Sooty blotch and flyspeck in the mango variety Ataulfo/Honey – a literature review and potential ramifications of the disease for the mango industry

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Abstract

Sooty blotch and flyspeck (SBFS) is caused by a group of ectophytic fungi, which cause fruit blemishes. These blemishes can significantly reduce the sale price of fresh fruit. We conducted a literature review of SBFS in mango. One issue for SBFS studies is that the disease is likely caused by a large set of fungal species, as in SBFS of apple, but characterization of other pathogen species and their geographic distribution in mango production is still needed. Most research about SBFS has addressed apple production, and we consider the potential for the same management approaches to be useful for mango SBFS.

Introduction

The mango (*Mangifera indica L.*) is an important fruit crop in tropical and subtropical regions of the world. Pests and diseases, including sooty blotch and flyspeck (SBFS), impact the productivity of many orchards. A large number of ascomycete species and other fungi have been associated with SBFS in various fruit crops such as apple and mango, among others (Ploetz, 2018; Sauco and Lu, 2018). These fungi may reduce sunlight that reaches plant surfaces and limit photosynthesis (Ploetz, 2018), although the evidence for this effect is considered lacking by some experts (In contrast, the similarly named sooty molds produce a much denser mycelial mat.) In addition, the presence of SBFS on fruits is one of the major causes of economic losses since such blemished fruit have reduced marketability (Ploetz, 2018). Sooty blotch often reduces the value of fruit from premium fresh-market grade to processing use (Gleason et al., 2011).

Sooty blotch and sooty mold

The names sooty mold and sooty blotch have sometimes been used interchangeably (Misra et al., 1992; Prakash et al., 2001). They both can block sunlight and potentially reduce photosynthesis (Ploetz, 2018). However, they are two different disease complexes (Ploetz, 2018). Current thinking is that sooty blotch and flyspeck are a single disease complex (Gleason et al. 2011; Gleason et al 2019).

Sooty molds have been characterized as a group of facultative plant pathogens, although this idea has been challenged by experts. They affect a wide range of plants. Some sooty mold fungi require the presence of honeydew. Consequently, any plant that hosts phloem-feeding insects and/or upon which there is an accumulation of honeydew from these insects, is a potential target for these sooty mold species (Hughes, 1976; Nelson, 2008). However, it was also reported that some sooty mold fungi can grow on plants exudates in the absence of honeydew (Flessa et al, 2021).

Species causing sooty blotch and flyspeck grow directly on host surfaces, and do not require the presence of honeydew (Sauco and Lu, 2018; Ploetz, 2018). In general, symptoms of SBFS appear more diffuse than those of sooty mold (Figure 1) (Ploetz, 2018). The blemished fruits are not as marketable. The causal agents of mango SBFS appear to be similar to those on apple, carambola and pear (Martinez et al., 2009). The thalli of these fungal pathogens have a range of morphologies, ranging from dark irregular blotches of mycelia to groups of sclerotium-like bodies (Gleason et al. 2011).

Figure 1. Symptoms of sooty mold (left) (Fig. 12.38 in Cooke et al. 2009), and SBFS (Ploetz, 2018) on surfaces of mango fruit.

Causal agents of sooty blotch and flyspeck

Sooty blotch and flyspeck (SBFS) is a disease complex caused by over 100 different fungal species and affecting a range of fruit crops (Gleason et al. 2019). SBFS taxonomy from 1832 to 1997 was synthesized by Williamson and Sutton (2000). In 1832, Schweinitz described *Dothidea pomigena* (Schwein) as the single causal agent of SBFS. SBFS was subsequently thought to be two specific diseases: sooty blotch and flyspeck. "Sooty blotch" traditionally referred to colony morphologies that may contain dark mycelium with sclerotium-like bodies. "Flyspeck" traditionally referred to colonies that are characterized by groups of sclerotium-like bodies with no visible intercalary mycelium (Batzer et al., 2014). *Schizothyrium pomi* was described in the early stages of study of the disease as the pathogen associated with flyspeck (Colby, 1920), whereas *Gloeodes pomigena* was identified as the causal agent of sooty blotch (Groves, 1933). Based on colony morphology on apple, sooty blotch was further divided into distinct mycelial types (Colby, 1920), which were further classified as variants of *Gloeodes pomigena*

(Groves, 1933; Sutton and Sutton, 1994; Hickey, 1960). With the use of both mycological techniques and molecular techniques, many more species that are associated with SBFS have been deciphered (Gleason et al., 2011). It appears that SBFS is caused by a fungal complex that includes species assemblages, influenced by geographic region as well as disease management practices. SBFS includes more than 100 named and putative species worldwide in 30 genera of Ascomycota and Basidiomycota (Gleason et al., 2019). Some of these fungi are in the Dothideomycetes order Capnodiales (Batzer et al., 2014)

Several species have been listed as causal agents of SBFS of mango. In China, *Cladosporium cladosporioides* was reported as a causal agent of mango SBFS (Yang et al., 2015a; Yang et al., 2015b), although experts have reported doubts about the role of this species, since *Cladosporium* spp. are common inhabitants of the fruit surface and would readily be isolated. For flyspeck, Ajitomi et al., (2017) reported the pathogen *Stomiopeltis* sp. as a causal agent of flyspeck of mango. Various putative *Stomiopeltis* spp. have also been found in North America; they lack a complete Latin binomial since there has been no sporulation in *in vitro* culture (Gleason et al., 2019).

Ecology

It is likely that SBFS of mango is caused by a large number of fungal species, as in apple. Many SBFS species can occur in a single apple orchard, with different assemblages of species observed across different orchards (Gleason et al., 2019). Three key questions about the ecology of SBFS of mango are important for developing management strategies.

1. Which species cause SBFS in mango?
2. What is the geographic distribution of these species in mango growing areas?
3. Which of these species are different enough in terms of their responses to management (and weather variables) that they require different management approaches?

Orchard management appears to play an important role in SBFS species distribution and prevalence (Díaz Arias et al., 2010; Batzer et al., 2014). For example, SBFS species diversity was higher in apple orchards with no fungicide sprays than in those that had received fungicide applications (Díaz Arias et al., 2010). Understanding which mango SBFS pathogen species are widespread throughout mango production regions, and which are more localized, could help in formulating management strategies. Likewise, understanding which species are particularly important for Ataulfo/Honey mango production will help in developing efficient management.

Leaf wetness duration is an important factor for SBFS fungal communities, whereas broad ranges of temperature optima have been observed in the eastern US (Gleason et al., 2019). There is the potential for including environmental variables such as leaf wetness duration and relative humidity (Rosli et al., 2017) in decision support models for SBFS management in mango. The development of such models will depend on achieving conclusive answers to the three questions above.

Understanding of the phenological development of SBFS of mango is another important dimension. For SBFS in general, leakage of sugars and organic acids through fruit peels has been associated with increases in SBFS (Gleason et al., 2019). The phenology of surface nutrient availability may be cultivar-specific, and could be important for understanding efficient timing of fungicide applications.

The species present in an epidemic of mango SBFS may also influence the course of epidemics if they have different amounts of secondary spread within a season. Interactions among fungi and other microbes in the fruit surface microbiome may also influence disease progression.

Research challenges for understanding SBFS pathogens

Gleason et al. (2019) have outlined challenges for studying SBFS, in apple and in general. These challenges will have to be addressed to better understand SBFS in mango, as well. As discussed above, the multiple species potentially contributing to mango SBFS is an issue. Another challenge for study is that surface sterilization of plant samples tends to kill SBFS fungi. Therefore, sampling SBFS fungi without also including a wide range of unrelated species in samples can be difficult. SBFS fungi often do not sporulate readily on fruit surfaces or in culture, and colony morphology has limited utility for taxonomy.

Management and economic considerations

There are few published studies of SBFS management for mango. However, we can consider the potential for methods used in apple SBFS management to also be useful in mango production. When considering use of these methods in mango production, it will also be important to consider the differences in environmental conditions between generally temperate apple production and tropical mango production.

Fungicides

SBFS pathogens have been controlled with fungicides in apple orchards (Williamson and Sutton, 2000). Gleason et al. (2019) review development of decision support systems for fungicide use to manage SBFS in apple production. The Brown-Sutton-Hartman warning system was developed in the eastern US, additional information about rain was added, and then a midwestern US version with relative humidity used in place of leaf wetness duration, the Gleason-Duttweiler warning system.

Development of a decision support system for mango SBFS management with fungicides could begin with these decision support tools. Other factors that could be important in forecasting the need for fungicide applications include the features of the mango orchard (cultivar, planting density, tree size, etc.) and potential inoculum sources.

Different species causing apple SBFS can have different sensitivity to fungicides (Tarnowski et al., 2003), making an understanding of the geographic distribution of species useful for tuning management approaches. Warning systems likely need to be specifically tuned to specific geographic locations.

Organic mango production has the potential to benefit from SBFS management based on organic fungicides used in apple production. Gleason et al. (2019) review the potential in apple orchards for use of biological control, kaolin-based films, methionine-riboflavin and potassium bicarbonate, but it appears these may help with management but were not always economically successful.

In general, research should address the potential to reduce the need for fungicides by improving other aspects of disease management.

Management of inoculum from reservoir host plants

Many plant species have the potential to act as reservoir host plants for pathogens causing mango SBFS, although there are likely to be subsets of these species that are important for particular pathogen species. In apple, many potential reservoir hosts for SBFS have been identified, including in the Rosaceae and Ebenaceae, but inoculum has not been reported to travel more than a few hundred meters from reservoir hosts (Gleason et al. 2019), suggesting that management of reservoir plant species immediately in or around mango production is likely sufficient. Identifying which reservoir plants are of particular concern in mango production systems is one research priority.

Apple mummies and decaying fruit can be a source of inoculum for apple orchards. It would be useful to evaluate what role dried mango fruit may play in epidemics of SBFS of mango.

Site selection

Mango production situated so that plant surfaces dry more quickly may have fewer problems with mango SBFS. For example, sites that are exposed to more wind may have less damage.

Pruning

Similarly, there is the potential for more open canopies to dry more quickly. Selective pruning of plants to produce a more open canopy may be useful for reducing mango SBFS, and may have synergistic effects in combination with other management approaches.

Fruit bagging

Fruit bagging has seen success in SBFS management in apple (Gleason et al., 2019). Fruit bagging is expensive because of the labor required for positioning the bags before SBFS fungi are established and removing the bags in time for fruit maturation. Other diseases that benefit from the enclosed environment may become more common with bagging. Mango fruit bagging is already in use in some production systems, and can also protect fruit from fruit fly damage, potentially reducing the need for insecticides. Research to support mango fruit bagging should address the magnitude of reduction in SBFS incidence and severity, the cost of bagging, the potential savings in pesticide use, the cost and environmental consequences of production and disposal of bag materials, and the potential increase in other diseases due to bagging.

Postharvest treatments

Post-harvest washes of apple fruits have enabled the removal of blotch on apple fruit (Batzer et al., 2002). Similar postharvest dips may be useful for mango, where testing of potential such as chlorine bleach, soaps, and sodium bicarbonate might identify useful treatments. Brushing has sometimes been useful in postharvest treatment of apples (Gleason et al., 2019) and systems for apple have the potential to be adapted to the different fruit texture of mangoes.

Conclusions

1. An important first step will be to better understand the full set of species that contribute to SBFS of mango.
2. The geographic distribution of the species can help to guide formulation of management, along with an understanding of how the species differ in their management needs and which are most important in Ataulfo/Honey mango.
3. Studies of management options for apple SBFS can contribute to developing management strategies for SBFS in mango. These management options should be tested for their effectiveness and for their economic efficiency in Ataulfo/Honey mango production.

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