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Review Article

Management of Anthracnose Disease of Mango Caused by *Colletotrichum gloeosporioides*: A Review

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Abstract

Mango (*Mangifera indica* L.), the King of the fruits, is the eighth most produced fruit over the world with a production of more than 43 million tons in Bangladesh, India, Nepal and many other tropical countries. It is an essential component of diet in many developing countries as it supplies vitamins and minerals and the demand is increasing day by day. In Bangladesh, mango ranks the first position in annual production with an average yield of 82 kg per acre. This amount is not high when compared to other mango producing countries in the world due to different pest attacks and diseases. This review was carried out to investigate the different pre- and post-harvest treatment methods used in controlling anthracnose disease with their efficiencies. Anthracnose disease, caused by *Colletotrichum gloeosporioides* is one of the most important disease of Mango in humid areas and also in Bangladesh. About 25 to 30% loses of total mango production has been reported due to anthracnose and stem end rot which can spread with rain drops. Several pre-harvest and post-harvest management approaches has been used to control this anthracnose disease of mango fruits including chemical treatments.

Keywords: Mango; Anthracnose; *Colletotrichum gloeosporioides*; Pesticides; Benomyl

Introduction

Mango (*Mangifera indica* L.) is an important fruit crop from Anacardiaceae family and it is believed to have originated within a vast area including Myanmar, Bangladesh and India. It is the King of all fruits ranking eighth position in terms of production around the world. Annual production of mango is more than 43 million tons in Bangladesh, India, Nepal and many other tropical countries [1,2]. Global Demand for fresh mango fruit is increasing day by day especially in developing countries because it is an essential component of diet and supplies vitamins and minerals [1]. In Bangladesh, mango ranks the second position in production area and first in annual production among the fruit crops which is equal to 93480 hectares of land and 1161685 tons of annual production with an average yield of 82 kg per acre [3]. The yield is not high compared to other countries like Pakistan, India and other mango producing countries in the world [4]. The reasons behind the lower yield is pest attack and diseases caused by nematode, fungi, viruses, insect, bacteria etc. At least 18 major and minor diseases of mango have been reported in Bangladesh. Anthracnose disease of mango is one of the major pre- and post-harvest disease of mango fruit throughout the world and also in Bangladesh which is caused by *Colletotrichum gloeosporioides* [5-8]. Anthracnose attacks flowers, young fruits, leaves and twigs, even this disease can also appear in the storage of mature fruits [5]. Disease symptoms appear as slightly, black, sunken irregular shape lesions, which gradually enlarge and developed, leaf spotting, blossom blight, fruit staining and rot. In Bangladesh, about 25 to 30% loses [9] of total production due to anthracnose and stem end rot. This disease spread occurs through rain drops. Thus a proper knowledge of this disease is essential for its proper management to ensure the fruitful yield because proper management of these disease is likely to increase the return from the fruit crop to the farmers. Several spray and dip treatments of chemicals are used in anthracnose disease management, some of which are more effective and others are less effective. This study has been carried out to investigate the anthracnose disease of mango fruits, pre- and post-harvest management of anthracnose and the efficiencies of different control measures.

Materials and Method

Information were collected from different scientific research papers, reports and the literatures published in different national and international journals, either peer reviewed journals or not, annual reports, periodicals, relevant books, proceedings and other sources. Electronic media was another important source of information. Information was also collected visiting the websites of different autonomous and private research institutes. Collected information from the secondary sources have been compiled systematically and chronologically.

Review of Findings

Etiology of *Colletotrichum gloeosporioides*

Colletotrichum gloeosporioides causes Anthracnose of mango is worldwide which is pathogenic to more than 470 different plants at various development stages such as mango, almond, apple, avocado, guava, Arabica coffee, cassava, dragon fruit, sorghum and strawberry [10,11]. Among these, anthracnose of mango is very important commercial prospective. Anthracnose of mango disease is caused by two species where *Colletotrichum gloeosporioides* is mainly responsible [12] and *Colletotrichum acutatum* plays very less role in few locations [13]. Another *Colletotrichum gloeosporioides* var. *minor*, is no longer recognized. High humidity and moist condition are primary factors that helps in spread and development of anthracnose disease in mango.

Figure 1: Colletotrichum gloeosporioides, the causative agent of mango anthracnose disease (a) top view of colony in a Petri dish (b) reverse view and (c) Microscopic view [14].

Disease cycle of mango anthracnose

1. **Dissemination:** Conidia (spores) of *Colletotrichum gloeosporioides* pathogen are dispersed passively by rain splashing or water during irrigation.
2. **Inoculation:** Pathogenic spores land on the sites of infection such as panicles, leaves, branch terminals [10].
3. **Infection and pathogen development:** After germination of the spores, they penetrate through the cuticle and epidermis to ramify through the tissues on immature fruits and young tissues. Infection appears after the spores penetrate the cuticle on mature fruits and remain quiescent until ripening of the climacteric fruits begins [2].
4. **Symptom and disease development:** rapidly expanding black and sunken lesions develop on affected parts of plants and fruits.
5. **Pathogen reproduction:** Sticky masses of conidia are produced in acervuli on symptomatic tissue, especially during rainy or humid weather. Many diseases can occur as the fungus continues to multiply during the season [15].
6. **Pathogen survival:** The pathogen of *Colletotrichum gloeosporioides* survives between seasons on affected and defoliated branch terminals and on mature leaves.

Symptoms of mango anthracnose

The symptoms are numerous oval or irregular vinaceous brown or deep brownish spots of various sizes scattered all over the leaf surface under damp conditions. The post-harvest anthracnose of mango incited by latent infection is developed during ripening and transportation to distant markets. The symptom appeared black round or irregular, sometimes sunken spots on the epicarp upon which salmon buff masses of spores developed [10]. As the fruits ripe, these spots may extend over whole surface accompanied by

Figure 2: Anthracnose disease cycle of Mango [16].

the fruit softening and rotting. Under moist conditions, the blackened areas become covered with minute pinkish reproductive bodies of the fungus, staining, russetting and tear streaking [17]. Conidia of *Colletotrichum gloeosporioides* produces and develops on mummified inflorescences, panicles, branch terminals, twigs, flower bracts, mummified fruit and leaves are main sources of fungal inoculum [15,16]. Their production is most in free moisture condition and lower at relative humidity percentage of 95%. Conidia are spread by rains plash and for infection it requires free moisture [16,18]. As appressoria age, they become melanized. It strengthens the appressorium and helps in penetration of the cuticle by infection pegs that the appressoria produce [19]. Small fruit, disease can produce minute brown spots and abort if infected early in their development. Once an appressorium is developed and fruit exceed 4 - 5 cm in diameter in size, infections stop development. Quiescent infections restart development once concentrations of preformed fungal inhibitors in fruit declining during ripening. On larger fruit, lesions can be developed anywhere, but linear smears that radiate from the stem end to the apex of mango fruit are common.

In fruits, lesions are superficial and extend into the flesh only after large portions of fruit surface are affected. Even superficial disease development results in serious damage and rejection of fruit. On stored fruits, black round spots are produced which later coalescence to form large irregular botches or even cover the entire fruit [10]. The spots have large deep cracks. Under moist conditions, the blackened areas are covered with minute pinkish reproductive bodies of the fungus. Staining, russetting and tear

Figure 3: Leaf symptoms of mango anthracnose.

Figure 4: Panicle symptoms of mango anthracnose [20].

streaking, involving only the skin of the fruit, are attributed due to the same fungus [15,20].

Product Loss Caused by *Colletotrichum gloeosporioides*

Estimated loss caused by Anthracnose disease has been reported 60% or higher in the heavy rainy season [5,21,22]. Crop losses generally occur in the form of direct reduction in quantity or quality of the harvested produce. The disease incidence from different countries has been reported to be 32% in South Africa, 64.6% in Costa Rica which can reach almost 100% under wet or highly humid condition. 50.28% yield loss caused by anthracnose has been reported in Gondunglegi of Indonesia [10,16] and 29.6% post-harvest loss has been reported from Himachal Pradesh of India during 1990-92 [23]. Prakash., *et al.* reported 20 - 30% rotting of mango fruits caused by *Colletotrichum gloeosporioides* from Hyderabad. *Colletotrichum gloeosporioides* also causes reduction in flower set, losses in yield and damage foliage, serious problems may appear under crowded and moist conditions in nurseries and orchards [24]. In 2010, incidence and severity of anthracnose were 37 - 57% and 16 - 31% respectively. In 2011, anthracnose disease

Figure 5: Symptoms of Anthracnose Disease on Mango Fruits caused by Colletotrichum gloeosporioides [10].

incidence ranged from 33% to 65% while severity varied between 17% and 35%. Incidence disease and its severity were 77% and 46%, respectively, during surveys at market [15].

Disease management approaches

Use of resistant cultivars is an ideal, simplest and cheapest method for the control of plant disease. Heat treatment reduced disease incidence in plantain banana, mango, lychee and longan [25]. Anthracnose is one the most important diseases of mango fruit that affects pre-harvest and post-harvest quality of fruits. It also affects the flowers, leaves and inoculum year-round throughout the canopy. Anthracnose disease is prevalent but well controlled and non-significant in dry regions. Management of these diseases is essentially needed to produce high yield and quality fruit. Management of disease requires an awareness of this ever-present threat and the weather conditions that increase infection and disease development. Optimum control relies on Disease management [8].

Pre-harvest management

Early works showed that, the non-systemic fungicides zineb, maneb or captan provide good control if sprayed at weekly intervals during flowering and then monthly during fruit maturation. In Florida, farmers use up to 25 sprays per season to maintain fungicide layer on trees. Improved results were obtained with copper fungicides. Benomyl with a surfactant provide excellent control of anthracnose superior to protectant fungicides [18]. Copper oxychloride or mixtures of copper oxychloride and zineb applied in every 14 days and 28 days thereafter in wet and dry conditions respectively have been recommended for anthracnose control in South Africa [26]. Mancozeb has been applied in every 14 days between panicle emergence and fruit set. In addition, copper oxychloride were also applied in every 3 weeks. These fungicides were alternated until harvest on a monthly basis once the fruit had set. The treatment was effective in wet seasons when fruit set is prevented in the absence of fungicide application. Prior and Ryder (1987) compared copper oxychloride as single dose prior to flowering with a fortnightly use of mixture containing a lower concentration, subsequent to flowering [27]. Copper oxychloride significantly increased fruit set but the other did not. The timing of sprays is therefore crucial in preventing disease spread.

The Blossom Blight phase of the anthracnose disease has devised the spray program to manage anthracnose in the Philippines which can drastically reduce the number of fruits set. Now-a-days, five sprays are applied between flower induction and fruit set with a sixth spray between fruit set and harvest. Benomyl, captafol and mancozeb have all been shown to give adequate control of blossom blight, increasing fruit set per inflorescence by 55 - 80% compared with untreated controls [28]. Chlorothalonil has been also used altering the copper sprays in commercial orchards in the Philippines and found economically effective. Thompson (1987) has reported on the misuse of similar spray programs in an expected consequence [29]. Benomyl tolerant strains of *C. gloeosporioides* can tolerate post-harvest treatments with this fungicide. In recent years, similar problems have been recorded on the pre-harvest overuse

of benomyl in Malaysian mango orchards. An alternative multi-site curative fungicide prochloraz has been shown to have significant *in vitro* activity against *Colletotrichum* species [30]. Another study reported that, prochloraz applied with sprays gave significantly better control of blossom- blight than mancozeb and copper. A subsequent field trial of prochloraz showed that up to eight sprays could be saved during flowering compared with the normal protective spray programs [31].

Country	Pesticides	Number of sprays	Spray Timing
Australia	Mancozeb + copper	13	Panicle emergence onwards
Malaysia	Mancozeb + insecticide	Every 10 days	Flower bud onwards
Australia	Prochloraz + copper (applied strategically)	Variable but significantly reduced in dry years	Panicle emergence onwards
Philippines	Mancozeb/ chlorothalonil + copper + insecticide	6	Five sprays from induction to fruit set

Table 1: Pre-harvest spray programs used in the control of anthracnose of mango fruit [28].

Post-harvest management

The mango is harvested in the mature green state and stored for 2 - 3 weeks at 10 - 120C before ripening. Since the fruit is sold to buyers still remaining on the trees, the problem of post-harvest control of anthracnose is passed from the grower to exporter. Storage fungi van cause anthracnose rot in mango fruits and lead to loss of quality of fruits [32]. A variety of treatments have been employed to control post-harvest development of anthracnose with varying degrees of success.

Chemical fungicides are the primary means for management of the post-harvest diseases of fruits and vegetables. However, the potential impact of fungicides on environment and human health largely limits application. Eco-friendly management has emerged as one of the most promising alternative to chemicals. Several fungicides have been tested as dip treatments. Benomyl was found more effective against quiescent infections of anthracnose of mango in hot water than cold water. This was due to the thicker mango cuticle acting as a barrier to fungicide ingress, compared with the thinner cuticles of banana or papaya [33]. Recently prochloraz has been proved effective against anthracnose in hot or cold dips, but less effective than a hot benomyl dip [33]. Other fungicides have been also used successfully for certain mango varieties including thiophanate-methyl and hot imazalil [34,35]. The postharvest dips of fruit are considered as moderately effective against mango anthracnose [16].

The effectiveness of hot water dips as post-harvest treatments for the control of mango anthracnose has been known for many years [36]. Hot water treatment of mango is an old and successful strategy recommended by several workers [32]. Hot water dips alone can significantly reduce anthracnose development, but fruit can show signs of heat damage under some conditions of storage [37]. Hot water treatment of 55 and 60°C was found effective against post-harvest anthracnose of mango. Jabbar., *et al*. (2011) reported that, hot water treatment significantly reduces the anthracnose incidence on fruit [17]. Prakash and Pandey (2000) reported that, hot water dips at 52°C for 5, 15 and 30 minutes is effective for the control of post-harvest anthracnose of mango [17]. Trials using gamma irradiation to control mango anthracnose have concluded that, incorporation of hot fungicide dip is necessary to improve disease control afforded by irradiation [38]. Appropriate post-harvest treatment have to be selected for individual mango cultivars and possibly even for the same cultivar in different environments. The use of sodium hypochlorite and film-wrapping have been found unsuccessful in controlling the development of anthracnose post-harvest [39].

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Biological control is an eco-friendly, effective and alternative approach for any kinds of disease management practice. Singh investigated the effect of heat treatment in combination with fungicides and plant extract to control storage anthracnose of mango fruits caused by *Colletotrichum gloeosporioides*. Dip treatment with propiconazole at 500 ppm and *Cannabis sativa* extract were most effective against anthracnose. Heat treatment at 45°C enhanced the curative properties of pesticide and extract along with maintaining shelf life of mango at room temperature [32]. Sundravadana., *et al.* (2006) evaluated the efficacy of a fungicides named azoxystrobin both *in vitro* and *in vivo* conditions. In *in-vitro* tests, azoxystrobin inhibited mycelial growth of *C. gloeosporioides*. In field experiment, azoxystrobin significantly suppressed the development of both panicle and leaf anthracnose. Mango trees treated with azoxystrobin produced more fruits compared to control and showed no phytotoxicity [40]. Kefialewa and Ayalewb (2008) evaluated several isolates of bacteria, yeasts and fungi to be used against anthracnose and found that, cell suspensions and culture filtrates of the isolates inhibited spore germination and growth of *Colletotrichum gloeosporioides in vitro*. The bacterial isolates were *B. diminuta, S. maltophilia* and a member of Enterobacteriaceae while the yeasts isolates were *C. membranifaciens* and a new species [17]. The following Post-harvest treatments can be used in the control of mango anthracnose [32,36,38-44]:

1. Scrubbing with 1% NaOCl
2. Hot water dip (50-55oC for 3 - 10 minutes)
3. Hot benomyl dip (500 - 1000 ppm)
4. Hot/cold prochloraz dip (400 - l000 ppm)
5. Hot imazalil (1000 ppm)
6. Hot water + 20 k RAD irradiation
7. Hot water + 75 k RAD irradiation
8. Hot benlatc/iprodionc (1000 ppm)+ 75 k RAD irradiation + waxing

Conclusion

Anthracnose disease of mango is one of the major pre- and post-harvest disease of mango fruit throughout the world which attacks flowers, young fruits, leaves and twigs and it causes huge pre and post-harvest losses to mango crop [5]. In Bangladesh, about 25 to 30% loses of total production due to anthracnose and stem end rot [9]. Several sprays and dip treatments of chemicals are used in anthracnose disease management, some of which are more effective and others are less effective. Timely application of fungicides spray is effective to control anthracnose is by, which also raises environmental and health hazard. Another way is to use Eucalyptus and neem leaf extract against the infection caused by *Colletotrichum gloeosporioides*. Proper knowledge of these disease is essential for its proper management to ensure the fruitful yield. Hence, at the present time more emphasis is made on other methods of disease management like growing resistant varieties, use of plant and natural products, bio-control agents and alteration in agronomic practices because they are more economical, eco-friendly and safe.

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