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Economic impact, pathogen identification and management of blossom and peduncle blight in tuberose: A review

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Abstract

In the global floriculture industry, tuberose [*Agave amica* (Medik.) Thiede & Govaerts syn. *Polianthes tuberosa* L.] holds significant economic and cultural value, particularly in regions like Tamil Nadu, India. However, the cultivation of this valuable flower is increasingly threatened by diseases such as blossom blight and peduncle blight. This review examines the economic importance of tuberose and the severe impact of these blights, caused by *Fusarium equiseti* and *Lasiodiplodia theobromae* respectively, which can result in crop losses of up to 43 %. The identification and morphological characteristics of these pathogens are discussed, emphasizing the need for accurate detection and diagnosis to manage these diseases effectively. This article also reviews current management strategies, including chemical fungicides, biocontrol agents and cultural practices, highlighting the efficacy of carbendazim and tebuconazole against *L. theobromae* and the potential of Aimcozim and organic amendments against *F. equiseti*. Climate change exacerbates the impact of these diseases, necessitating adaptive management practices. Despite progress, research gaps remain in developing integrated disease management strategies and understanding the long-term effects of climate change on disease epidemiology. This review aims to provide a comprehensive overview of the current knowledge and to encourage further research, with the goal of enhancing the sustainability of tuberose cultivation in the face of these increasing challenges.

Keywords

Lasiodiplodia theobromae ; *Fusarium equiseti* ; tuberose; management

Introduction

Floriculture, a branch of horticulture, involves the cultivation, processing and marketing of ornamental plants for aesthetic purposes. It plays a crucial role in the global economy by generating income, creating jobs and supporting industries such as retail, tourism and agriculture, especially in India (1). Tuberose (*Agave amica*), commonly known as the 'lily' in the Indian market and locally called 'Sampangi' in Tamil Nadu, is a flower crop of significant economic and cultural importance. Native to Mexico, this bulbous crop belongs to the Asparagaceae family and is extensively cultivated in tropical and subtropical regions for its cut flowers and aromatic properties (2). The chemical constituents of tuberose are essential for various applications. The aerial parts of the plant contain cholestane glycoside, spirostanol saponins and 1-tricosanol alcohol, while the bulbs contain glycosides and tricosanol and the underground parts are rich in spirostanol saponins and monosaccharides (3).

Tuberose is renowned for its fragrant flowers, which are commonly used in garlands, bouquets and floral decorations, particularly for bridal makeup. Its essential oil is highly valued in the perfume and cosmetics industries and the flowers are also employed in aromatherapy to alleviate stress and promote relaxation (4). Additionally, tuberose has various medicinal applications; its bulbs contain the alkaloid-lycorine, which has emetic properties and is used in traditional remedies (5). Tamil Nadu, a leading producer of tuberose in India, is notable for its favourable soil and climate conditions, particularly in districts such as Madurai, Dindigul, Theni, Dharmapuri and Tirunelveli. The Dharmapuri district, with a net cultivated area of 195740 ha out of a total geographical area of 443741 ha, devotes about 80000 ha to horticultural activities. The region is well-known for its production of pulses, millets and various horticultural crops, including tuberose (Department of Horticulture and Plantation Crops, Tamil Nadu).

Despite its economic significance, tuberose cultivation is challenged by various pests and diseases. Common diseases include sclerotial wilt, alternaria leaf spot, rust, blossom blight, peduncle blight, botrytis blight and powdery mildew. Among these, blossom blight and peduncle blight are particularly damaging, leading to yield losses of up to 43 %. Blossom blight, caused by *Fusarium equiseti*, is characterized by light brown lesions on the petals, resulting in tissue drying and flower drop. Peduncle blight, caused by *Lasiodiplodia theobromae*, affects the flower stem, causing collapse and significantly reducing the market value of the flowers (6, 7). This review examines the economic importance of tuberose, the identification of pathogens responsible for blossom and peduncle blight and the management strategies necessary to mitigate these diseases, ensuring sustainable cultivation and enhanced market potential of tuberose.

This study aims to review the economic significance of tuberose cultivation and the impact of blossom blight and peduncle blight diseases. It also seeks to examine the identification and characteristics of the causal pathogens *F. equiseti* and *L. theobromae* and evaluate existing management strategies, including chemical, biological and cultural practices, for controlling these diseases. Furthermore, the study aims to identify research gaps and suggests future directions for developing sustainable and climate-resilient disease management approaches in tuberose cultivation.

Economic significance of pathogens

L. theobromae is a fungus known to infect both monocot and dicot plants, causing dieback and shoot blight symptoms (Fig. 1a). This fungus is prevalent in tropical and subtropical regions and has a broad host range (8). It has been documented to cause necrosis and dieback in the shoots of cashew (9), grapevine, (10) and mango (11). A study reported that *L. theobromae* also affects *Polianthes* in Cuba (12) and a similar impact on tuberose has been observed in India (13). In the Madurai and Dindugal regions of Tamil Nadu, peduncle blight can affect up to 43 % of tuberose production. A survey in northern Karnataka indicated that the vegetative stage of the plants is more susceptible to the pathogen than the flowering stage. Additionally, red soil was associated with higher disease severity compared to black soil. The highest severity of peduncle blight was recorded in Tumminakatti village (45.33 %) in Haveri

Fig. 1. Symptoms of peduncle blight (**a**) and blossom blight (**b**) on tuberose plant.

district, while the lowest severity was observed in Chandanamatti village (13.33 %) in Dharwad district (14). The infection begins with blossom blight, followed by peduncle blight starting from the tip and eventually causes leaf blight at the tips, leading to the disappearance of all flower buds. Peduncle blight, previously unidentified has now been identified as a significant threat to tuberose cultivation.

F. equiseti is a pathogen that affects humans, animals and plants and is a common inhabitant of soil worldwide (15). Although typically considered a weak pathogen, it can infect the seeds, roots, tubers and fruits of various crops such as asparagus, cotton, cowpeas, cumin, ginseng, lentils, pine, potato and sugar beet, causing a range of symptoms (16). *F. equiseti* is often mistaken for other species due to its spindle-shaped macroconidia, but it can be distinguished by specific characteristics: the shape of the apical cell of its macroconidia differentiates it from *F. compactum*, the shape of the apical cell and macroconidial septation set it apart from *F. ipomoeae*, the absence of microconidia distinguishes it from *F. scirpi* and the pigment formation on PDA is brown in *F. equiseti* vs. red in *F. longipes* (15, 17). *F. equiseti* has been reported to cause chili wilt in the Himalayan region of Kashmir Valley, wilt in cauliflower in China and wilt in cumin in parts of India (18, 19). A study reported 2 new *Fusarium* diseases in India, with *F. equiseti* being one of them (20). It has also been documented to cause blossom blight in tuberose (21). The prevalence of tuberose blossom blight (Fig. 1b) ranged from 6.67 % to 26.67 % in the Jashore district (22). Soil-borne diseases such as those caused by *Fusarium* spp. can lead to significant issues in field crops, orchards and greenhouses. In tuberose, light brown lesions develop on the petals, which quickly darken, causing the tissue to dry out. The blighted blossoms then drop from the plant and infection on the flower stalk leads to its collapse.

Detection and diagnosis of pathogens

The identification of the pathogen responsible for blight disease in tuberose was confirmed based on its morphological and pathological characteristics. Initially, tuberose blooms were infected, displaying spots that appeared on the diseased flowers and subsequently spread to nearby buds, resulting in the complete loss of all buds. The fungus *L. theobromae* was identified as the causative agent of tuberose peduncle blight disease. White mycelium was first observed on the culture media, which later developed into black pycnidia and eventually turned gray. Pycnidial primordia initially appeared as small, dark brown, slightly elevated dots. Subsequently, flask-shaped, ostiolate pycnidia emerged, characterized by a dark brown color and a round ostiole at the tip of an extended neck, allowing conidia to protrude. The conidia were initially hyaline, unicellular and globose to oblong, but later became brown and septate (22).

L. theobromae was isolated from afflicted peduncles, flowers and leaves, forming white mycelium on potato dextrose agar (Fig. 2a). In 7 days old cultures, the initially small pycnidia developed into dark brown, flask-shaped, ostiolate structures, leading to its identification (23). The identity of the fungus was confirmed by the Indian Type Culture Collection Centre of the Division of Plant Pathology, Indian Agricultural Research Institute, New Delhi (24).

Blight symptoms included water-soaked patches on the petals, which rapidly progressed to tissue darkening and petal drying, ultimately causing the blossoms to fall off. Infection of the bloom stem resulted in collapse and high humidity led to the browning of flower tips, where brown spore masses formed. *F. equiseti* was identified as the causative agent of tuberose blossom blight (Fig. 2b). A pure culture of white, cottony mycelial growth was observed on PDA media within seven days. Under a compound microscope, small, oval-shaped microconidia, either single or bicelled and hyaline, multicelled macroconidia with three septations, exhibiting a sickle-shaped, knotted base at one end were detected.

For molecular verification, genomic DNA was extracted from the mycelium of *L. theobromae* and *F. equiseti* isolates using the CTAB method (25). After DNA

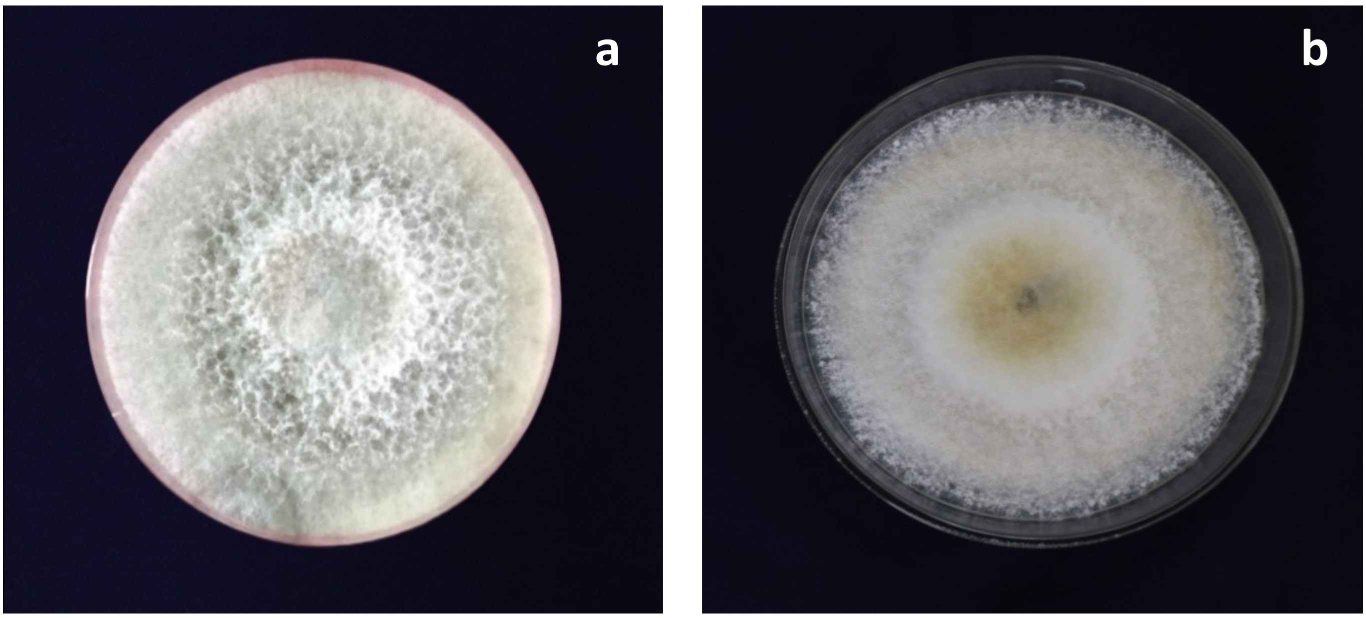

Fig. 2. Isolate plates of *Lasiodiplodia theobromae* (**a**) and *Fusarium equiseti* (**b**) in tuberose plant.

extraction, PCR amplification of the ITS1-5.8S-ITS2 region of ribosomal DNA was performed using ITS1 (5'-TCCG TAGGTGAACCTGCGG-3') and ITS4 (5'-TCCTCCGCTTATT GATATGC-3') primers. The sizes of the PCR products were determined by comparison with standard 100 bp or 1 kb molecular markers. Sequencing and BLASTn analysis of the PCR products revealed 98 %–100 % sequence homology with GenBank sequences.

Climate change and occurrence of diseases

The severity and occurrence of *L. theobromae* vary distinctly across an East-West gradient, ranging from minimal to maximal. Eastern regions, such as Sissili and Nahouri, which have a climate similar to that of North Sudan, exhibit higher disease severity compared to other Sub-Sudanese areas. A second-order linear model effectively fit the data, demonstrating a strong correlation between incidence and severity, indicating that disease severity can be predicted from incidence data. Additionally, a significant relationship was found between longitude and disease incidence, with increased disease rates observed in eastern locations with higher longitudes. The incidence of mango decline was positively correlated with mean annual temperature and inversely correlated with mean annual rainfall (26).

Supporting the hypothesis that climate change facilitates the spread of *F. equiseti* to new hosts in northern Italy, experiments conducted in phytotrons simulated climate change scenarios with elevated temperatures and CO_2 levels. These experiments revealed that *F. equiseti* exhibited the highest virulence on rocket and radish at the highest tested temperatures (27). Lettuce, in particular, is highly susceptible to *F. equiseti*, especially at temperatures of 25 and 30 °C. At temperatures ranging from 30 to 35 °C, just 1 to 3 h of leaf wetness can result in a high incidence and severity of disease on wild rocket. However, at cooler temperatures, at least 12 h of leaf wetness are required to cause significant damage. Additionally, while high humidity for 6 to 12 h can lead to notable disease at lower temperatures, shorter periods of high humidity are generally insufficient to cause significant losses (28).

Existing management strategies

The pathogen *L. theobromae* was treated with various fungicides (carbendazim, tebuconazole, azoxystrobin, cholorotalonill, copper oxy chloride and kocide) at different concentrations (500, 1000, 1500 and 2000 ppm). Among the 6 compounds examined *in vitro*, carbendazim at 0.1 % was the most effective, reducing disease incidence to 4 %, which represents a 95.50 % decrease compared to the control. Tebuconazole was the second most effective, with an 8 % disease incidence and a 91 % disease reaction in disease severity. These 2 treatments were significantly more effective than the others. Tebuconazole and carbendazim proved to be the most successful in reducing the severity of *L. theobromae* disease (29). Azoxystrobin showed an inhibition of *L. theobromae* by 54.44 % and 67.74 % at concentrations of 500 and 2000 ppm respectively (24). In mango cultivation, various fungicides (carbendazim, zamir, mancozeb, funguran and sulphur 80) were tested, with all effectively inhibiting *L. theobromae* mycelial radial growth. Funguran and carbendazim also promoted vegetative growth in shoots and leaves. Following the third spray, mango plants treated with carbendazim exhibited no signs of disease. The severity of *L. theobromae* was further reduced by applying urea fertilizer in conjunction with carbendazim (50 g 15 L^{-1} water) at 2 weeks intervals during field spraying (30).

For controlling *F. equiseti*, *in vitro* tests were conducted using four selected fungicides (aimcozim, cupravit, dithane M-45 and newban) at three different doses (100, 200 and 400 ppm). Aimcozim demonstrated notably superior results, completely inhibiting radial growth. Dithane M-45 and cupravit achieved moderate inhibition of 75.00–77.94 % in preventing the hyphal growth of *F. equiseti*, significantly outperforming newben (22). Bavistin (0.02 %) was also effective in managing the disease (7). In mungbean, the systemic fungicide trifloxystrobin + tebuconazole 75 % WG was the most effective, achieving an 80.30 % mean suppression of *F. equiseti* colony growth. Tebuconazole 25.9 % EC suppressed *F. equiseti* colony growth by 71.83 %, while carbendazim 50 % WP inhibited it by 69.42 %. Propiconazole 25 % EC was the least effective, showing only a 64.08 % suppression of colony growth (31).

Biological control and host plant resistance

Among the biocontrol agents tested, the combination of *Pseudomonas florescence* and *Bacillus subtilis* resulted in a 31.60 % disease incidence. This was closely followed by the combination of *Trichoderma viridae*, *P. florescence* and *B. subtilis,* which yielded a 30.50 % disease incidence; both treatments were comparable in effectiveness. *T. viridae* applied as a foliar spray and bulb treatment showed a 42 % disease incidence, reflecting the lowest disease reduction at 54.44 %. While all 3 *Bacillus* isolates suppressed the growth of *L. theobromae*, *B. subtilis* was found to be the most effective (24). Previous studies have also reported that strains of *B. subtilis* inhibit *L. theobromae* (32). In mango cultivation, biopesticides derived from *Carica papaya*, *Azadirachta indica* and *Chromolaena odorata* were applied against the pathogen *L. theobromae* demonstrating high effectiveness (30). Additionally, strains of *Bacillus velezensis* (YK194, YK201 and YK268) have been identified as effective biocontrol agents against *L. theobromae*, reducing avocado branch blight incidence and producing lipopeptides that inhibit spore germination (33).

The impact of organic amendments on *F. equiseti* hyphal growth showed that mustard oil cake, at the highest concentration (3 %), provided the greatest inhibition of hyphal growth at 59.07 %, significantly outperforming other amendments. Mustard oil cake and til oil cake, at 3 % and 2 % concentrations respectively, showed significant inhibition of 56.11 % and 54.43 %. Soybean oil cake exhibited the lowest inhibition (0.42 %) at 1 %, while mustard oil cake demonstrated substantial inhibition of *Fusarium* spp. growth (34). The suppression of *F. equiseti* may be attributed to the fungitoxic compounds produced during the breakdown of organic amendments. Using a dual plate culture method, 18 isolates of *Trichoderma harzianum* (T_1

–T_{18}) were screened against *F. equiseti*. The results revealed that isolate T_{18} achieved the highest average mycelial inhibition of 66.80 % compared to other isolates. Significant reductions in mycelial growth of *Fusarium* spp. in the presence of *T. harzianum* have also been reported (35-37). A *Trichoderma asperellum*-based formulation improved seedling growth, root and aerial biomass, increased shoot length and leaf count and reduced *Fusarium* symptoms in chickpea. This treatment successfully re-isolated plants infected with *F. equiseti* in roots, root crown, stem and petioles (38).

Conclusion

This review explores the threats posed by peduncle blight and blossom blight to tuberose cultivation, caused by *Lasiodiplodia theobromae* and *Fusarium equiseti*, respectively. It assesses their economic impact, identification and management strategies in the context of changing climatic conditions. The study highlights a correlation between climate factors and disease severity, particularly the effects of temperature and humidity on pathogen virulence, suggesting new directions for climate-adaptive management strategies. Additionally, the review analyzes various management approaches, including chemical, biological and cultural methods. The evaluation of fungicides, biocontrol agents and organic amendments provides a foundation for developing integrated disease management strategies. It also identifies critical research gaps in integrated disease management, climate-resilient strategies and the development of resistant tuberose varieties. This review serves as a valuable resource for researchers, agriculturists and policymakers, offering insights for innovative and sustainable approaches to tuberose cultivation.

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Authors' contributions

SV: Contributed in collecting the literature, writing and original draft preparation. MD: Contributed in collecting material, guiding for preparing the manuscript, reviewing, editing and supervision. AS: Contributed in editing, supervision and translation. MAV and KI: Helped in editing, grammar correction and revision.

Compliance with ethical standards

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