A REVIEW ON ANTHRACNOSE OF MANGO CAUSED BY *COLLETOTRICHUM GLOEOSPORIOIDES*

F. Jenny[1], N. Sultana[2], M. M. Islam[3], M. M. Khandaker[4] and M. A. B. Bhuiyan[2]*

[1]*Seed Certification Agency, Ministry of Agriculture, Gazipur, Bangladesh*
[2]*Department of Plant Pathology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh*
[3]*Department of Plant Pathology, Sylhet Agricultural University, Sylhet, Bangladesh*
[4]*Department of Botany, Jagannath University, Sadarghat, Dhaka, Bangladesh*
***Corresponding author:** baki@bsmrau.edu.bd

ABSTRACT

Jenny, F., Sultana, N., Islam, M. M., Khandaker, M.M., and Bhuiyan, M. B. A. 2019. A review on anthracnose of mango caused by *Colletotrichum gloeosporioides*. Bangladesh J. Plant Pathol. 35(1&2):65-74

Mango is one of the most important fruit crops in Bangladesh. At maturity, the hydrolytic processes are elicited with depletion of starch and breakdown of insoluble pectin, therefore, increase the ethylene production and catalase and peroxidase activities. The ripe mangoes are subjected to infect by multiple microorganisms causing various diseases. Among these anthracnose is one of the major post-harvest diseases responsible for reducing the shelf-life of mango. In addition, hot and humid climatic conditions also favor the multiplication of post-harvest pathogens. Integrated management practices such as heat treatment, application of bio-agents, botanicals, essential mineral oils etc. could reduce the post-harvest diseases without any residual chemical effects on fruits and environment. This review highlighted the information on the present status of mango trading across the globe, symptomatology, biology, disease cycle, etiology and management of anthracnose of mango.

Key words: anthracnose, induced resistance, botanicals, essential mineral oil, oxalic acid, mango

INTRODUCTION

Fruits are known for their nutritional and commercial importance. They are indispensable food commodities across the globe. They play a vital role in human nutrition by supplying essential growth elements such as vitamins, minerals, amino acids, carbohydrates, fats and many other essential nutrients in daily diets; therefore, help to keep good and normal health (Singh and Sharma 2007) (Table 1).

The antioxidant potential of fruits is well recognized (Parengkuan *et al.* 2013). Mango (*Mangifera indica*) belongs to the family *Anacardiaceae* is one of the most demanding fruits across the globe for its rich source of essential nutrients (Alam *et al.* 2017). Mango is acclaimed as the king of fruits (Ahmed 1994), which is adapted to a warm tropical monsoon climate with a pronounced dry season followed by rains (Arauz 2000). Mango typically produces flowers in the dry season and set fruits at the start of the wet season (Hofman *et al*. 1997). Its production is increasing in the tropical areas and in the developed countries (Diedhiou *et al*. 2007). It was originated from the Indian sub-continent (Indo-Burma region) in the prehistoric times about 4000 years ago; therefore, it is considered as one of the oldest tropical fruits across the globe (Dinh 2002).

Table: 1. Essential nutrient contents present in 100 g of mango pulp

Nutrient contents (g)	
Nutrients	Amount (g)
Protiens	0.51
Carbohydtrates	17.0
Fats	0.27
Fibres	1.8
Vit-A (carotene)	0.008
Vit-C	0.027
Niacin	0.00058
Thiamin	0.00056
Iron (Fe)	0.00013
Calcium (Ca)	0.01
Magnesium (Mg)	0.009
Potassium (K)	0.0156
Phosphorous(P)	0.011

Source: BARI, 2018

Mango is a commercial horticultural crop in many countries of South-East Asia, India, Pakistan, Philippines, Malaysia, Thailand, Burma, Sri Lanka and Java. The main mango producing countries of the world are India, Pakistan, Mexico, Brazil, Haiti, the Philippines and Bangladesh (Alam *et al*. 2017). Global mango production was 603.75 lac ton in 2018 from

64.16 lac ha of land; more than 90 countries are currently producing mango (FAOSTAT 2018). Asia accounts for approximately 73%, and Americas and Africa account for approximately 15% and 11% of global mango production, respectively (FAOSTAT 2018).

Mango ranked fifth in terms of quantum of production among the fruits producing across the globe (Joyce *et al*. 2001). Post-harvest mangoes show a climacteric pattern of respiration i.e., dramatically physiological and chemical changes take place during ripening. At maturity, hydrolytic processes are triggered taking place depletion of starch and breakdown of insoluble pectin. The beginning of ripening is comprised with five times increase in heat production followed by an increase of ethylene production as well as increase of catalase and peroxidase activities (Lazan *et al.*1986). The fruit is progressively softening, changing its color and developing an aroma at a rate determined by the storage conditions (Memon *et al*. 2013). Rapid ripening process coupled with infection by microorganisms reduces the shelf-life of mango after harvest which limits the transportation of fresh fruits from the site of harvest (Mitra and Baldwin 1997).

Mango is infected by a number of pathogens from bloom to harvest and in storage which cause considerable deterioration of the fruit quality and quantity. A major threat for mango industry is postharvest decay or spoilage of fruits by micro-organisms. Microbial decay accounts for 17.0-26.9% of the total postharvest losses in Asian countries. Postharvest losses of fresh mango fruits are reported to be 25-40% in India and 69% in Pakistan (Chowdhury *et al*. 2014). Similarly, in Bangladesh, one of the major constraint of mango production is the occurrence of anthracnose both at field and storage (Naznin *et al*. 2007).

Among the limiting factors of mango production, pre- and post-harvest diseases are the major constraints. About 20-25% of the harvested fruits are decayed by pathogens during post-harvest handling (Droby 2006). Because of high moisture content, mango fruits become susceptible to both fungi and bacteria after harvest; mostly during transportation and storage. In addition, the hot and humid climatic condition of Bangladesh favors the growth of microorganisms at storage. Major mango diseases are anthracnose (*Colletotrichum gloeosporioides*); alternaria fruit rot (*Alternaria alternata* and *A.tenuissima*), stem end rot (*Lasiodiplodia theobromae* and *Dothiorella* spp.) fruit rot (*Phoma mangifera, Pestalotia mangifearae, Macrophomina* sp.) (Diedhiou *et al*. 2007). According to Sakalidis *et al.* (2011) about 5% of fruit is lost due to post-harvest diseases which could damage upto100% if conditions favor disease development and proper management practices are not undertaken. Major objective of this article is to review the current status of mango trading across the globe, the biology, symptomatology, disease cycle, etiology and management of anthracnose of mango.

Statistics of global mango trade

About 1- 2% of the world production is traded internationally while the rest is traded and consumed within the countries of production. The highest exporting country is Mexico (23%) followed by Brazil (14.3%), Peru (10.3%), India (9.71%) and Pakistan (3.2%) (Fig. 1). The largest importing destinations are the European community (34%), USA (20%), Arabian Peninsula (14%) and Asia (27%) (Gerbaud 2009; Bally 2011). The key factor on international mango trade is fruit quality which is determined by fruit shelf life, ripening stage, taste, color, smell and total soluble sugar (TSS) (Bally 2011).

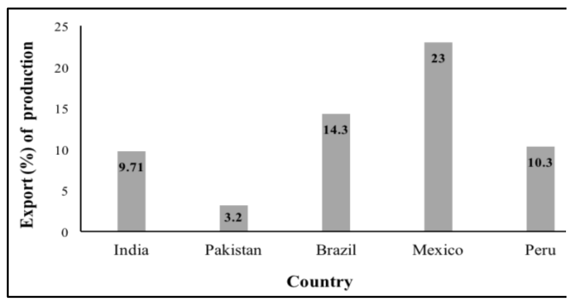

Fig. 1. Mango exporting (%) out of the total production of a country in the world (Bally 2011).

Bangladesh exported only 111 tons of mango with value 495,000 USD in 2017 while, it imported 1564 tons with value 985,000 USD in the same year (FAO 2018). Post-harvest losses due to pathogen attack, poor phytosanitary activities, lack of technologies for production and marketing system may be the major reasons for poor mango export in Asia.

The pathogen and symptoms of anthracnose of mango

The causal agent of anthracnose of mango is *Colletotrichum gloeosporioides* (Siddiqui and Ali 2014) as the asexual (imperfect) stage and *Glomerella cingulata* as the sexual (perfect) (López-Vásquez and Castaño-Zapata 2010). 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. This pathogen belongs to the Family: *Glomerellaceae*; Order: *Glomerellales*, Class: *Sordariomycetes*, Phylum: *Ascomycota* and Kingdom: *Fungi* (Chen *et* *al*. 2015). Globally, anthracnose is one of the most important post-harvest diseases of mango (Zhang *et al*. 2013). The symptoms of anthracnose appear at both pre- and post-harvest stages of mango. However, post-harvest anthracnose is responsible for severe losses both qualitatively and quantitatively (Arauz 2000; Akem 2006; Zheng *et al*. 2007). Pre-harvest anthracnose symptom is characterized by 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) (Fig 2a). Sometimes, the lesions enlarge along the leaf margin affecting the growth of leaves; often the lesions become dry and fall out to form 'shot hole' appearance. Under favorable conditions (relative humidity 95% and temperature 25-28°C for 12 h) conidia dispersed through the wind and invade the young twigs to develop die back symptoms (Ploetz 1999; Dinh 2002).

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. At the advanced stage, the fungus produces acervuli, with numerous orange to salmon pink masses of conidia develop on the lesions (Arauz 2000, Nelson 2008). Islam (2011) and Chillet *et al*. (2018) demonstrated anthracnose as irregular dark brown to black depressed lesion having orange to pinkish masses of conidia on cracked and decaying mango (Fig. 2b).

Host range of *C. gloeosporioides*, causal agent of anthracnose

Besides mango, other hosts of *C. gloeosporioides* are banana, avocado (Coates *et al*. 1993; Nelson 2008); guava (*Psidium guajava* L.) (Moraes *et al.* 2013); apple (Munir *et al*. 2016); papaya (Maharaj and Rampersad 2012); yam (*Dioscorea rotundata*) (Abang *et al*. 2002); ornamental lupine (*Lupinus hartwegii* L), marsh lupine (*Lupinus polyphyllus* Lindl.), various herbs such as angelica (*Archangelica officinalis* Hoffm,), thyme (*Thymus vulgaris* L.) caraway (*Carum carvi* L.) and elder (*Sambucus nigra* L.) (Paulitz 1995, Machowicz-Stefaniak *et al.* 2011). According to Ploetz (1999) the strains of *C. gloeosporioides* from mango are genetically and phylogenetically distinct. Therefore, they are essentially host-specific.

Favorable conditions for anthracnose

Anthracnose lesions progresses rapidly in warm (20-30°C for 12 h) and humid (95% relative humidity) conditions (Kamle *et al*. 2013). According to Diedhiou *et al*. (2007), the ambient temperature for anthracnose is 28 ± 2 °C with rainy weather (Machowicz-Stefaniak *et al*. 2011). The range of temperature above28°C might be responsible for epidemic development of *C. gloeosporioides* (Machowicz-Stefaniak *et al*. 2011).

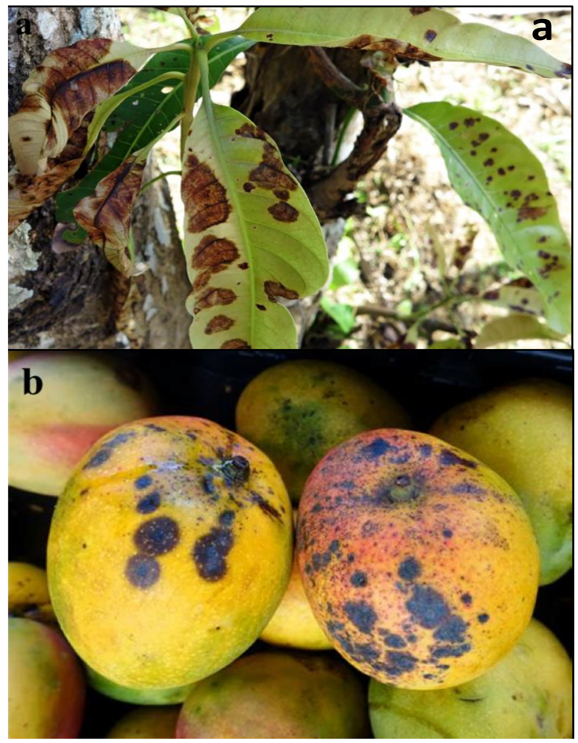

Fig. 2 Symptoms of anthracnose of mango
a) Symptoms on leaves of mango (https://www.greenlife.co.ke/mango-anthracnose/)
b) post-harvest symptoms of anthracnose on mango fruits (Chillet *et al*., 2018)

Disease cycle of anthracnose

Conidia are developed abundantly in the mango canopy which is considered as the primary source of inocula. They produced on lesions on twigs, leaves, panicles and mummified fruits. Through rain-splash, conidia spread to other leaves and inflorescences; so, they are considered as the secondary source of inocula (Fitzell and Peak 1984). Therefore, this disease is considered as polycyclic (Akem 2006). The developing fruits could be infected resulting pre-harvest losses of mango. The developing fruits get infected in the field but the infection remains quiescent until the onset of ripening. In this case, anthracnose symptoms appear at post-harvest stage when there is no fruit-to-fruit infection; thus, anthracnose at post-harvest is monocyclic (Arauz 2000, Akeem 2006).

Molecular characterization of *C. gloeosporioides*

Recently, molecular methods were popularly used to diagnose a particular pathogen because of their sensitivity and specificity. Generally, both internal transcribed spacer (ITS) and β-tubulin genes are used to resolve the taxonomic status of *Colletotrichum* at species level (Zakaria *et al*. 2015). Besides ITS gene, eight other genes such as actin (ACT) [316 bp], calmodulin (CAL) [756 bp], chitin synthetase (CHS-1) [229 bp], glyceraldehyde-3-phosphate dehydrogenase (GAPDH) [308 bp], the ribosomal internal transcribed spacer (ITS) [615 bp], glutamine synthetase (GS) [907 bp], manganese superoxide dismutase (SOD2) [376 bp], and β-tubulin 2 (TUB2) [716 bp] are used for multiple-genes analysis to resolve *C. gloeosporioides* complex (Weir *et al*. 2012).

Induced resistance

Induction of resistance by using physical, biological, and chemical elicitors is becoming popular alternatives to chemical fungicides for controlling post-harvest diseases of mango (Terry and Joyce 2004). For example, exogenous chemical elicitors such as salicylic acid (SA), isonicotinic acid (INA), benzo (1,2,3) thiadiazole7-carbothionic acid S-methyl ester (BTH), β-aminobutyric acid under very low concentrations effectively provide resistance against anthracnose of mango at storage (Zhang *et al*. 2013; Hu *et al*. 2014; He *et al*. 2017). Treatment of mango inflorescences with salicylic acid (100 mg/ L) reduces the incidence of anthracnose of mango (Liu *et al*. 1998). The disease resistance mechanisms by using SA in postharvest fruit are including oxidative burst, production of phytoalexins and synthesis of pathogenesis-related proteins (PR) (Cao *et al*. 2013; Xue *et al*. 2014; He *et al*. 2017). In addition, a non-protein amino acid named β-aminobutyric acid (BABA)-has the potentiality to induce resistance against a broad range of pathogens mainly fungi, bacteria, viruses and nematodes (Cohen 2002; Van der Ent *et al.* 2009; Quaglia *et al*. 2011). Application of β-aminobutyric acid (100 mM) suppresses the expansion of lesion in mango fruit caused by *C. gloeosporioides* during storage at 25°C (Zhang *et al.* 2013). The mechanism of suppression of anthracnose of mango by using BABA is yet to be studied. However, Zhang *et al.* (2013) reported that the treatment of mango fruit by BABA (100 mM) induced the activities of -1,3-glucanase (GLU), chitinase (CHT) and phenylalanine ammonia lyase (PAL); also involved in accumulation of hydrogen peroxide (H_2O_2) but, decreased the production of superoxide radical (O_2^{-}). Simultaneously, it increased the activity of superoxide dismutase (SOD) but, inhibited the activities of catalase (CAT) and ascorbate peroxidase (APX). Besides mango fruit, BABA-treatment reduced the lesion expansion in apple and grapefruit by *Penicillium digitatum* and *P. expansum* by increasing the gene expression and defense-related enzyme activities (Porat *et al.* 2003; Zhang *et al*. 2011). In addition, BABA enhances the activities of antifungal metabolites such as peroxidase (POD), polyphenoloxidase (PPO), phenyl alanine ammonialyase (PAL), lignin, flavonoids and phenols in potato slices; therefore, increased the resistance in potato tubers against dry rot of potato caused by *Fusarium sulphureum* (Yan *et al*. 2010).

Another promising exogenous inducer is nitric oxide (NO)–a hydrophobic and extremely diffusible free radical takes part in diverse physiological processes of fruits. Application of NO through gas fumigation or through sodium nitroprusside (SNP), delays the ripening process of many climacteric and non-climacteric fruits (Hu *et al*. 2014; Singh *et al.* 2013). According to Hu *et al*. (2014) exogenous application of 0.1 mM SNP enhances resistance of mango to anthracnose caused by *C. gloeosporioides* at storage.

Management of anthracnose of mango

The yield of mango is reduced due to anthracnose at pre-harvest; in addition, the mango fruits decayed and lost due to post-harvest decay caused by anthracnose. Bad quality mango fruits are not accepted by the consumers; therefore, these are losing the market price. An integrated pre- and post-harvest disease management practices could reduce anthracnose of mango (Esguerra and Rolle 2018). The quality of fruit after harvesting cannot be improved but can only be maintained. It can be improved only at the production level. Therefore, an understanding on integrated management strategies in place is very crucial to ensure premium quality at harvest (Memon *et al*. 2013). Following management practices singly or in combination are recommended to reduce the pre- and post-harvest anthracnose.

Cultural control

As the occurrence of anthracnose is more prevalent in the condition of high relative humidity or wetness therefore, mango orchards should be developed in areas where dryness is prevailing during the period of flowering and fruit setting (Akem 2006). The severity of anthracnose would be worst when trees flower late in dry season or when fruit development takes place during the rainy season. Incidence of anthracnose is 90% when fruits develop during the rainy season. Meanwhile, when fruit development takes place during the dry season then the occurrence of anthracnose is almost zero (Arauz 2000). As part of cultural control, field sanitation by collecting fallen fruits and trees followed by burning is essential to control pre-harvest anthracnose (Lim and Khoo 1985).

Time of harvesting mature fruit

Harvesting immediately after rain should be avoided because fruits are subjected to attack by multiple microorganisms after rain (Cooke and Johnson 1993). Harvesting of mature fruits ensures absolute fruit quality such as fruit size, development of proximal shoulder, development of pulp and skin color, sugar content and fruit firmness. Fruit maturity at the time of harvest is the most important factor which guarantee better storage life (Kader 1997). However, significant losses take place due to harvesting of mango fruits at inappropriate stage of maturity (Yahia 1998). Likewise, when over matured mangoes are harvested then they become susceptible to various pathogens. Storage condition is also important, at the storage temperature of 12°C, physically mature fruits can survive for long time as compared to immature fruits (Medlicott *et al*. 1990, Rehman *et al*. 2015).

Harvesting methods

Although, there is advancement occurred in different ways of harvesting of fruits in many countries but, still hand picking is one of the best methods because of the delicate nature of mango fruits. A little pressure on the fruit causes injuries to the pulp resulting in unattractive patches on ripening. In addition, this injury allows multiple microorganisms to cause post-harvest spoilage of fruit. Therefore, proper harvesting method should be followed by using secateurs and cutting the stem 1-2 cm away from the fruit which reduces latex exudation and staining and reduces the possibility of entrance of fungal organisms. Care should be taken so that mangoes are not knocked from the tree, dropped or thrown to the ground. The equipment which are hard enough should not be used for harvesting (Memon *et al*. 2013, Hussen and Yimer 2013).

Handling

Post-harvest handling includes two basic elements such as, management of quality and preparation of the product to reduce loss from damage caused by diseases and physical injury. Cool chain handling is important to slow down the ripening process. It includes rapid cooling after packaging, holding in cold storage before dispatch and transportation should be carried under refrigerator conditions. The length of time at low temperature is varied with cultivar and maturity. Optimum temperature is 13°C; below which causes chilling injury (Ledger 1989). The handling of fruits is started immediate after harvesting followed by transportation to the store room at packing floor, cleaning of fruit and clipping the stem/ peduncle from fruit, gathering of crates and truck loading. Proper handling ensures better quality fruit (Memon *et al*. 2013).

Grading and packaging

In the field, bagging of individual fruit in mango tree reduces the occurrence of anthracnose; however, cost effectiveness of this method is depended on the market price of the product (Arauz 2000). At storage, grading of fruit is a common practice to obtain better prices. Grading is an important post-harvest operation which should be started before the packing of mango in crates. Both the producer and consumers are benefited when the fruits are graded according to their size, weight, colour and maturity (Memon *et al*. 2013). In order to obtain the uniformity during packaging, smaller and larger fruits should not be mixed together. Additionally, immature, scarred, bruised, overripe, damaged and diseased fruits should be discarded (Memon *et al*. 2013). Transportation of mango in basket is useful to carry fruits to local market (Hussen and Yimer 2013). However, due to rough surfaces, mango fruits are subjected to injure which allows microbes to cause post- harvest diseases. In some cases, plastic boxes are used to pick fruits because of its smooth surface. It also reduces contamination and bruising. Materials such as tissue paper or newspaper wrapping keep the fruit in good condition for less spoilage and a better appearance (Memon*et al*. 2013). Film packaging delays the ripening process which extends the shelf life of mango (Joseph and Aworh 1992). Wrapping of individual fruit with tissue paper or newspaper is one of the best ways of packaging to reduce the incidence of anthracnose at storage (Arauz 2000; Sharma 2014).

Oxalic acid treatment

Oxalic acid is an organic acid universally found in plants, fungi, and animals. It plays various roles in living organisms (Libert and Franceschi 1987; Zheng *et al*. 2007). Currently, application of oxalic acid for food preservation has created much attention to scientist and food processing industries. Oxalic acid is used not only as anti-browning agent (Castaner *et al*. 1997) but also used as a natural antioxidant (Kayashima and Katayama 2002). Zheng *et al*. (2007) reported that pre-storage oxalic acid treatment (mango dipping in 5mM solution of oxalic acid for 10 min) in combination with controlled condition such as 6% CO_2 +2% O_2, and at 14±1°C prolong the shelf life and reduces the incidence of mango fruit decay because oxalic acid decreased the ethylene production which delayed the ripening process (Zheng *et al*. 2007). According to Zheng *et al*. (2012) oxalate treatment is used to delay the ripening process in mango and decrease the incidence of decay during storage. The effect of oxalic acid treatment to reduce the incidence of anthracnose may be undertaken as a safer alternative.

Hot water treatment with waxing

Hot water treatment (HWT) is one of the most effective post-harvest treatments against anthracnose and stem end rot of mango. It is a non-chemical method which has no health risk for post-harvest disease management (Pennock and Maldonado 1962). For this method, green mature fruits are to be dipped for 20 min in water heated to 53ºC significantly reduce *C. gloesoporioides* without injuring fruits. Temperature below 52 ºC is not effective to control pathogen and above 55 ºC causes scalding of the peel (Alvindia and Acda 2015). Application of hot water without waxing affects the natural wax layer on the fruit surface which enhances fruit shriveling and senescence. This treatment accelerates the ripening and de-greening process (Klein and Lurie, 1992). Therefore, fruits are susceptible to cause damage by anthracnose. However, coating with wax delays the ripening process and respiration which extends shelf-life of the fruit. Moreover, *Bacillus licheniformis* is used as a protectant against microorganisms when it is applied on the surface of mango in wax coatings (Govender *et al*. 2005).

Biological control

Globally, application of fungicides is not welcoming because of serious health hazards resulting from their residual effects on environment. Therefore, strong public support is in favor of ecofriendly and safer alternatives for reducing the decay loss of the harvested commodities (Cooke 1993; Mari *et al*. 2007). *Trichoderma viride*, an antagonist isolated from mango fruit surface was used to control anthracnose at storage (Bhuvaneswari and Rao 2001). In South Africa, *B.licheniformis* was used to reduce the incidence of anthracnose at storage (Korsten and Lonsdale 1993).

Use of essential oils and botanicals

The major benefit of essential oils is their bioactivity in vapour phase which act as fumigants to protect stored products. These essential oils are found to be effective against many phytopathogens (Mihaliak *et al*. 1991); and to protect post-harvest diseases (Hidalgo *et al*. 2002). The quality of mango fruit could be improved by application of some harmless substances in the form of plant extracts such as botanicals (Iram *et al*. 2019). These botanicals are sustainable, cost-effective and effective against many post-harvest pathogens (Kanwal *et al*. 2010). Botanicals viz., Indian lilac (*Azadirachta indica*), eucalyptus (*Eucalyptus camaldulensis*), garlic (*Allium sativum*), ginger (*Zingiber officinale*) and rubber bush (*Calotropis procera*) at 5, 7 and 8% concentrations were used with spraying to control post-harvest diseases of mango (Iram *et al*. 2019).

Essential oils viz., basel oil (*Ocimumba silicum*), orange oil (*Citrus sinensis*), lemon oil (*Citrus medica*) and mustard oil (*Brassica juncea* L. at 150 ppm (µg/mL) are used to reduce post-harvest losses of mango by *C.gloeosporioides* (Abd-Alla and Haggag 2013). Thymol-based essential oil showed a strong fungi toxic activity against *C. gloeosporioides* (Chillet *et al*. 2018). Moreover, coating of individual mango with coconut oil, mustard oil, deshi ghee and natural wax are used to protect the fruit from many post-harvest pathogens. The oils are smeared on the surface of the fruit with cotton swab. After coating, fruits should be air dried and stored at room temperature in pierced brown bags for 7 days (Sharma 2014).

Fungicidal treatment

Synthetic fungicides are principally used to control post-harvest diseases of fruits and vegetables (El-Ghaouth *et al*. 2004). Pre-harvest spray of Rovral 50 WP (Iprodione) reduced the microbial population of *C. gloeosporioides* at storage (Hossain 2017). Post-harvest application of Tecto [Thiabendazole] (1.8 mL/L) alone or in combination with Sportak [Procloraz] (0.5 mL/L) significantly reduces the post-harvest diseases of mango. But, none of the treatments provide complete disease control (Johnson *et al*.1991). Post-harvest hot water treatment followed by fungicidal dip of Tecto @1.8 mL/L alone or in combination with Sportak @ 0.5 mL/L at 52°C for 5 min provided better disease control (Amin *et al.* 2011). In Bangladesh, application of Bavistin (1000 ppm) and Tilt (1000 ppm) provided the best inhibition of mycelial growth of *C. gloeosporioides* (Nahar *et al*. 2017). Management of anthracnose is relied mostly on the application of copper-based pre-harvest sprays (Ploetz and Prakash 1997) and post-harvest hot water dips including fungicides (Swart *et al*. 2002). Application of hot benomyl immediately after irradiation effectively controls anthracnose (*C. gloeosporioides*) of mango for short-term storage (15 days at 20°C) (Johnson *et al*. 1990). Moreover, application of hot benomyl dip for 5 min at 52 ºC within 24 h after harvest is used to prevent post-harvest diseases of mango in Australia (Ledger 1989).

CONCLUSION

Loss of mango due to the occurrence of anthracnose (*Colletotrichum gloesporioides*) at pre- and post-harvest conditions is a common phenomenon which is responsible for potential economic losses every year. The hot and humid climatic conditions favor the outbreak of anthracnose of mango. In order to curb the disease incidence, synthetic fungicides are generally used. However, these chemicals have adverse effects not only in human body but also in environment. Therefore, integrated management of mango anthracnose is essential. But, these approaches require knowledge on biology of the pathosystem, disease cycle and economic and ecological feasibilities of other management practices such as hot water with waxing, application of bio-agents, use of botanicals and essential mineral and oxalic acid treatments. The application of fungicides depends on weather conditions, the stage of fruit development and its marketability (organic or conventional). In the field, the hot (20-30°C for 12 h) and humid conditions (95% RH) should be avoided during fruit development. Similarly, at the post-harvest stage, dryness and low temperature should ensure to avoid the occurrence of *C. gloeosporioides*.

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