis citrulli* during cucurbit grafting. *Plant Dis.* 2017;101(11):1895-902. <https://doi.org/10.1094/PDIS-03-17-0451-RE>
41. Afroz M, Rahman MA, Nahar MS, Yasmin L, Alam SM. Selection of resistant variety, effective organic amendment and fungicide against gummy stem blight (*Didymella bryoniae*) of bottle gourd. 2012;10(1):1-8.
42. Jones JG, Korir RC, Walter TL, Everts KL. Reducing chlorothalonil use in fungicide spray programs for powdery mildew, anthracnose and gummy stem blight in melons. *Plant Dis.* 2020;104(12):3213-20. <https://doi.org/10.1094/PDIS-04-20-0712-RE>
43. Ruangwong OU, Wonglom P, Phoka N, Suwannarach N, Lumyong S, Ito SI, et al. Biological control activity of *Trichoderma asperelloides* PSU-P1 against gummy stem blight in muskmelon (*Cucumis melo*). *Physiol Mol Plant Pathol.* 2021;115:101663. <https://doi.org/10.1016/j.pmpp.2021.101663>
44. Nuangmek W, Aiduang W, Kumla J, Lumyong S, Suwannarach N. Evaluation of a newly identified endophytic fungus, *Trichoderma phayaense* for plant growth promotion and biological control of gummy stem blight and wilt of muskmelon. *Front Microbiol.* 2021;12:634772. <https://doi.org/10.3389/fmicb.2021.634772>
45. Ha TN. Using *Trichoderma* species for biological control of plant pathogens in Viet Nam. *J Int Soc Southeast Asian Agri Sci.* 2010;16(1):17-21.
46. Ali A, Zeshan MA, Mehtab M, Khursheed S, Mudasir M, Abid M, et al. A comprehensive note on *Trichoderma* as a potential biocontrol agent against soil borne fungal pathogens: a review. *Plant Prot.* 2021;5(3):171-96. <https://doi.org/10.33804/pp.005.03.3934>
47. Mukhopadhyay R, Kumar D. *Trichoderma*: a beneficial antifungal agent and insights into its mechanism of biocontrol potential. *Egypt J Biol Pest Control.* 2020;30:1-8. <https://doi.org/10.1186/s41938-020-00333-x>
48. Kumar A, Scher K, Mukherjee M, Pardovitz-Kedmi E, Sible GV, Singh US, et al. Overlapping and distinct functions of two *Trichoderma virens* MAP kinases in cell-wall integrity, antagonistic properties and repression of conidiation. *Biochem Biophys Res Commun.* 2010;398(4):765-70. <https://doi.org/10.1016/j.bbrc.2010.07.020>
49. Ngo TQ, Thai TH, Tran TX, Tran DH. Evaluation of *Bacillus* sp. strains for biological control of gummy stem blight, *Didymella bryoniae* (Auersw.) in watermelon (*Citrullus lanatus*). *Crop Res.* 2023;58(5and6):238-42. <https://doi.org/10.31830/2454-1761.2023.CR-935>
50. Paret ML, Dufault NS, Newark M, Freeman JH. Management of gummy stem blight (black rot) on cucurbits in Florida: PP280, rev. 8/2018. *EDIS.* 2018;2018(4). <https://doi.org/10.32473/edis-pp280-2018>
51. Chan-In P, Wangkaew B, Anankul N, Teerawatsakul Y, Thiyagaraja V, Tamakaew N, et al. Effect of silicon on the fruit quality and disease response to gummy stem blight in cucumber. *Chiang Mai J Sci.* 2023;50(6):1-13. <https://doi.org/10.12982/CMJS.2023.073>
52. Rahman MZ, Kibria MG, Talukder MM, Akhter MS, Amia MF. Evaluation of fungicides for control of gummy stem blight of watermelon caused by *Didymella bryoniae*. *Bangladesh J Plant Pathol.* 2019;35:47-52.
53. Keinath AP. Premix fungicides that reduce development of fruiting bodies but not leaf lesions by *Stagonosporopsis citrulli* on watermelon leaves in the field. *Plant Dis.* 2021;105(05):1415-21. <https://doi.org/10.1094/PDIS-08-20-1807-RE>
54. Katoch A, Kapoor P, Singh A. The emergence of gummy stem blight: A threat to cucurbits in India. *Agrica.* 2017;6(1):1-6. <https://doi.org/10.5958/2394-448X.2017.00001.3>
55. Yao X, Li P, Xu J, Zhang M, Ren R, Liu G, et al. Rapid and sensitive detection of *Didymella bryoniae* by visual loop-mediated isothermal amplification assay. *Front Microbiol.* 2016;7:1372. <https://doi.org/10.3389/fmicb.2016.01372>
56. Keinath AP. Differential susceptibility of nine cucurbit species to the foliar blight and crown canker phases of gummy stem blight. *Plant Dis.* 2014;98(2):247-54. <https://doi.org/10.1094/PDIS-05-13-0510-RE>
57. Gasparotto F, de Oliveira RR, Penharbel MP, Tessmann DJ, do Nascimento JF, Vida JB. Effect of grafting on the control of gummy stem blight in muskmelons. *Semin: Ciênc Agrár.* 2016;37(5):2859-66. <https://doi.org/10.5433/1679-0359.2016v37n5p2859>
58. Gimode W, Bao K, Fei Z, McGregor C. QTL associated with gummy stem blight resistance in watermelon. *Theor Appl Genet.* 2021;134:573-84. <https://doi.org/10.1007/s00122-020-03715-9>
59. Zhao Q, Gong Z, Jiang S, Li Z, Zhang L, Wang L, et al. Gene mining to discover pumpkin response genes to gummy stem blight infection caused by *Stagonosporopsis cucurbitacearum*. *J Plant Interact.* 2022;17(1):1-8. <https://doi.org/10.1080/17429145.2021.2006331>
60. Wang H, Wei X, Mo C, Wei M, Li Y, Fan Y, et al. Integrated full-length transcriptome and metabolome analysis reveals the defence response of melon to gummy stem blight. *Plant Cell Environ.* 2024;47(6):1997-2010. <https://doi.org/10.1111/pce.14865>
61. Zhang N, Xu BH, Bi YF, Lou QF, Chen JF, Qian CT, et al. Development of a muskmelon cultivar with improved resistance to gummy stem blight and desired agronomic traits using gene pyramiding. *Czech J Genet Plant Breed.* 2017;53(1):23-9. <https://doi.org/10.17221/84/2016-CJGPB>
62. Ren R, Xu J, Zhang M, Liu G, Yao X, Zhu L, et al. Identification and molecular mapping of a gummy stem blight resistance gene in wild watermelon (*Citrullus amarus*) germplasm PI 189225. *Plant Dis.* 2020;104(1):16-24. <https://doi.org/10.1094/PDIS-04-19-0753-RE>

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