

Studies on Leaf and Fruit Diseases of *Musa* spp. Caused by Different Groups of Fungal Pathogens – A Review

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ABSTRACT

Banana is (*Musa* spp.) one of the most exoteric and materialistic fruit crops of many tropical and subtropical areas in India. It's a large herbaceous plant believed to have originated in Southeast Asia and Papua, New Guinea. There are many varieties of bananas and undoubtedly, they are a good source of nutrient by providing soothing effect on the gut due to their high content of pectin, a soluble fibre which not only helps lower cholesterol but normalises bowel function. The high fibre content of bananas helps to promote feelings of fullness and appears to reduce bloating. Bananas have played a significant role in many cultures. Different diseases affect cultivation of Banana crop found in India. Among different diseases, banana crops are affected mostly by leaf and fruit diseases. This paper highlights about leaf and fruit diseases of Banana crop in India. The most common fungi causing leaf diseases of Banana are - *Curvularia* sp., *Alternaria alternata*, and *Mycosphaerella fijiensis*. Fruit diseases are- *Fusarium oxysporum*, *F. semitectum*, *F. verticillioides*, *F. subglutinans*, *F. sambucinum*, *F. moniliforme*, *Colletotrichum musae*, and *Acremonium* sp.. This paper is an attempt to review about the descriptions of the fungal leaf and fruit diseases, their symptoms, outward manifestations and consequences when the fungal pathogens infect the banana plants.

Keywords: Leaf diseases, Fruit diseases, *Musa* sp., Fungal pathogens

INTRODUCTION

India is the world's largest producer of bananas, producing approx 30.5 million tonnes, followed by China, Indonesia, Brazil, and Ecuador. Almost all of India's states and regions cultivate bananas and make up 20% of the country's total cultivated land. The major banana-growing states in India are Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu, and Uttar Pradesh. Together, these five states produce over 67% of all the bananas grown in India. Numerous cultivars of bananas are grown in India, including Robusta, Monthan, Dwarf Cavendish, Poovan, Nendran, Red banana, Nyali, Safed Velchi, Basrai, Ardhapuri, Rasthali, Karpurvalli, Karthali, and Grand Naine.

Banana plants are mainly affected by major diseases such as black Sigatoka, *Fusarium* wilt, sometimes known as Panama wilt, crown rot, Cigar-end rot. Banana leaf and fruit diseases are caused by several fungal pathogens and harm banana crops and spread harmful diseases. Early detection as well as proper

identification of such fungal pathogens is necessary to cure the diseases.—Pearson and Jones, (2000) reported on the global records for pathogenic fungi that harm banana and their work revealed that there are about 39 different fungi causing diseases and harm banana crops.

The banana plant is susceptible to a number of fungal-related diseases including Panama disease, Sigatoka, Septoria leaf spot, Cordana leaf spot, Anthracnose, Cigar end rot, Tip end rot, Diamond spot, Brown spot, Pitting disease and Root rot (Stover *et al.*, 1972). Fungal diseases include *Fusarium* wilt, anthracnose, cigar end rot, tip end rot. *Cercospora* leaf spot, eye spot, and root rot adversely affect banana farms. In Iran's Sistan & Bluchestan province, the *Fusarium* wilt, Cigar end rot and *Alternaria* leaf spot in *Musa* sp. were recorded (Amani *et al.*, 2006). *Fusarium* wilt, caused by *Fusarium oxysporum* f. sp., was initially identified in 1911 in West Bengal, India. Today, the disease is destructive and prevalent in nearly all of the states in India that cultivate bananas. In plants,

the disease incidence can reach 85% in ratoon crops and 30% in plant crops. It is a soil-borne fungal disease that poses a severe danger to Cavendish clones of banana crop and around 47% of banana production is attributed to this disease (Ploetz, 2021).

LEAF DISEASES OF BANANA

Fusarium wilt, black and yellow Sigatoka are the major diseases that harm the leaf (Gaikwad *et al.*, 2017). In banana leaf spot caused by *Alternaria*, the spots began to form at the leaf's tip and subsequently migrated to the base. The mature spots featured a light black border and greyish mspot in the mid region. The brown, thin stripes first show up on the leaf's underside. Subsequently, they grew wider and longer, with the size of the spots varying from 6 x 3 mm to 30 x 5 mm. The mature spots were surrounded by a noticeable brilliant yellow halo and brown discoloration. 10% of the spots were in the inter-veinal space, and 90% of the spots were in the veins. Tiny reddish-rusty brown flecks that are particularly noticeable on the underside of leaves are the initial signs of black sigatoka disease in leaves. Leaf streaks that are reddish-brown, dark brown, or black are formed by them gradually getting longer, wider, and darker. On the underside of the leaf, the early streaks are more noticeable and run parallel to the leaf veins. *Fusarium*-affected plants usually experience a progression of yellowing and wilting from the older to the younger leaves. Apart from hanging down the pseudostem, the wilted leaves tend to break at the petiole.

The most popular method of preventing banana leaf spots and post-harvest diseases is the application of fungicides. It has been observed that prochloraz and triazoles are very effective fungicides for controlling these diseases. Yet, excessive fungicide application usually leaves behind toxic residues in banana trees and their surroundings, raising public anxiety. Hence, using less fungicide to manage banana disease requires the use of environmentally friendly techniques (Fu *et al.*, 2010). Using an integrated management package, Lishma *et al.* (2024) tested a range of chemical fungicides and biocontrol agents in both laboratory and field settings to combat the pathogen that causes

Fusarium wilt disease in bananas. The most effective method of managing disease was an integrated package that included sucker treatment with the biocontrol agent *Pseudomonas fluorescens*, soil application of enriched cow dung and Arbuscular Mycorrhizal Fungi and *Trichoderma viride* (biocontrol agent) at planting time, and soil drenching with a triazole fungicide, tebuconazole, two and four months after planting. Shukla *et al.*, (2024) investigated fourteen distinct fungicides and new compounds under both *in vitro* and *in vivo* settings to mitigate Panama wilt, a banana disease caused by *Fusarium oxysporum* f.sp. cubense TR4. When grown in pot conditions, *Fusarium oxysporum* f.sp. cubense TR 4 strain B2 in cultivar Alpan (AAB) showed 86.2% inhibition over control, while native (tebuconazole 50% + trifloxystrobin 25%) showed 100% inhibition over control *in vitro*. According to Pradhan *et al.*, (2020) study on the *Mycosphaerella musicola* caused sigatoka leaf spot disease in bananas, the application of 0.05% propiconazole in addition to 1% mineral oil had the greatest effect on disease control, followed by a combination of Difenconazole 1 ml l L (0.1%) + 1% mineral oil.

Several diseases, including banana sigatoka and banana speckle, are a threat to banana production. *Mycosphaerella fijiensis* or *Pseudocercospora fijiensis* is the fungus that causes black sigatoka disease. Its symptoms initially appear as tiny, chlorotic patches, which progress to thin, brown streaks that are bordered by leaf veins (Amara *et al.*, 2017). Black Sigatoka is also known as "black leaf streak disease". When the fungus affects banana, the fungus kills the leaf tissue, by drastically reducing photosynthesis (Caucasella *et al.*, 2018). The fungal plant pathogen *Mycosphaerella musicola*, also known as *Pseudocercospora musae*, is the cause of the Yellow Sigatoka leaf spot disease that affects banana trees. Pale yellow streaks, measuring one to two millimetres, are the initial symptoms. These streaks eventually combine to create dark brown to black patches encircled by a yellow halo. Fruit that has been severely infected may exhibit irregular ripening, decreased bunch size, and defoliation. *Alternaria alternata*, causes banana leaf blight and leaf sport diseases (Wang *et al.* 2022). Another two most significant diseases caused by fungal isolates

are the pseudostem wilt disease caused by the four races of Panama disease (*Fusarium oxysporum* f. sp. cubense) (Jones *et al.*, 2000).

Fusarium wilt

The most common name for the disease is Panama infection, a fatal fungal infection caused by the soil-borne fungus *Fusarium oxysporum*. A Panama disease outbreak in the 1950s nearly brought an end to commercial Gros Michel banana production. The predominant banana cultivar at the time was the Gros Michel, but Fusarium wilt caused massive losses and compelled growers to move to more resilient varieties. The production of the Cavendish banana, which is currently the most popular cultivar, has been endangered since the 2010s by a fresh epidemic of Panama disease brought on by the strain Tropical Race 4 (TR4). Among the most devastating plant diseases of the contemporary era is Panama disease (Stover, 1962; 1987). It was first documented in Australia in 1876 (Ploetz, 2000), and it is thought to have originated in Southeast Asia (Dita *et al.*, 2018). It was not until the early 1900s that the disease started to negatively impact banana plantations in Panama and Costa Rica that it garnered international notice (Hansford, 1923). It had spread to every location in the world that produced bananas by 1950.

If the disease is not detected and treated at an early stage, it might result in a 100% yield loss (Ploetz, 2015). Fungus enters the plant through the root and settles in the xylem vessels, which blocks the flow of water. Initially it appears to be a light yellow tint and later on, it takes on a black appearance. Its shape is asymmetrical, the young leaves' margins are pale and the leaf blades are warped. Wilting, which turns the border of the elder leaf yellow, is the initial symptom (Narayanan *et al.*, 2022). From older to younger leaves, the leaf yellowing develops. A "skirt of death" is formed when the leaves progressively die, bend at the petiole, usually near to the midrib and hang downward. Younger leaves typically display symptoms last and frequently continue to stand unnaturally upright, like bristles. An infected plant continues to grow and the newly emerging leaves are light in color. The lamina of an emerging leaf may be noticeably shrunken, twisted and decreased (Dita *et al.*, 2014).

Black sigatoka disease

It is known as a *Mycosphaerella* induced black leaf streak. After discovering it in 1963, black sigatoka was given its name due to its resemblance to yellow sigatoka, which is caused by *Mycosphaerella musicola* and was named after the Sigatoka Valley in Fiji. Between 1912 and 1923, a disease outbreak in the same valley reached pandemic situations. Tiny reddish-rusty brown flecks, which are most noticeable on the underside of leaves, are the first signs of a leaf. Leaf streaks that are reddish-brown, dark brown or black are formed by them gradually getting longer, wider, and darker. On the underside of the leaf, the early streaks are more noticeable and run parallel to the leaf veins. Fijians believe that the sigatoka infection is a complex collection of closely related fungi. Large infected lesions on leaves will start to collapse, which prevents photosynthesis and therefore leading to chlorosis followed by death. The lesions appear rusty brown when they are first infected. Further development causes them to darken and evolve into drooping of leaves (Narayanan *et al.*, 2022). Depending on how severe the disease infection is, this can reduce the yield by 30 to 50% (Yonow *et al.*, 2019). The most typical treatments for it involve spraying carbendazim, propiconazole, mancozeb and tempol three times over a period of 10 to 15 days. In light of this, it is crucial to identify pathogens and diseases early on (Saleem *et al.*, 2019). Hence, hybrid CNN and SVM models (hybrid convolutional neural network - support vector machine) based on deep learning are created for the purpose of identifying and categorizing the aforementioned prevalent disease seen in banana leaves. This aids in early disease detection and classification of its type (Lopez *et al.*, 2020).

Leaf spot disease of banana, caused by Curvularia lunata

Between December 2021 and January 2022, leaf spot disease was observed on leaves of field-grown banana plants in Sarai, Raiganj, Uttar Dinajpur District and West Bengal. Symptoms first appeared as yellowish brown spots in the middle and margin of leaves. The fungus was identified as *Curvularia lunata*. Disease symptoms developed within 5 days on inoculated detached leaves,

and *C. lunata* was reisolated from the infected spots. This is the first report of *C. lunata* affecting banana from Sarai, as reported by Chowhan and Chakraborty (2022).

Details of leaf disease of Banana crops caused by different fungal pathogens are provided in **Table 1**.

Table 1: List of causal organisms causing leaf diseases in banana plants

<i>Fungus name</i>	<i>Host</i>	<i>Disease</i>	<i>References</i>
<i>Fusarium oxysporum</i>	Banana Leaf (<i>Musa acuminata</i>)	Panama disease	Jones <i>et al.</i> , (2000)
<i>Alternaria alternata</i>	Banana Leaf (<i>Musa acuminata</i>)	Leaf spot	Majid <i>et al.</i> , (2014)
<i>A. alternaria</i>	Banana Leaf (<i>Musa acuminata</i>)	Leaf spot	Majid <i>et al.</i> , (2014)
<i>Cercospora musae</i>	Banana Leaf (<i>Musa acuminata</i>)	Leaf spot	Majid <i>et al.</i> , (2014)
<i>Fusarium sambucium</i>	Banana Leaf (<i>Musa acuminata</i>)	Leaf spot	Majid <i>et al.</i> , (2014)
<i>Drechslera gigantean</i>	Banana Leaf (<i>Musa acuminata</i>)	Leaf spot	Majid <i>et al.</i> , (2014)
<i>Mycosphaerella fijiensis</i>	Banana leaf (<i>Musa paradisiaca</i>)	Black sigatoka	Amara <i>et al.</i> , (2017)
<i>Pseudocercospora fijiensis</i>	Banana Leaf (<i>Musa acuminata</i>)	Black leaf streak	Caucasella <i>et al.</i> , (2018)
<i>Alternaria alternata</i>	Robusta Banana Leaf (<i>Musa acuminata</i> cv. Giant Cavendish, AAA Group)	Leaf spot	Wang <i>et al.</i> , (2022)
<i>Curvularia lunata</i>	Banana Leaf (<i>Musa paradisiaca</i>)	Leaf spot	Chowhan and Chakraborty (2022).

FRUIT DISEASES OF BANANA

Compared to other matured fruits, bananas are highly nutritious and have a very limited shelf life because they are seasonal and tropical fruits. Mature fruits have a high rate of loss due to their susceptibility to several postharvest diseases (Maqbool *et al.*, 2011).

All nations that produce bananas are impacted by the complex postharvest disease known as crown rot, which affects export bananas. Crown rot is the name given to the infection that starts in the peduncle area during harvest. But the symptoms appear gradually during the ripening and shipping process. The fruit eventually detaches due to the fungal complex's softening and darkening of the crown region. The tissues that connect the fingers to one another, known

as the crown, are impacted by this disease, which is characterised by rot and necrosis. When crown rot is severe, it can spread to the pedicel and even the pulp of the banana. Bananas that were treated and those that weren't have losses ranging from 10% to 86%, respectively (Lassois and Lapeyre, 2014).

Although a variety of organisms can cause banana crown rot, *Colletotrichum musae* is usually regarded as the most harmful and most frequently isolated fungus. Crown rot disease is the term used to describe the deterioration of the crown (chock) of banana fruits. Several fungal species, either alone or in combination with other species, have been identified to be responsible for the development of complicated crown rot disease. *Lasioidiplodia*

theobromae and *Fusarium* species are also reported as fungal pathogens, responsible for crown rot disease (Merve *et al.*, 2022; da Silva *et al.*, 2024). *Fusarium verticillioides*, *F. oxysporum* and *F. proliferatum* are the most frequently identified *Fusarium* species responsible for crown rot. Some common banana fruit pathogens are *Fusarium oxysporum*, *F. semitectum*, *F. verticillioides*, *F. subglutinans*, *F. sambucinum*, *F. moniliforme*, *Colletotrichum musae*, *Acremonium* sp. (Marjid *et al.*, 2014).

Botryodiplodia theobromae is found to be associated with finger rot disease (Ploetz *et al.*, 1994). When fruits are overripe, *Aspergillus niger*

produces light brown discoloration on peel and rotting pulp (Ali *et al.*, 2021). When fruits are fully ripped or at the point of over ripeness, *Curvularia* sp. forms tiny pinkish or blackish patches but do not infect the pulp. The infection is gradually expanded in size and finally pericarp portion is affected (Khan and Javaid, 2020). Another fungal isolate- *Acremonium* sp. causes dark internal rotting near the fruit's bloom end (Nath *et al.*, 2015).

Details of fruit diseases caused by different pathogens in Banana crop are provided in **Table 2**.

Table 2: List of causal organisms causing fruit diseases in banana plants

<i>Fungus name</i>	<i>Host</i>	<i>Disease</i>	<i>References</i>
<i>Musicillium theobromae</i>	Fruit (<i>Musa acuminata</i>)	Cigar-end rot	Majid <i>et al.</i> , (2014)
<i>Fusarium subglutinans</i>	Fruit (<i>Musa acuminata</i>)	Anthracnose Fruit	Majid <i>et al.</i> , (2014)
<i>F. verticillioides</i>	Fruit (<i>Musa acuminata</i>)	Tip-end rot	Majid <i>et al.</i> , (2014)
<i>F. oxysporum</i>	Fruit (<i>Musa acuminata</i>)	Rot	Majid <i>et al.</i> , (2014)
<i>F. proliferatum</i>	Fruit (<i>Musa acuminata</i>)	Cigar-end rot	Majid <i>et al.</i> , (2014)
<i>F. semitectum</i>	Fruit (<i>Musa acuminata</i>)	Tip-end rot	Majid <i>et al.</i> , (2014)
<i>M. theobromae</i>	Fruit (<i>Musa acuminata</i>)	Cigar-end rot	Majid <i>et al.</i> , (2014)
<i>F. verticillioides</i>	Fruit (<i>Musa acuminata</i>)	Tip-end rot	Majid <i>et al.</i> , (2014)
<i>Cylindrocarpon</i> sp.	Fruit (<i>Musa acuminata</i>)	Speckle	Majid <i>et al.</i> , (2014)
<i>M. theobromae</i>	Fruit (<i>Musa acuminata</i>)	Tip-end rot	Majid <i>et al.</i> , (2014)
<i>F. semitectum</i>	Fruit (<i>Musa acuminata</i>)	Cigar-end rot	Majid <i>et al.</i> , (2014)
<i>F. oxysporum</i>	Fruit (<i>Musa paradisiaca</i>)	Crown rot	Faruk <i>et al.</i> , (2021)
<i>F. proliferatum</i>	Fruit (<i>Musa paradisiaca</i>)	Crown rot	Faruk <i>et al.</i> , (2021)

<i>Fungus name</i>	<i>Host</i>	<i>Disease</i>	<i>References</i>
<i>F. verticillioides</i>	Fruit (<i>Musa paradisiaca</i>)	Crown rot	Faruk <i>et al.</i> , (2021)
<i>Aspergillus fumigatus</i> , <i>Aspergillus flavus</i> <i>Aspergillus niger</i>	Fruit (<i>Musa paradisiaca</i>)	post-harvest fruit rotting	Ali <i>et al.</i> , (2021)
<i>Curvularia lunata</i>	Fruit (<i>Musa acuminata</i>)	post-harvest fruit rotting	Khan and Javaid, (2020)

CONCLUSION

Banana is a crop that is grown all over the world and it is important to prevent them from becoming infected with dangerous diseases including banana *Fusarium* wilt (BFW) and banana black sigatoka (BBS). In this review, a comprehensive deep learning-based approach has been suggested for identifying and categorizing the banana disease especially focusing on leaf and fruit diseases. *Cercospora musae*, *Fusarium verticillioides*, *F. semitectum*, *F. sambucinum*, *F. moniliforme*, *M. theobromae*, *Curvularia lunata* are found to be the major causal organisms for causing fruit infections. On the other hand, *Drechslera gigantean*, *Alternaria alternata*, *Fusarium proliferatum* are reported as leaf disease causing fungal pathogens in banana plants.

CONFLICT OF INTEREST

No competing interests are reported among the authors.

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