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Chapter

# Anthracnose Disease of Mango: Epidemiology, Impact and Management Options

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## Abstract

Mango is one of the frequently cultivated seasonal fruit crops in several tropical and subtropical regions. It is consumed as whole fruits apart from serving as raw materials for most industries that are into mineral production. Mango production is, however, constrained by diseases, pests, and poor post-harvest handling of fruits. Anthracnose disease, caused by *Colletotrichum gloeosporioides* Penz and Sacc, is one of the most important yields limiting constraint in mango production across the globe. The disease occurs in both the field and post-harvesting. In the field, it affects aboveground parts, such as the stem, branches, leaves, flowers, and fruits. Anthracnose disease reduces the shelve life and marketability of mango fruit. In Ghana, anthracnose disease is responsible for about 30% yield/fruit loss. Most farmers do not control it, although some have resorted to the application of various fungicides not registered for mango anthracnose disease management in Ghana. This chapter will highlight on the importance of the disease on the mango industry in Ghana, control strategies currently employed thereby reducing the over-reliance on chemical control option and propose ways to minimize the effect of the disease in the country.

**Keywords:** aetiology, anthracnose, botanicals, *Colletotrichum* spp., epidemiology, mango

## 1. Introduction

Mango (*Mangifera indica* L) is a major fruit crop with an immense economical relevance in Ghana. Due to the special qualities of its fruits, it is also considered as one of the most frequently considered fruits in various fruit markets across the global. Some of the qualities mango are delicious taste, beautiful colour, excellent carotene content, excellent flavour and attractive flavour [1]. The crop is known to contribute up to a half of the overall tropical fruits that are produced globally [2]. Africa contributes about 10–15% of the total mango produced per annum. In Ghana and other neighbouring countries, the crop serves as one of the most frequent non-traditional fruits exported to other countries. Mango in Ghana is currently in high demand in the form of both fresh and dry fruits, juice and flavours, and jams. In as much as mango production in Ghana and other production countries has seen some increase in recent times, it is frequently faced with challenges such as pests and diseases attack. One of the most devastating diseases is the anthracnose disease. The mango anthracnose disease caused by *Colletotrichum gloeosporioides* Penz and Sacc is a major fungal disease of economic importance to mango production across the globe [3–6]. To manage this menace, various strategies has been adopted by various stakeholders in the mango production value chain [7]. These strategies ranges from pre-harvest to post-harvest. Both the pre-harvest and post-harvest control measures are successfully implemented through proper field hygiene, after harvest treatments or a combination of the two. However, the management strategy chosen at any point by an individual must be consumer friendly, economical, and environmentally friendly. In composite, these management strategies can further be categorised into cultural, chemical, biological, use of resistant cultivars, and/or their integration [7].

## 2. Impact of anthracnose on mango production in Ghana

Different kinds of diseases affect productivity of several plants contributing significantly to global food/fruit shortage. Destructions/Catastrophe caused by the outbreak of plant diseases in multiple plants as well as its impact on humans such as starvation, malnutrition and death have been well publicized. In Ghana, the impact of diseases on tree and horticultural crops have been reported and well documented. Mango production in Ghana has gained prominence in recent times with the projection of overtaking cocoa as the most economically valuable crop. The potential gains due the country from mango production is however, threatened by the existence and outbreak of multiple diseases due to the crop's susceptibility to several fungal pathogens. Mango is highly susceptible to diseases due to the high water-nutrient content which serves as a perfect media for fungal pathogen development [8]. Production and export of mango in Ghana keeps dwindling due to the prevalence and severity of diseases such as the anthracnose [9]. Among the many diseases limiting mango production is the Anthracnose disease caused by the fungus *Colletotrichum gloeosporioides* Penz. & Sacc. It is a major limitation to mango production as it has been reported to has led to a yield loss of 30% in the Yilo Kobo District of Ghana [10]. Similarly, about 39% yield loss in mango production in India has been attributed to anthracnose disease [11]. The disease is so devastating in crop production that it has also been reported that 60% of harvested avocado fruits affected by the disease were discarded and rendered unmarketable in Kenya [12].

Although the disease leads to massive losses in the field, the most significant loss occurs during post-harvest conditions. The post-harvest damage due to the disease is of more interest and economically relevant because it reduces the fruits quality as well as shelf life which invariably affects standard for the export market. This pose great challenge to various actors along the value chain especially those involved in international trade as low-quality fruits cannot be marketed on the international market. Although in some instances, producers and traders may sell these low-quality fruits on the local market, differences in revenue from export and local markets leads to serious economic loss to all stakeholders as well as mango exporting countries like Ghana as they are denied of foreign exchanges.

Attempts to mitigate the effects of anthracnose disease on mango production have centred mainly on the employment of conventional pesticides to treat trees and even fruits at harvest and storage. Although effective in minimizing the severity of the disease, this strategy is limited due to the growing negative concerns associated with fungicides on the environment, human health and rapid surge in antifungal resistance by several pathogens. In addition to these, is the high cost of these pesticides leading to increased cost of production to the farmer and reduced income which can further increases poverty in the rural economy.

## 3. Aetiology and epidemiology of anthracnose disease of mango

### 3.1 Aetiology of anthracnose disease of mango

Anthracnose disease of mango is one of the serious diseases of mango worldwide as it affects the crop from nursery through growth (pre-harvest) to harvested fruits (post-harvest) [11, 13, 14]. Many reporters have confirmed that two closely related species of Colletotrichum are involve in disease initiation and development. These species are *Colletotrichum gloeosporioides* Penz and Sacc. (Teleomorph: *Glomerella cingulata*) and *Colletotrichum acutatum* (Teleomorph: *Glomerella acutata*) [15–17]. In Ghana, literature has predominantly reported that the *C. gloeosporioides* is the causal agent of the disease [18, 19].

### 3.2 Epidemiology and disease cycle

The disease initiation, growth and development of the pathogen are influenced greatly by the nutritional and environmental factors of the host plant (Mango). Among the nutritional factors are sources of nitrogen and carbon [20] whereas the environmental factors for disease development wet, humid, hot weather [21] as well as pH and Temperature [20]. The pathogen is also considered generally inactive in dry weather [3].

It is reported that the source of primary inocula of the disease if the abundance of conidia in the tree canopy [3]. The disease attacks every part of the plant i.e. young nursery seedling leave and twigs, young flowers/flower clusters (panicles), young fruits as well as mature fruits. The cycle of the disease begins with the dissemination of the conidia (asexual spore) of the pathogen which are dispersed passively through rain splashes or irrigation water. The plant is inoculated when conidia land on the infection courts or sites (most of which are above ground parts of the plant). Infection and disease development are also achieved on young and immature fruit and tissues, conidia are germinated and penetrated in the cuticles and epidermis to ramify through the tissues. On mature fruits, infections occur immediately when spores penetrate the cuticle. However, they remain at a latent state until climacteric fruit ripening begins. During disease symptoms development, black, sunken, rapidly expanding lesions develop on affected organs. On leaves, symptoms are seen as small, brown-to-black lesions on most affected parts.

On fruits where major destruction occur both in pre and post-harvest, symptoms of black/dark is visibly as well as slightly sunken lesion with irregular shape, then gradually enlarges and subsequently causes fruit rot. The first appearance of symptoms as spots usually coalesces and penetrate deep into the fruit, resulting in extensive fruit rotting. In most green fruits, infections remain latent and largely invisible until ripening, that fruit that appear healthy at harvest can develop significant symptoms upon ripening. The second symptom type of the fruit is one that commonly refers to as an "alligator skin" in which on the fruits consist of a "tear stain" symptoms, in which appear a linear necrotic region on the fruits that experience superficial cracking of the epidermis. Lesions on stem and fruits may produce visible, pinkish-orange spore masses under wet conditions. During reproduction of the pathogen, sticky masses of conidia and production of fruiting bodies (acevulli) on symptomatic tissues during humid conditions. Repeated cycles of the disease may occur as a result of continuous multiplication of the fungus during the season which can serious epidemics. In the absence of favourable conditions, the pathogen overwinters in plant debris such as defoliated leaves, dead branches and other volunteer tree species.

## 4. Management strategies of mango anthracnose disease

### 4.1 Cultural control

One of the main conditions that favours the development of the mango anthracnose is high humidity. It is therefore important to establish mango orchards in areas with a well-defined dry season. This creates an unfavourable condition for the development of the disease [12]. In most tropical regions, flowering in mango plants occurs usually in the dry seasons. Nevertheless, this is dependent on other factors such as photoperiodism, growth stage of the shoot, specie of the mango, ambient temperature, as well as the nutritional state of the soil under cultivation. This brings some level of variations in the flowering period of mango from region to region. It has been noted that a very early flowering, usually before the dry season leads to a huge infection of the disease due to the higher relative humidity at the time of fruit formation and establishment [22, 23]. From another standpoint, a worst scenario of infection is seen when mango trees flower at the latter part of the dry season or when early-stage fruit development coincides with the peak of the raining season [24]. This can lead to a disease incidence of up to 90% in such occasions. For proper anthracnose disease management in the tropics, a plausible approach must be adopted to avoid situations where flowering an early-stage fruit development will coincide with the rainy season. A proper adherence to this approach could cumulatively, leads to a disease incidence and severity near zero present. However, despite the effectiveness of this strategy, it is near inapplicable in the subtropical regions where the main stimulants for flowering in mango is atmospheric temperature rather than lower water deficit. One of the most effective ways of managing the incidence and severity of this disease in these areas is the foliar application of a growth and flowering retardant (e.g. Paclobutrazole) either singly or in combination with potassium nitrate [24, 25]. By that, flowering in mango can be advanced by several days or weeks. Furthermore, traditional cultural practices such as the removal and proper incineration of infected plant parts such as fruits, branches, leaves among others can also be reliable in the cultural management system of mango anthracnose disease. In addition, practices such as removal of dry, infected, or malformed panicles and fruits can serve as one of the effective ways of managing the disease. However, these later practices can be laborious and time consuming on large area farms. Research has also revealed that wrapping of young developing fruits in paper bags as a way of creating barriers between the fruits and any possible inoculum of the disease can immensely reduce the incidence and severity of the disease. However, his method can also reduce the bright red/yellow colour observed in ripped mangoes. This, on a broader perspective could insinuate that choosing a particular method or practice in managing the disease could highly depend on the objective and the target market of the farmer. For example, most industries that would rather prefer chemical free fruits to bright coloured ones will rather appreciate this approach as compared to the application of various synthetic fungicides other methods such as chemicals.

### 4.2 Resistant varieties

The use of cultivars that are resistant to disease has always been one of the most effective and economical ways of managing diseases in many crops, including mango. However, in mango, several studies have shown that most cultivars that are commercially available to farmers are susceptible to the disease. Nevertheless, some experiments in controlled environments have reported that there are some few genotypes with some considerable levels of resistance to the mango anthracnose disease (**Table 1**). These traits can be harnessed in future breeding intervention to development some potential cultivars with higher resistance to the disease [26].

### 4.3 Chemical control

Just like in most scenarios, the application of chemicals seems to be one of the most effective and fastest ways of managing the mango anthracnose disease. Nevertheless,

| Name | Designation | Country |
|---|---|---|
| 'Carrie' | R | Australia |
| 'Caraboa Florigon' | R | Australia |
| 'Tommy Atkins' | R | Australia |
| 'Saigon' | R | Australia |
| 'Kensington Pride' | MR | Australia |
| 'Palmer' | R | Philippines |
| 'Siam' | R | Philippines |
| 'Velei-Colomban' | R | Philippines |
| 'Joe Welch' | R | Philippines |
| 'Fernandin' | MR | Philippines |
| 'Arumanis' | MR | Philippines |
| 'Edward' | MR | Philippines |
| 'Gedong | MR | Philippines |
| Tjenkir' | MR | Philippines |
| Paris', 'Fairchild | R | Hawai'i |
| 'Rapoza' | R | Hawai'i |
| 'Haden' | MR | Hawai'i |
| 'Zill' | R | Florida |

*R = resistant; and MR = moderately resistant.*

**Table 1.**
*Mango cultivars resistant to the anthracnose disease [21].*

under severe pressures, one has to conduct up to 25 applications in a season to achieve desired results. Also, the choice of fungicide is also dependent on the variation in requirements of proposed destination or purpose of the fruit. For example, Dithiocarbamate (an effective active ingredient for anthracnose disease control) produces ethylene thiourea (ETU) as a bio-product. Due to this, fruits that has a history of the application of ethylene-bisdithiocar- bamates such as mancozeb and maneb are prohibited in the United States. Most frequently, copper fungicides are recommended for the control of most fungal disease, which the mango anthracnose is not an exception. In as much as some success stories has been documented, there are also contrasting studies that has revealed that under higher disease pressures, copper-based fungicides are usually less effective as compared to the carbamates. Not only that, few reports have also reported some phytotoxicity associated with the application of fungicides of various sorts. Post-infection fungicides such as the benzimidazoles has also been used in combination with protectant fungicides such as the imidazole prochloraz to retard the build-up pressure of the mango anthracnose disease [27–29]. This chemical s usually affects the mycelia development of the fungi by supressing the synthesisation of ergosterols, a very important component of the cell membrane of a fungus [30]. One advantage for this combination is that it also retards the build-up of resistance in the population of the pathogen. Other reports have also documented the use of clarified hydrophobic neem oil (70%) to effectively control the mango anthracnose disease.

### 4.4 Biological control

Biological approach of managing disease is the use of antagonistic organisms in managing diseases. In the cases of mango anthracnose, an array of microorganisms have been postulated to have an antagonistic association on its causative agent (*C. gloeosporioides*) [31]. However, even though this looks very promising, there is no current documentation of commercial implementation of this finding. In expense, keen attention has rather been placed on the postharvest control method. Perhaps, this could be as a result of the ability to manage controlled environment conditions as compare to field situations. Nevertheless, the antagonistic potentials from such biological agents can be harnessed as an intervention to developing a more robust management approach to the disease. An example was cited in a study on the efficacy of essential oils in managing the mango anthracnose disease [32]. As all other disease management approaches, the efficacy of biological control method can be enhanced with an integration of other control measures [33].

### 4.5 Current research on the management of anthracnose disease in mango with botanicals

Anthracnose an important pre and post-harvest disease of mango infests mango parts such as leaves, twigs, flowers and fruits. The disease can dwindle the productivity of infected mango plants as well as the quality of mango fruits; hence, resulting in economic losses. There is therefore the need to manage mango anthracnose disease in order to enhance the health and productivity of mango plants and also maintain the quality of mango fruits. Several methods such as culture, use of synthetic fungicides, resistant varieties and biological have been employed in the management of mango anthracnose diseases. The use of synthetic fungicides is one of the major methods employed in managing mango anthracnose disease. However, the use of synthetic fungicides is usually accompanied with challenges such as pollution of the environmental, development of pathogenic resistance, residual toxicity and harmful effects on humans [34, 35]. The excessive and improper use of synthetic fungicides can result in the accumulation of fungicidal residue in plants and plant organs used as food which may pose health risk to consumers. For instance, the residual effects of some synthetic pesticides have been recorded in fruits of melon, guava, orange, peach and mango at levels toxic to human consumption [36]. There is therefore the need to find environmentally friendly alternatives in managing anthracnose disease of mango.

The use of botanical fungicides in plant disease management can help promote sustainable agriculture since botanicals are natural, easily biodegraded into harmless substances; hence do not persist in the environment and plant parts used as food. The antifungal activities of botanicals result from the phytochemical they contain. These phytochemicals which are secondary metabolites produced by plants in nature play an important role in the ability of plant to defend themselves against phytopathogens. Phytochemicals have antimicrobial properties [37]; hence, can prevent or reduce infection when applied on plants or plant parts.

Currently, several studies have documented the use of botanical in the management of anthracnose of mango [38–40]. At the pre-harvest of mango anthracnose disease, studies has showed that aqueous extracts leave of *Eucalyptus camaldulensis* and *Azadirachta indica* inhibited the mycelia growth of *C. gloeosporioides in vitro* and also under field conditions, the foliar application of the extracts reduced the incidence and severity of anthracnose on mango plants [38]. Furthermore, literature has also reported that mango fruits treated by dipping in aqueous extracts of *Ruta chalepensis* at concentration of 50 grams of the powdered plant material in 100 ml of distilled water before storage remarkably reduced the occurrence of anthracnose disease, maintained the quality and marketability of the fruits [41]. Some botanicals in comparison to synthetic fungicides have exhibited an equivalent level of antifungal activity against *Colletotrichum* spp. For instance, studies has showed that essential oil of basil leaves inhibited the mycelia growth of *C. acutatum* that caused anthracnose disease in fruits of mango cat hoc variety, and also significantly reduced the incidence and severity of anthracnose on the mango fruits comparable to those treated with the synthetic fungicide Tolent 50 WP (Prochloraz) [40].

Botanicals can be used for the eco-friendly management of both the pre- and post-harvest anthracnose disease of mango [39]. Their studies reported that the pre-harvest anthracnose disease of mango was effectively controlled by the foliar application of aqueous extracts of *Azadirachta indica, Eucalyptus camaldulensis, Allium sativum, Zingiber ofcinale* and *Calotropis procera,* and at the post-harvest stage, mango fruits sprayed with the botanicals reduced the anthracnose infection of the fruits and improved their quality. Although many botanicals have exhibited some potential to be used in managing anthracnose disease of mango, the main challenge is that most of these findings have not moved beyond the research stage and as such not readily available to mango growers and marketers. To encourage the use of botanical in the management of mango anthracnose disease, there is the need to develop and register botanicals which have exhibited the potential to manage the disease into commercial botanical fungicides products which can easily be assessed by mango growers and marketers.

## 5. Postharvest treatments

Usually, fruits that are contaminated or infected with disease inoculum shortly before harvesting do not show any symptom of the disease due to latency. This state of infection at the time of harvest leads to a lethal level of the disease shortly after harvest. This leads to huge quantitative loss of the produce. As much as synthetic fungicide applications still remains as one of the most basic and effective ways of managing the disease [42], their application to the fruit after harvest seams not to be safe for human consumption as it could lead to fatality [43]. This calls for an eco-friendlier approach in managing the disease postharvest, as an effective alternative for chemical control. Various treatments are applied to the fruit to prevent or perhaps retard the development process of the disease [44]. This treatment usually has to do with temperature manipulation [45]. At the onset of ripening of the fruit postharvest, fruits can be refrigerated at 10°C to retard the development of the disease. However, it must be noted that fruits should not be chilled before ripening to reduce or avoid chilling injury and further reduce the quality of the fruit. Fruits may also be dipped in hot water (usually at temperatures 50–60°C) for a duration of up to 15 minutes [46]. The effectiveness of this method has made it to been known as one of the most effective and environmentally friendly postharvest control methods of the mango anthracnose and has been recommended by several disease control departments across the globe. Fruits may also be exposed to vapour heat, forced-air dry heat for about 3–6 hours at appropriate temperatures. However, in all these treatments, the temperature levels and duration of exposure depends greatly on the variety of the subject. Also, various treatment combinations has been found to be effective in the management of the disease [47]. For example, beromyl has been reported to be very effective in the management of quiescent infections of the anthracnose disease in mango when it is coupled with the various hot water treatments. On the other hand, prochloraz has also been found very effective when combined with cold water treatment. However, this was said to be less effective as compared to the beromyl treatment. It is also important to note that the effectiveness of any of these methods has a direct baring with the variety or cultivar. This means that in choosing a particular postharvest management method, one as to put into consideration the variety of the mango. For example, morphological feathers such as skin thickness of mango varies from variety to variety. For optimum effectiveness, treatment should be applied to varieties as may be applicable. The overall effectiveness of postharvest treatment approaches is said to be moderate in the management of the disease. This could perhaps be because treatments are only aimed predominantly at managing the disease and not as a protectant. In summary, the following treatments has been recommended to be effective for postharvest management of mango anthracnose; scrubbing with 1% NaOCl, hot water dip (50-55oC for 3–10 minutes), hot benomyl dip (500–1000 ppm), hot/cold prochloraz dip (400–l000 ppm), hot imazalil (1000 ppm), hot water +20 k RAD irradiation, hot water +75 k RAD irradiation, hot benlatc/iprodionc (1000 ppm) + 75 k RAD irradiation + waxing [48, 49].

## 6. Colletotrichum: current status and future directions

### 6.1 Colletotrichum: current status

*Colletotrichum* species are important cosmopolitan pathogens of many plant species. Globally, *Colletotrichum* can cause anthracnose disease on various types of suitable host plants at the pre- and post-harvest stages resulting in economic losses in crop production.

In the absence of the host plant, the inocula of *Colletotrichum* species can survive unfavourable conditions on plant debris, alternate and collateral hosts, and volunteer crops on harvested crop fields. There has been continuous first reports of anthracnose disease caused by *Colletotrichum* species on various plants across the world [50–53]. This indicates that the inocula of *Colletotrichum* species are persistent in the environment and expanding their plant host range; hence, remain a major threat to crop cultivation.

Cross infection of anthracnose disease caused by *Colletotrichum* species from one species of plant or its product to another has been reported [54, 55]. A great diversity of *Colletotrichum* species can cause anthracnose disease on a particular host plant and also cross infect another suitable host. *Colletotrichum* species such as *C. asianum, C. cliviicola, C. cordylinicola, C. endophytica, C. fructicola, C. gigasporum, C. gloeosporioides, C. karstii, C. liaoningense, C. musae, C. scovillei, C. siamense* and *C. tropicale* were found to cause mango anthracnose disease and also cross infect other crops [56].

Methods such as chemical, culture, biological and use of resistant varieties have been employed in the management of anthracnose disease. A major challenge confronting the management of anthracnose disease caused by *Colletotrichum* is how to properly identify closely related species of the pathogen causing the disease, since some of the *Colletotrichum* species have similar morphological characteristics and show similar symptoms on infected plants [56, 57]. To avoid the issue of improper identification, several studies have advocated the use of molecular methods for accurate identification of *Colletotrichum* species [54, 56, 57]. Accurate identification of Colletotrichum species causing a particular plant disease would aid in the proper management of the disease.

### 6.2 Colletotrichum: future directions

Anthracnose disease of plants caused by *Colletotrichum* species is real and remain a major threat to crop production now and into the future. Going forward, the general public should be sensitized about plant diseases caused by *Colletotrichum* species. This would make the general public aware of the disease and as such play a key role in managing the disease. For example, people who are conscious of the disease would help minimize the rate at which they aid in spreading the *Colletotrichum* inocula from one anthracnose infected plant or its products to another of the same species or others of different species which may also be suitable host for the pathogen.

Going forward, there is the need to properly identify the particular species of *Colletotrichum* causing a plant disease to allow for the proper management of the disease. Expects in the field of fungi identification should be consulted when identifying *Colletotrichum* species and the identified species confirmed using molecular methods. Anthracnose disease of plants caused by *Colletotrichum* species should be of public concern since it can pose a major threat to food security in the future. More studies should be conducted on the epidemiology, aetiology and sustainable methods of managing diseases caused by *Colletotrichum* species.

## 7. Conclusions

Mango anthracnose disease is one of the most important economic diseases of mango in many mango production areas across the globe. It affects the almost all above ground parts of the plant and demands both preharvest and postharvest approaches for effective management [17]. The management regimes range from timely application of appropriate fungicides on the field, smart use of traditional cultural practices, the use of resistant cultivars, to postharvest treatments such as dip treatments and refrigeration. Adequate knowledge of this disease is one of the most essential requisites in choosing the most appropriate control measure for an optimum control.

## Conflict of interest

Authors declare no competing interest.

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