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Management of mango anthracnose: An overview

Nallamani M[1], Mohammed Bahurudeen H[1], Sobanbabu G[2*], S Suguna[2]
[1] UG Scholar, Department of Plant Pathology, Roever Agriculture College Perambalur, Tamil Nadu, India
[2] Assistant Professor, Department of Plant Pathology, Roever Agriculture College Perambalur, Tamil Nadu, India

Abstract
Mango is one of the most important seasonal fruit crop in tropical and subtropical regions. It has affected by various biotic and abiotic stress which reduce the yields and quality of fruits. The major fungal pathogen has *Colletotrichum gloeosporioides* (also known by *Glomerella cingulate* var. minor) responsible for the cause of Mango Anthracnose. The disease has caused in both pre and post harvesting conditions. Spore production is favored by wet or humid weather. This disease mostly affects during post- harvest stage and cause poor quality of fruits. This study will discuss about the causes, identification and various strategical approaches in recent years to manage the disease incidence during pre and post-harvest stage.

Keywords: mango, anthracnose, *Colletotrichum gloeosporioides*, management

Introduction
The Mango (*Mangifera indica* L.) is a climatic fruit belongs to family: Anacardiaceae. The trees grows best in well-drained sandy loam soil. It does not grow in heavy wet soil. The optimal pH of the soil should be 5.2 to 7.5. Mango is a perennial, branching, evergreen tree approximately 30-40 feet tall. Its fruit is large, fleshy drupe containing a laterally compressed stone housing the seed. Mango cultivars vary considerably in fruit size, color, shape, flavor, texture and taste (Nelson, 2008) [10]. It is native to India and Southeast Asia. It is one of the five most economically important worldwide, with production occurring in most countries in tropics and subtropics (Tovar-Pedraza *et al*., 2020) [16]. India is the first largest producer of mango with 24.7 million tonnes of production followed by Indonesia. Mango has affected by many fungal, bacterial and viral diseases cause maximum yield loss and fruit quality.
Anthracnose disease of mango is one of the major pre- and post- harvest disease of mango throughout the world (Uddin *et al*., 2018) [17]. Varieties like Alphonso and other cultivars of mango is most prone to anthracnose caused by *Colletotrichum gloeosporioides* (Manasa *et al*., 2018) [9]. The pathogen also causes blossom blight, leaf blight, and in severe cases tree dieback. The post- harvest phase is the most economical phase. In this case, the disease were effectively managed by using some fungicides. The fungicides are thiram, azoxystrobin, trifloxystrobin, fluazinam, prochloraz, difenoconazole, metconazole, pyraclostrobin and tebuconazole and some biocontrol agents are involved to manage the disease. The biocontrol agents such as *Bacillus* spp, *Pseudomonas* spp, etc., alternative method for fungicides and also effective to plant disease management. It doesn't cause any environmental and health hazardous to human (Liang *et al*., 2022) [8]. In this article we have focus about management of anthracnose disease by different methods.

Etiology
Some species of *Colletotrichum* are responsible for causing anthracnose in tropical fruits. (Silva *et al*., 2013) [14]. The mango anthracnose is caused by fungus *Colletotrichum gloeosporioides* Penz and Saac. (Nelson, 2008) [10]. It belong to phylum: Ascomycota, class: Sordariomycetes, order: Glomerellales, family: Glomerellaceae, genus: *Colletotrichum*, species: *gloeosporioides* (Chen *et al*., 2015) [2]. The name *C. gloeosporioides* was proposed for the first time in Penzig, Poland in the year 1882 based on the type specimen *Vermicularia gloeosporioides*, collected from citrus in Italy (Jenny *et al*., 2019) [19]
The infection begins after flowering or in the last stage of fruit development, during wet period. The pathogen enters into the host by invasion with aid of appressoria or by injury. The symptoms occurs all part of the plant. More than 95% humidity and 20 – 30°C is required for spore germination and for the formation of appressoria. (Silva *et al*., 2013) [14]. Panicle burning occurs during flowering if the relative humidity is 95 to 97% therefore no setting of fruits occurs. During rainy season the anthracnose development is high in inflorescence and younger leaves.

Symptoms
During pre-harvesting period the typical symptoms are sub-cuticular and angular black lesions develop on stems, leaves and inflorescences which enlarged and coalesced to destroy the leaf edges or whole inflorescences (Kamle *et al*. 2013) [7]. At postharvest stage, initially water soaked lesions develop on fruit surface that become soft and sunken. The appearance of anthracnose spot is rounded brown to black lesions with an indefinite border on the fruit surface. The lesion size extends to 2 cm is common. Different sized lesions are coalesced together to cover the extensive areas of the fruit, which develops from the basal toward the distal end of the fruit. Lesions are generally confined to the peel. However, in severe cases the fungus could invade the pulp (Jenny *et al*., 2019) [19].

Leaves
Brown, rounded or irregular lesions. With the increase in lesion size, coalescence and breakup of the limb occurs (Fig. 1).


Brown, rounded or irregular lesions


Increase in lesion size, coalescence

Fig 1: Typical symptoms in leaves

Flowers

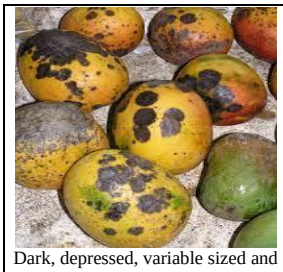
Panicle anthracnose or blossom blight can affect both the inflorescence stalk and the individual flowers. In the stalk, elongated dark gray to black lesions appear. Blighted flowers are dry, and their color varies from brown to black. Deep dark spots, causing the death of flowers. Fruits may fall (Fig. 2).


Deep dark spots, death of flowers

Fig 2: Typical symptoms in inflorescence

Fruits

Dark, depressed, variable sized and generally round lesions. Lesions may coalesce to involve the whole fruit, sometimes causing cracks in the bark. Fruit smaller than pea-size can be infected and aborted. Larger fruit that are aborted because of normal self-thinning or due to other physiological causes are usually mummified. Mummies are invaded saprophytically by *C. gloeosporioides*, and the fungus sporulates abundantly on them. Mummified mango fruit attached to the tree, showing sporulation of *Colletotrichum gloeosporioides* (Arauz, 2000) [1] (Fig. 3).


Dark, depressed, variable sized and generally round lesionS


Mummified mango fruit

Fig 3: Typical symptoms in fruits

Pathogen character

The fungus *Colletotrichum gloeosporioides* which cause anthracnose in mango produce white to greyish colonies on PDA medium and bears septate mycelium. Conidia are hyaline, unicellular and cylindrical or dumbbell with rounded ends containing one or two oil globules towards end of conidium (Shivakumar *et al*., 2015) [12].

Mode of disease spread

Mango anthracnose is caused by the fungus *Colletotrichum gloeosporioides*. Wet or humid weather favours spore production. The formation of conidia on the mango canopy is considered to be the primary source of inoculum. In the field *C. gloeosporioides* produces conidia on lesions on leaves, twigs, panicles and mummified fruits. Conidia are spread through rain splash to other leaves or flowers (Arauz, 2000) [1]. Post- harvest anthracnose is caused by spores remains in the developing fruits while in field condition and infect during onset of ripening.

Management of anthracnose

1. Pre-harvest stage

In pre harvest stage management practices include cultural practices and chemical application. In case of cultural practice field sanitation by collecting fallen fruits and leaves followed by burning is essential to control anthracnose (Jenny *et al*., 2019) [19].

1.1 Integrated crop management

Pruning + weeding + spading + fertilizer application + Dithane M-45 (3 times) + irrigation at 14 days interval. By following this method 94% of fruits are produced as disease free fruits (Chowdhury and Rahim, 2009) [3]

1.2 Chemical method

In chemical application, chemicals like benzimidazoles such as thiabendazole, benomyl, and Carbendazim and sterol inhibitors such as imazalil, prochloraz, and propiconazole have long been used to effectively control anthracnose disease (Zakaria, 2021) [19].

Pre-harvest sprays of azoxystrobin at 0.1 % significantly minimised the field inocula (24.54 %) on mango leaves and thereby reduced the latent infection and manifestation of the anthracnose disease (3.3 %) on fruits at postharvest stage (Manasa *et al*., 2018) [9].

Application of mancozeb at 0.25% inhibits 89.38% of fungal growth and 0.3% of propineb inhibits 58.57% of fungal growth (Iqbal *et al*., 2022) [5].

1.3 Biological method

Application of *T. harzianum* isolate 1 at 5% concentration of three sprays starting with initiation of disease followed by other two sprays at an interval of fifteen days, were the most effective and reduced the disease to an extent of 59.91, 54.77% disease control on leaves and 56.57, 52.66% disease control on fruits (Sharma *et al*., 2021) [11].

The *Lactobacillus* isolates are effective against *C. gloeosporioides* and inhibits the mycelial growth. *Lactobacillus* isolates produces extracellular enzymes to degrade the mycelia of the pathogen (Fenta and Kibret, 2021) [4]

2 Post-harvest management

2.1 Chemical method

Benomyl is used for the effective control against quiescent infections of anthracnose of mango. Recently prochloraz is proved to control anthracnose in hot or cold dips, but less effective than a hot benomyl dip. Other fungicides have been also used successfully for certain mango varieties including thiophanate-methyl and hot imazalil. The postharvest dips of fruit are considered as moderately effective against mango anthracnose. The Hot water dips alone can significantly reduce anthracnose development, but fruit can show signs of heat damage under some conditions of storage Hot water treatment of 55 and 60°C was found effective against post-harvest anthracnose of mango (Uddin *et al*., 2018) [17].

Hot water dip for 52-53°C effectively control anthracnose and hot water treatment with prochloraz fungicide (550µL) Will completely control mango anthracnose at post-harvest stage (Urquiola *et al*., 2022) [18].

2.2 Biological method

Fruit dip treatment of *T. harzianum* for 5 min is the most effective and provided disease control to the tune of 81.67%. Combine application of effective bio-control agents like treatment of *T. harzianum* + *Pichia anomala* was very effective with 93.39% control of mango anthracnose at post-harvest stage (Sharma *et al*., 2021) [11]. Bacterial bioagents *P. fluorescens* and *B. subtilis* are most effective in reducing the anthracnose symptoms on fruits and recorded the minimum percent disease index PDI (%) of 37.70% and 33.81% (Sudha *et al*., 2021) [15].

3. Nano particles

Nanomaterials, such as copper, silver, nickel, and magnesium, have antifungal properties and may be effective at managing anthracnose pathogens and post-harvest disease. Composites Inhibits conidial germination of *C. gloeosporioides*. Nanomaterials composite with other materials can also control mango anthracnose. When chitosan-silver composite (495–616 nm diameter) is used, which suppressed *C. gloeosporioides* conidial germination. An *in-vivo* study reported that 0.5% and 1% nanomaterial composite reduced anthracnose disease by 45.7% and 71.3%, respectively. Neem extract is used to synthesize copper oxychloride conjugated silver (21–25 nm) and treat *C. gloeosporioides*, resulting in pathogen growth suppression (Zakaria, 2021) [19].

Carbendazim- conjugated silver nanoparticles (Cz-AgNPs), a spherical shaped nanoparticle ranges from 19-24nm found to be effective against the pathogen *Colletotrichum gloeosporioides* which cause mango anthracnose (Nagaraju *et al*., 2020) [13].

Conclusion

Mango anthracnose caused by *Colletotrichum gloeosporioides*, occurs during pre and post- harvest stages cause major economical loss to the producer. It can be controlled in pre- harvest stage to avoid loss in post- harvest stage by applying synthetic fertilizers but they are harmful to both environment and human beings. Use of bio-control agents are the most effective and safest method to control mango anthracnose. Eucalyptus and neem extract are also used to control anthracnose in mango. The anthracnose of mango can be controlled by having proper knowledge about the pathogen and its management in environmentally, healthier manner.

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