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A CASE STUDY

Anthracnose- A devastating pre and post-harvest disease in mango

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ABSTRACT

Anthracnose is presently recognized as the most important pre and post harvest fungal disease of mango world wide caused by *Colletotrichum gloeosporioides* Penz. The post-harvest phase is the most damaging and economically significant phase of the disease worldwide. This phase is directly linked to the field phase where initial infection usually starts on young twigs and leaves and spreads to the flowers, causing blossom blight and destroying the inflorescences and even preventing fruit set. It is major constraint on the expansion of export trade of mango causing substantial yield losses which can reach 60 per cent or higher during the heavy rainy season. Causing direct yield loss in the field and packing plant, and quality and affects the marketable fruit rendering it worthless. The successful management of anthracnose relies on understanding the conditions that promote disease development, and the economics, efficacy and market acceptability of the various control measures, mango cultivar that is grown, the production area, and the intended final market, an integration of two or more tactics may be needed. A review of the etiology and epidemiology of the disease is provided below as background for the various approaches that have been used to manage the disease.

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INTRODUCTION

The mango (*Mangifera indica* L.) is an important crop in India and other tropical and subtropical region of the world. It is grown in more than 100 countries but no where it is greatly valued as in India where 40 per cent of total fruits grown is mango.

In India, the mango is found adapted to diverse environments and management conditions which has introduced new dimension to problems and hence challengeges. Among them anthracnose is one of the devastating pre and post-harvest fungal disease which has wide occurrence and is the most important biological constraint to mango production in Southeast Asia resulting in substantial yield loss (Dodd *et al.,* 1991). Anthracnose caused by *Colletotrichum gloeosporioides* Penz., is the most destructive disease of mango causing substantial yield losses which can reach 60 per cent or higher during the heavy rainy season (Ann *et al.,* 1997). In humid and high rain fall area in India is serious concern in production and post harvest management of mango fruits because abundance of mango flowering has happened before and yet the yields or fruit quality were very disappointing by anthracnose disease, especially in wet areas of mango cultivation. Anthracnose is presently recognized as the most important field and post harvest disease of mango world wide (Ploetz and Prakash, 1997). It is major constraint on the expansion of export trade of mango (Jeger and Plumbley, 1988). Post harvest decay due to anthracnose was 29.6 per cent in Himachal Pradesh, India during 1990-92 (Sharma and Verma, 2007). The disease incidence from different countries has been reported to be 32 per cent in South Africa, 64.6 per cent in Costa Rica during 1990 (Arauz *et al*., 1994) and could reach into almost 100 per cent in fruits produced under wet or humid conditions (Arauz, 2000). A systematic study was conducted during the year 2000 to assess the extent of loss due to post harvest loss due to anthracnose disease in mango in Coimbatore, India at field, wholesale, retail and consumer levels. The magnitude of loss due to anthracnose diseases on mango varied at different stages of storage and marketing. Anthracnose spoilage of mango was higher at retail (40.79 %) and consumer level (24.62 %) and was minimum at wholesale (3.01 %) and the least at field level (1.13 %) since the symptoms of the disease of unripe mango manifested only upon ripening. It was observed that the extent of post harvest loss due to Anthracnose was higher in the months of July (47.90 %) and August (51.70 %) when compared to other months (Prabakar *et al*., 2005).

Anthracnose a serious concern :

First, most flowers in a mango panicle are male flowers that do not yield fruit. The number of fruits produced depends in part upon the number of hermaphrodite flowers in the anicles, a number which vary among mango cultivars. Second, where mango flowering coincides with or is followed by wet weather, a devastating disease known as anthracnose can become established on panicles, virtually destroying them. Or, should the panicles make it through the season without being destroyed by anthracnose, the fruits produced may still be seriously affected by the disease when they are young, and symptoms appear especially during and after ripening of the infected, mature fruit. The mango tree produces a delicious fruit that is widely consumed in India and throughout the world. The export of fresh fruits and vegetables valued at Rs. 365915.53 lakh. Among the fresh fruits, mangooes particularly of varities Alphonso, Kesar, Deshehari, Banganapalli constitute bulk of exports. It is an important export crop in countries or locations where quarantine pests and diseases can be controlled satisfactorily. Mango production could be significantly greater if anthracnose was not such a major problem. So in India and worldwide, mango anthracnose is the most important and destructive disease of mango.

Anthracnose disease :

The ubiquitous fungus, *Colletotrichum gloeosporioides* Penz and Sacc. is the anamorph stage (asexual stage of the pathogenic fungus). *C. gloeosporiodes* is responsible for many diseases, also referred to as “anthracnose,” on many tropical fruits including banana, avocado, papaya, coffee, passion fruit, and others.

Characterization of pathogen :

According to Ploetz (1999), “characterizations of worldwide populations of *Colletotrichum gloeosporioides* indicate that strains from mango comprise a genetically and pathologically distinct population of this species. The mango population of the pathogen always predominated on mango, was not found on other tropical fruit crops, and had a restricted host range in sofar as individuals from the population were highly virulent only on mango.” In other words, populations of the pathogen are essentially host-specific.

In Colombia was reported that mango crop is likely to suffer considerable losses from anthracnose caused by *Colletotrichum* species, which were identified by the study on infected parts of the mango, sampled in different regions of the country. Identification was based on molecular characteristics. Molecular identification of the *Colletotrichum* species was carried out through amplification of rDNA ITS regions by means of *Colletotrichum gloeosporioides* (*Cg*Int) specific primer PCR combining the use of ITS4 universal primer. The results indicate that *Colletotrichum gloeosporioides* is the infectious agent in mango.

Disease symptoms :

On mango, anthracnose symptoms occur on leaves, petioles, twigs, flower clusters (panicles) and fruits.

Symptoms on leaves :

On leaves, lesions start as small, angular, brown to black spots that can enlarge to form extensive dead areas. The lesions may drop out of leaves during dry weather (Fig. 1).

Fig. 1: Leaf symptoms of mango Anthracnose (*Colletotrichum gloeosporiodes*)

Symptoms on twigs and stems :

Development of the typical black lesions can be noticed on twig and stem. Dieback occurs apically when severe, elongated, blackened lesions form on stems and twigs. abundant sporulation of the pathogen covers the most decomposed points of the infection (Fig. 2 and 3).

Fig. 2 : Symptoms on twig

Fig. 3 : Symptoms on stem

Symptoms on panicles:

The first symptoms on panicles are small black or dark-brown spots, which can enlarge, coalesce, and kill the flowers before fruits are produced and thus, greatly reducing the yield (Fig.4 a and b).

Symptoms on fruits :

Ripe fruits affected by anthracnose develop sunken, prominent, dark brown to black decay spots before or after picking. Fruits may drop from trees prematurely. The fruit spots can and usually do coalesce and can eventually penetrate deep into the fruit, resulting in extensive fruit rotting. Most

(a) (b)

Fig. 4a and b : Symptoms on panicles

green fruit infections remain latent and largely invisible until ripening. Thus, fruits that appear healthy at harvest can develop significant anthracnose symptoms rapidly upon ripening (Fig. 5).

Fig. 5 : Symptoms on ripe fruits

A second symptom type on fruits consists of a "tear stain" symptom (Fig. 6) in which are linear necrotic regions on the fruit that may or may not be associated with superficial

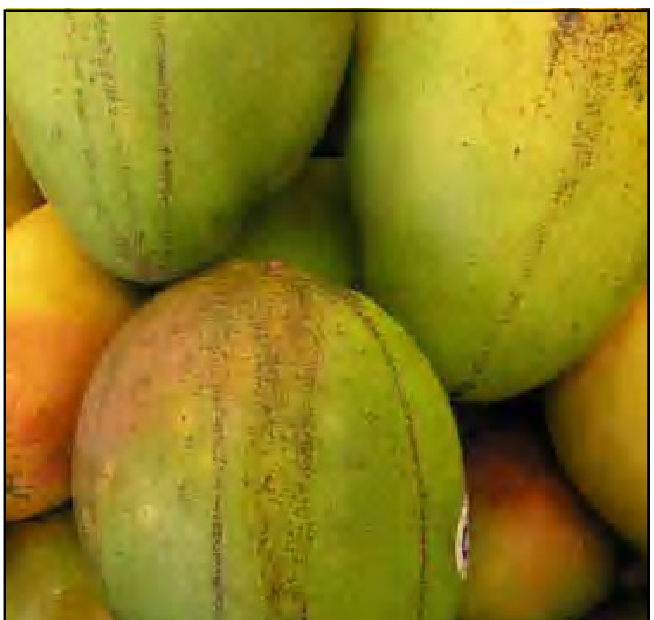

Fig. 6 : Tear strain symptoms on mango fruits

cracking (Fig. 7) of the epidermis, lending an "alligator skin" effect (Fig. 8) and even causing fruits to develop wide, deep cracks in the epidermis that extend into the pulp.

Fig. 7 : Cracking of epidermis

Fig. 8 : Aligator-skin effect on fruits

Lesions on stems and fruits may produce conspicuous, pinkish-orange spore masses under wet conditions. Wet, humid, warm weather conditions favor anthracnose infections in the field. Warm, humid temperatures favour post harvest anthracnose development.

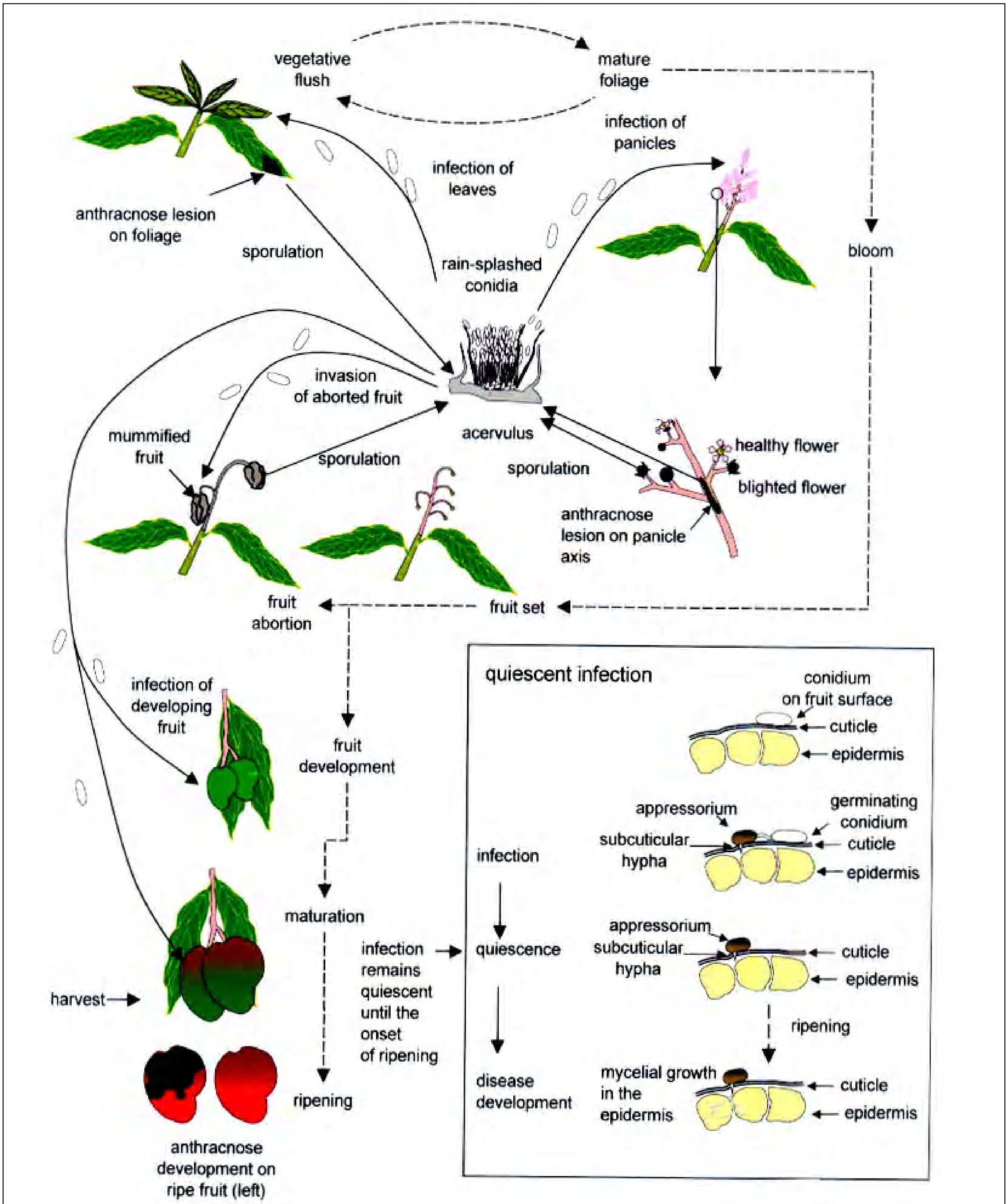

Fig. 9: Disease cycle (Arauz, 2000)

Disease cycle of pathogen :

***Climatic conditions for dissemination pathogen* :**

High humidity, frequent rains and a temperature of 24 - 32 ^{0}C.

Dissemination :

Spores (conidia) of the pathogen are dispersed passively by splashing rain or irrigation water.

Inoculation :

Spores land on infection sites (panicles, leaves, branch terminals).

Infection and pathogen development :

On immature fruits and young tissues, spores germinate and penetrate through the cuticle and epidermis to ramify through the tissues. On mature fruits, infections penetrate the cuticle, but remain quiescent until ripening of the climateric fruits begins.

Symptoms and disease development :

Black, sunken, rapidly expanding lesions develop on affected organs.

Pathogen reproduction :

Sticky masses of conidia are produced in fruiting bodies (acervuli) on symptomatic tissue, especially during moist (rainy, humid) conditions.

Pathogen survival :

The pathogen survives between seasons on infected and defoliated branch terminals and mature leaves (Sattar and Malik, 1939).

Epidemiology :

Moist conditions and high humidity are primary factors in the spread and development of anthracnose. Conidia produced on branch terminals, mummified inflorescences, flower bracts and leaves (most important) are significant sources of inoculum (Dodd *et al*., 1991; Fitzell and Peak, 1984). They are produced most abundantly when free moisture is available, but also at relative humidities as low as 95 per cent. Conidia are dispersed by rain splash and infection requires free moisture (Jeffries *et al*., 1990). As appressoria age, they become melanized. Melanization strengthens the appressorium and facilitates penetration of the cuticle by infection pegs that the appressoria produce. The presence and prevalence of melanized appressoria have been used to predict when infection is possible and anthracnose control measures are needed (Dodd *et al*., 1991; Fitzell and Peak, 1984). Small fruit can develop minute brown spots and abort if infected early in their development. Once an appressorium is formed and fruit exceed 4 – 5 cm in diameter, infections cease development. Quiescent infections renew develop once concentrations of preformed fungal inhibitors in fruit decline during the ripening process. On larger (especially ripening) fruit, lesions can form anywhere, but linear smears that radiate from the stem end to the apex are common. Lesions on fruit are superficial and extend into the flesh only after large portions of the fruit surface are affected. Nonetheless, even superficial disease development results in serious aesthetic damage and rejection of fruit along the marketing chain.

Disease management :

***Pre-harvest disease management practices* :**

Pre-harvest management of anthracnose relies on:

Site selection :

Choose a hot, dry area, and avoid wet areas.

Cultivars selection :

Aside from site selection, the best way to manage anthracnose is to plant a resistant cultivar.

Disease reaction	Cultivars
Susceptible	Haden, Palmer, Sensation (Pernezny and Ploetz, 2000).
	Neelum in Mangalore(Sohi *et al.*,1973), Alphanso (in Kerala)
Resistant	Edward, Tommy Atkins, Keitt (Pernezny and Ploetz, 2000).
Moderately resistant	Banbalia, Bombay Green, Dilpasand (Tiwari and Singh,1999)

Cultural practices :

***Orchard sanitation* :**

(Removing sources of inoculum)**:** Prune trees yearly and remove fallen plant debris from the ground. Despite its potential beneficial impact, sanitation is often not practiced due to its difficulty and expense (Akem, 2006; Prusky *et al.,* 2009).

Plant spacing :

Wider plant spacing will inhibit severe epidemics.

Intercropping :

Inter planting mango with other types of trees that are not hosts of mango anthracnose will inhibit epidemics.

Altering the time of flowering:

This can be done to ensure that fruit set and development occur during dry conditions (this also focuses on off-season production for profitable market windows). Flower manipulation is not possible in all situations (Johnson and Hofman, 2009). Floral induction is usually achieved with applications of KNO_3 and the growth retardant paclobutrazole is also used for this purpose. Applications of KNO_3 increase flowering but do not alter its timing. Thus, pre- harvest management of anthracnose often relies only on chemical, and to a lesser extent biological, inputs.

Chemical control :

In all but the most disease-conducive environments and on the most susceptible cultivars, pre-harvest anthracnose control focuses solely on protecting flowers and early fruit development. In moist environments, this entails one or two fungicide applications during flowering and early fruit set, and subsequent fungicide applications may be required before harvest (see below). In moist environments, applications are needed throughout the season. The timing and frequency of applications are very critical for adequate disease control. Sprays should begin when panicles first appear and continue at the recommended intervals until fruits are about $1\,^1/_2 – 2$ inches long.

Fungicides used to control anthracnose in mango :

Using of fungicide is constrained by the pesticide regulations that exist in the producing and destination countries, and the product's efficacy. In general, copper fungicides have the widest acceptance. There are minor differences among the different copper formulations. Retention on applied surfaces was greatest with CuO, compared to $CuCl_2$ and 3 Cu $(OH)_2$. $CuCl_2$ (copper oxychloride) (Johnson and Hofman, 2009). copper fungicides are usually not very effective unless they are applied with other fungicides. For example, monthly applications of copper oxychloride combined with mancozeb were effective for most post-harvest diseases. Systemic fungicides, that would provide superior control compared to the above contact fungicides, are also limited. The benzimidazoles, primarily benomyl and carbendazim, provided excellent anthracnose control before resistance to them developed in the field (Akem, 2006). Two imidazoles, prochloraz and imazilil, are used in some countries for, respectively, pre and post harvest anthracnose control. To a lesser extent, prochloraz has also been tested as a post-harvest treatment.

For anthracnose on mango, Johnson and Hofman (2009) suggested that one or two applications should be made during flowering and early fruit set, with two additional applications at 21 and 7 days prior to harvest.

Mango trees should be sprayed twice with Bavistin (0.1%) at 15 days interval during flowering to control blossom infection. Spraying of copper fungicides (0.3%) is recommended for the control of foliar infection.

Sharma and Verma (2007) reported 100 per cent control of *Colletotrichum gloeosporioides* on mango by bavistin and topsin- M (systemic fungicides). Venkataravanappa and Nargund (2008) reported that tricyclazole (0.1%), carbendazim (0.1%), hexaconazole and benomyl (0.1%) were most effective in managing mango anthracnose.

Post-harvest disease management practices :

Anthracnose during post-harvest phase is most damaging and economically significant phase of disease world wide. It directly affects the marketable fruits rendering it worthless. This phase is directly linked to the field phase where initial infection usually starts on fruits during development.

The following can retard or reduce symptom development:

Fungicides :

The benzimidazoles are still effective as post-harvest treatments, although benomyl's registration has been cancelled. Thiabendazole (TBZ) is almost as effective as benomyl (benomyl's formulation enables superior host penetration, a greater spectrum of acitivity, and great efficacy).

Non-fungicidal measures :

Since there is a close relationship between ripening and the development of post-harvest disease, post-harvest disease development can be managed indirectly by delaying the onset, and reducing the rate of ripening (Prusky and Keen, 1993). As a climacteric fruit, mango undergoes profound biochemical changes as it ripens. Ripening is a process in fruit senescence that is associated with and enhanced by increased ethylene production (Brecht and Yahia, 2009). Mature fruit can be stored in the nonripe state as long as the climacteric initiation of ethylene production is prevented. Ethylene levels in mango fruit increase naturally from $<0.1\mu l\ kg^{-1} \cdot h^{-1}$ to1 to $3\ \mu l\ kg^{-1} \cdot h^{-1}$ during the ripening process, and ripening can be initiated in nonripe fruit by very low concentrations of exogenous ethylene ($\geq 0.005\mu l\ l^{-1}$). In practice, the climacteric rise in ethylene production is delayed with refrigeration. However, mango is sensitive to chilling injury and most cultivars must be stored at $>10^0$ to 13^0C. External sources of ethylene must also be removed from the storage environment (e.g. ripening fruit, smoke, engine exhaust fumes, etc.).

Ripening can be inhibited by following process:

– Modified atmosphere (MA) storage
– Hypobaric storage
– Refrigeration

Modified atmosphere (MA) storage:

(Usually reductions in O_2 levels and increased CO_2)

(Brecht and Yahia, 2009). Some work has been conducted on the impact of MA on post-harvest disease. For example, when fruit were exposed to an atmosphere containing 30 % CO_2 for 24 h, Prusky *et al.* (2009) reported an increase in the concentrations of antifungal compounds in fruit and consequently less disease when these fruit ripened However, MA is usually not used to manage anthracnose since mango fruit flavour is affected in atmospheres with <1% O_2 or >15% CO_2 and much more extreme concentrations of O_2 and CO_2 are needed to impact plant pathogens (Burg, 2004).

Hypobaric storage :

It is the superior to MA for extending the nonripe, postharvest life of mango fruit, and has been shown to suppress the post-harvest development of anthracnose of papaya (Burg, 2004). Its use for the long distance shipment of mango is constrained by technical criteria that have not been addressed successfully in prior attempts to commercialize the process.

Refrigeration :

Keep at 50°F (10°C), but do not chill fruits before they are ripe or there may be chilling injury.

Hot water dip :

Dip fruits for 15 minutes at about 120–130°F (49–55°C), depending on variety. and always test a few fruits before treating large batches. Vapour heat, forced-air dry heat: apply for 3–6 hours at various temperatures, depending on variety. Heated fungicide dips (aqueous): products and temperatures may vary.

Biological control :

Relatively little research has been conducted on the biological control of anthracnose. Lise Korsten's group has the longest history in this area, and they have focussed on using a Gram positive bacterium, *Bacillus licheniformis*, that resists desiccation and is food safe. In general, minor reductions in disease occur at 10^0C and 25^0C, either alone or in combination with fungicides (Govender and Korsten, 2006). Although less publicized, significant reductions have also occurred with Gram negative bacteria and other amendments (Vivekananthana *et al.,* 2004). To date, no biocontrol measure has been as effective as the most effective fungicides.

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