Journal of Medicinal Plants Studies
www.PlantsJournal.com

ISSN 2320-3862
JMPS 2016; 4(3): 233-236

Received: 23-03-2016
Accepted: 24-04-2016

Anup Kumar Sarkar
Department Of Botany,
Prasanna Deb Women's College,
Jalpaiguri, West Bengal-735101,
India.

Correspondence
Anup Kumar Sarkar
Department Of Botany,
Prasanna Deb Women's College,
Jalpaiguri, West Bengal-735101,
India.

Anthracnose diseases of some common medicinally important fruit plants

Anup Kumar Sarkar

Abstract
Anthracnose, caused by *Colletotrichum* sp. is a relatively common disease of many medicinally important fruit plants. The anthracnose pathogen is rather unique in that this fungus can infect virtually all parts of the plants. It is more problematic as it harms ripe fruits, even after the harvest. Thus a huge loss is faced during storage and transport. This review peers into the pathological symptoms and mode of disease spreading of anthracnose of some common medicinally important fruit plants including Mango, Papaya, Olive and Banana.

Keywords: Anthracnose, Acervulus, Conidia, Teleomorph, Anamorph.

Introduction
Anthracnose refers to a group of fungal diseases characterised by the development of dark, sunken spots or lesions, often with a raised rim, on affected foliage, stems and fruit. Under warm, humid conditions, the surface of the lesion is covered by a sticky pink spore mass (conidia) produced in a fungal fruiting body termed an acervulus. Anthracnose is a relatively common disease but seldom is a cause for major economic losses in several crops. It is a reemerging disease problem for growers worldwide. It is considered as one of the most problematic and economically harmful plant disease occur on a variety of hosts from trees to grasses [1]. Many commercial plants are also hampered due to the high susceptibility against the disease. Along with cereals and pulses the disease affects many medicinally and economically important plants like Banana, Mango, Avocado, Passion fruit, Citrus, Coffee, Papaya, Guava, Strawberry, Cashew nut, Pine apple and various types of vegetables. The infection is also reported in gymnosperms and in some ornamental plants. Anthracnose is regarded as the most serious disease especially for fruit plants worldwide due to its seed borne nature and pathogenic variability. In addition many of these fruit trees are grown in close proximity within the orchards, facilitating the dispersal of propagules between plants and the risk of epidemics is huge.

Pathogen
A number of fungal genera are able to cause anthracnose diseases. These include *Diplocarpon* sp, *Elsinoe* sp and, in particular, species of *Colletotrichum*. Species of *Colletotrichum* are a major cause of loss in many tropical plants. The fungus is more abundant in tropical and subtropical regions than in the temperate but are reported from all corners of world. The pathogen belongs to the order Melanconiales, under the class Deuteromycetes. Although the fungus has a teleomorph or sexual stage *Glomerella* sp but this plays only a minor role in the disease cycle and the anamorph or asexual stage i.e., *Colletotrichum* sp causes anthracnose diseases. As the perfect stage of the fungi is rarely seen, the name of the imperfect stage i.e., *Colletotrichum* is regarded as the correct name to describe this pathogen. The pathogen of Anthracnose is an ubiquitous pathogen which attacks all plant parts at any growth stage. The perfect stage, *Glomerella* and the imperfect stage, *Colletotrichum*, may be present on the same host plant or even same parts of the host plant. However, *Glomerella* does not produce either the symptoms on the fruit or the pinkish spores on agar typical of *Colletotrichum* [1].
The symptoms are most visible on leaves and ripe fruits. At first, anthracnose appears on leaves as small and irregular yellow or brown or black spots. The spots then expand and merge to cover the whole infected area. The intensity of color of the infected part increases with the age of host plants. The disease can also produce cankers on petioles and on stems that causes severe defoliation and rotting of fruits and roots. Infected fruit has small, water soaked,

sunken, circular spots that may increase in size up to 1.2 cm in diameter. These spots often enlarge, and lead to wilting, withering and dying of infected plant tissues. As it ages, the center of an older spot becomes blackish and emits gelatinous pink spore masses. The pathogen usually requires warm and humid conditions to infect host plants. Differentiation between *Colletotrichum* species based on host range or host origin may not be reliable, since it infects broad range of host plants. As the primary inoculum is disseminated by wind or rain, the pathogen is cosmopolitan in distribution [2].

2. Anthracnose of Different Economically important plant:

2.1. Anthracnose of Mango

Mango (*Mangifera indica*) is widely called the 'king of asiatic fruits'. It has good nutritive value and it is also used as source of vitamins and minerals. It is known to have medicinal properties. It is has great health benefits both when eaten raw and as a ripe fruit. The fruits (ripe and unripe), barks, leaves, seeds, roots and even the smoke of burning leaves have healing properties. The mango is known to be a very good source of vitamins such as vitamin C, thiamine, riboflavin, niacin and ß-carotene. Mangoes contain numerous polyphenolic and phytonutrient compounds that have been shown to exhibit antioxidant properties. These compounds are linked to anticancer and anti-inflammatory activities in the body. It has been reported that the fruits can be processed in to dry mango, mango pickle, mango jelly or can be eaten cooked while the fat contained in the seed can be processed in to flour or as a substitute of cocoa butter [3].

Anthracnose is one of the common fungal disease of Mango in fields, greenhouses and Orchards. It causes a serious economic losses to growers. It reduces both the yield and quality of the fruits. Almost all varieties of mangoes are affected by anthracnose. The most devastating effects of anthracnose occur in areas where it rains during the flowering and fruit set stages. The causal organism of Mango anthracnose is *Colletotrichum gloeosporioides,* which is also known by the name of its perfect stage *Glomerella cingulata*. As the perfect stage unable to produce disease symtomps, imperfect stage i.e., *Colletotrichum gloeosporioides* considered as the pathogen. The infective part of the pathogen is conidia. The conidia bearing structure i.e., conidiophore of the pathogen is more or less hyaline and single celled. The pathogen usually produces thick walled and septate mycelia which are dark coloured at the base and lighter towards the tip. The disease tends to manifest itself later in the season. The critical stages for infection in mangoes are flowering and early fruit development. Initially it can occur either as leaf spots or as fruit anthracnose. Occasionally anthracnose lesions are visible in young green fruit, more commonly in larger green fruit but most commonly in ripening fruit. The anthracnose fungus has the ability to penetrate green fruit where it may go into a dormant state until the fruit ripens. Developing fruit that are infected may show symptoms soon after infection or the infection may become 'latent'. In latter case the symptoms do not develop until post-harvest, as the fruit ripen. After the fruit ripening the anthracnose fungus can be re-activated in response to physiological changes associated with ripening. The changes include the development of lesions with subsequent spoilage of the fruit, development of spots on leaves towards the margins etc. The leaf spot then become dark brown in colour often with a darker border. Infection of young leaf flushes may occur when their emergence coincides with rainy weather. In very humid weather new twigs may show a dark affected area from the tip backwards, sometimes with defoliation of the young shoots. When newly formed fruit are affected the anthracnose shows as large, sunken, black lesions and the fruits so affected drop off. Medium to large green immature fruit affected with pre-harvest anthracnose show large lesions which are glossy, black and sunken. With these fruit, splits and oozing often occurs [4]. On the fully ripened fruits typical pink to orange spore masses (acervuli) are found. Anthracnose spores are harboured in dead leaves and twigs, which are washed onto the flowers or fruit by rainfall, dew or irrigation [5]. In the presence of free water the spores germinate and infect leaves, flowers and fruit. If wet weather prevails during flowering, the disease can build up causing severe blossom blight destroying inflorescences and reducing fruit set. Postharvest symptoms of anthracnose are sunken black spots, which appear on the surface of the fruit during ripening [6, 7, 8].

2.2. Anthracnose of Papaya

Papaya *(Carica papaya)* is a small, bushy tree with a hollow trunk, large palmate leaves and oblong smooth-skinned fruits. The fruits are usually picked in a green state and allowed to ripen. When ripe, the flesh become sweet and juicy and edible. The green fruits are also used as vegetables. In some developing countries, the traditional use of papaya is being investigated as an alternative to standard treatments for a range of ailments. It has a wide range of purported medicinal properties for treatment of diabetes, as birth control, as an antiseptic, antimicrobial, or diuretic, to control parasites, reduce inflammation, lower blood pressure, and lower cholesterol. While there are only limited data to support most of these uses, there is some evidence for healing bed sores and other wounds and in treating intestinal worms in humans. Now a days Papaya is a major food and export crop for many countries. But one of the major problem of its cultivation is the significant yield losses due to anthracnose disease. It is severe in tropical and subtropical regions due to high humidity and ample amounts of rainwater. The disease can significantly affect fruits that are refrigerated and exported out and is recognized globally as a major post-harvest disease. The pathogen of this disease is *Colletotrichum gloeosporioides.* The fungus is actually the imperfect or asexual state of *Glomerella cingulata.* The sexual teleomorph state of *G. cingulata* occurres on a broad range of host species produce acervuli within the host tissue during asexual (mitotic) phase of their life cycle. The teleomorph state is known for their ability to cause serious disease. The pathogen can infect papaya leaves, but the fruit is much more severely affected [9]. At the maturity of infected fruit the first symptoms are small and light-colored spots. As the spots enlarge they become sunken and take on a water-soaked appearance. These spots can grow to merge and rapidly destroy a fruit. When an infected fruit continues to ripen the disease also progresses and pinkish-orange or salmon-colored "cordial masses" of *C. gloeosporioides* are formed. The cordial masses typically form concentric ring patterns in the sunken lesions. Another common symptom is "chocolate spot lesions." These are sharply defined reddish-brown, irregular or circular spots about 1–10 mm in diameter. As a fruit continues to ripen, these spots quickly enlarge, forming circular, sunken lesions up to 20 mm in diameter. The reason the same pathogen causes two different symptoms is still unknown [10].

Spread of this pathogen among fruits and other plant parts and infection of papaya depend heavily on moisture provided by rainfall. Thus, anthracnose reaches highest disease incidence and severity in areas where relative humidity and rainfall are highest and the air temperature is warm and conducive for fungal development. Optimum air temperatures for the

pathogen occur between 18 and 25 °C. The infective spores are produced on acervuli and are dispersed in splashing water, rain droplets, and wind-blown rain [11]. The spores can germinate and form germ tubes if deposited on immature green fruit and if there is free water and a minimum relative humidity of at least 97%. Appressorium, or specialized fungal cells used to infect their hosts, form at the ends of the germ tubes on the fruit surface. The appressorium penetrates the host cuticle and epidermal layer with a "penetration peg" to establish infection. The infection remains latent until the post-climacteric stage of the fruit [12]. As the fruit starts to ripen, the pathogen resumes growth and the typical anthracnose symptoms appear. The fungus absorbs nutrients from the fruit as it colonizes it, then again forms acervuli and spores to complete the life cycle. In tropical and subtropical areas the growing seasons is continuous and the disease cycle is perpetually repetitive. In the absence of its host plant, *C. gloeosporioides* can survive as a saprophyte in dead infected papaya tissue or other organic matter [13].

2.3. Anthracnose of Olive

Olives (*Olea europaea*) fruits and their oil are rich in Vitamin E, iron, copper, dietary fibre and the good mono-unsaturated fats. The leaves are full of bioflavonoids and have potent antioxidant properties. Olives, olive oil and olive leaves are very much a part of the Mediterranean diet and modern medical research has shown that they are all beneficial to our health. Eating olives or olive oil can help prevent wrinkles, and slow the aging process, can help stop hot flushes in menopausal women, combat the ravages of alcohol, prevent dandruff (rub some oil into a dry scalp), make the hair shiny and healthy, prevent dry skin and acne, stop muscles aching, lower blood pressure and strengthen nails. Anthracnose of Olive is a serious fruit disease of this crop worldwide. The disease is caused by two fungal plant pathogenic species namely *Colletotrichum gloeosporioides* and *Colletotrichum acutatum*. For a long time only Colletotrichum gloeosporioides was known to be responsible for this disease. Latter two species of this genus (*C. gloesporioides* and *C. acutatum*) were identified as casual agents of the disease. However, *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. Which is the imperfect stage of *Gloeosporium olivarum* Alm, is considered as major pathogen of Olive anthracnose. The pathogen reduces the size and quality of fruits [14]. The fungus also affects olive oil quality by increasing the free acidity and the peroxide number. The peroxide number may even surpass the threshold of 20 mEq O_2 kg^{-1} of oil, which represents the legal limit of edibility [15]. Under favourable environmental conditions, the disease can devastate entire production fields. It harms the host in both in the pre and postharvest phases. The pathogen usually attacks ripe or overripe fruits, and only rarely the leaves, peduncles and shoots. On the fruits, it causes soft circular rotted spots, on which slimy orange-colored masses of spores are produced under high humidity. On the leaves, it may cause small spots [16]. The pathogen *Colletotrichum gloeosporioides* has a latent period and its spores can survive saprophytically for long periods. Infections begin by the spores germinating from the acervuli on the fruits, leaves and young shoots [17]. Attacks commonly occur from over-wintering spores or mycelium under favorable climatic conditions [18]. They are produced in acervuli on infected drupes and are dispersed by rain splash and via windblown rain droplets, causing secondary infection cycles. In acervuli many elliptical, one-celled and hyaline spores are produced. The incidence and severity of anthracnose vary considerably depending on the environmental conditions, the susceptibility of the olive cultivar and the virulence of the pathogen's population. Susceptibility of the drupes to anthracnose increases with maturity, although green fruit of susceptible cultivars may be severely affected in favorable environmental conditions. Postharvest infection by anthracnose disease on olive fruits are also common. Due to post harvest infection soft circular rots, dark, sunken lesions are developed. This Resulting in an orange slimy mass of spores on the fruit surface and finally all or part of the infected fruit starts to rot and dries up, shrivels and becomes mummified. The spores live on in infected, mummified fruit [19, 20].

2.4. Anthracnose of Banana

Bananas (*Musa paradisiaca*) are the quick growing fruit crops which are widely cultivated in many tropical and subtropical countries. The fruits have a worldwide demand for its nutritional and medicinal food value. Because of its characteristic flavor, food value and the small size it has a great potential for increased production to service the export market. But he short storage life of banana is the major drawback inexporting this commodity [21].Post harvest diseases are the main cause for the short shelf life of banana. Anthracnose becomes severe when the banana fruits are wounded by scratches during handling and transportation, making the fruit unmarketable. It deteriorates the quality and nutritive value of the fruits and renders them unfit for marketing and consumption thereby causing severe loss to farmers and traders. Another problem is that most of the banana cultivars are susceptible for the diseases [6, 22].

Banana anthracnose caused by *Colletotrichum musae*. Although *C. musae* is the most common species associated with anthracnose of banana, *C. gloeosporioides* has also been reported to be associated with banana anthracnose [23]. The genus *Colletotrichum* and its teleomorph *Glomerella* are considered to be major plant pathogens worldwide. This disease usually occurs during long transportation and storage period with relatively low temperature and high humidity [24]. Infection on the banana usually starts during the development of the fruit but remains quiescent until the fruit ripens. The symptoms often manifest during storage and marketing. Initial symptom of Anthracnose of banana is characterized as brown spots, which become sunken lesions with orange or salmon-colored acervuli. Lesions some time associated with brown coloured spore masses or acervuli in the lesion [23]. The lesion ultimately become black with spore masses or acervuli in the lesion. The Spores are more or less cylindrical or ellipsoidal appears as brown. The size ranges between 11.8–19.1 x 3.2–8.5 (µm). Spores usually infect young banana. The pathogen may cause symptoms on green fruit and may also enter the cut crown after hands are severed from stalks. Premature ripening of affected fruits may occur after infection. After infection the spores then quickly germinate and form appressoria and then infect immature banana in the field. The symptoms appear at the ripening stage when appressoria germinate and form infected hyphae, leading to the development of quiescent anthracnose. When the fruits ripen, the disease is further induced by the accumulation of phytoaloxins. Such phytoaloxins can facilitate the penetration of the fungus [25, 26, 27]. *C. musae* has also been reported causing other symptoms like blossom end rot, crown rot and tip rot etc [25]. With crown rot, anthracnose- symptoms occur as peel blemishes, as black or brown, sunken spots of various sizes on fruits. The spots may have triangular-shaped or angular edges.

3. Conclusion

Anthracnose cause the major damage in a wide variety of economically important plants. Some of the plants are nutritionally and medicinaly important fruits and vegetables. The disease anthracnose is different from other diseases in that it may occurs even after harvest. As a result a great amount of yield loss is also take place during post harvest condition. Due to such loss of yield in these fruits results the high market price, even though some times the price unable to fulfil the production cost spent by farmers or ownar of Orchards. As a result the farmers or agri-consists become less interested about the cultivation of such crop at commercial level. In turn it results less availability of such fruits. On the other hand there is always a great worldwide demand of such fruits. All these factors greatly stimulate the rise of market price of such fruits. Keeping in view the medicinal importance of such fruits they must be protect in such a way that the price value of such fruit must be not beyond the level of poor people. As the disease not only harms during growing time but also after harvest, the development of fungicide or any other mode of plant protection is not enough to control the economic loss. It is also a notable fact that some species of *Colletotrichum* show pathogenic effect on two or more hosts. It is also fund that one species stimulate the infection of another species. Almost all the species use many alternative hosts for survival and thus the genus has a wide host range. For example *C. gloeosporioides* the pathogen associated with anthracnose of Mango and Papaya, has also been reported to be associated with banana anthracnose [31, 6]. In most of the cases development of disease is stimulated by some environmental factors specially warm weather and rainfall in both developing stage and at the time of storage. Such environmental conditions are very common the regions where the plants are cultivated. All these factors increase the frequency of severity of Anthracnose disease. Thus the review suggest that a holistic approach is required in controlling the disease both on the field and during storage.

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