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Citrus Black Spot Disease in Ghana: A Review on Impacts, Management Options and Current Status

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ABSTRACT

Citrus is one of the most common seasonal fruit crops cultivated across most semi-deciduous forest zones across the globe. Apart from its refreshing nature when consumed in a fresh state, it is also packed with an abundant supply of vitamins A, B and C. Apart from being served in the raw state as a fruit or a dessert, it also serves as a critical raw material for the beverage industry. In some instances, it also serves as a very important material for the pharmaceutical industry. As important as this fruit can be, its production is challenged by the incidence of pests and diseases. One of the major diseases facing the industry is the Citrus Black Spot (CBS), caused by *Phyllosticta citricarpa*. In Ghana, CBS is known to affect almost all citrus species and varieties in commercial groves, except for sour orange (*C. aurantium*) and its hybrids and Tahiti lime (*C. latifolia*). It is estimated to be responsible for about 22% of fruit/yield loss annually. This review highlighted the impact on the citrus production industry in Ghana, the management options available and future perspectives.

Key words: Citrus black spot, Citrus, Epidemiology, Fruit yield.

Citrus fruit is a significant economic crop across the globe. This is due to its high moisture and nutritional content, it has a refreshing taste and an abundant supply of vitamins A, B and C, making it appealing to consumers. It is a blend of acidic and sweet fruit, primarily from the genus Citrus, which are member of the Rutaceae family (Umer *et al*., 2021). About 161.8 million tons of citrus fruit were produced across the globe in 2021 on about 10.2 million hectares of land, placing them as the second most cultivated fruit across the globe (Pereira Gonzatto and Santos, 2023). The only fruits to surpass this amount were bananas and plantains combined, which totaled over 170.3 million tons (Pereira Gonzatto and Santos, 2023). Most of the citrus production in Ghana is mostly focused in the semi-deciduous forest zone, with the main production regions being the Eastern, Central and Ashanti regions (Brentu *et al*., 2012). As at 2016, Ghana was the 18th-highest citrus producer in the world (CDC Consult, 2016). Although citrus is vital to the Ghanaian economy, it faces several production constraints. One of the most prominent among the challenges is the incidence of pests and diseases, one of which is Citrus Black Spot (CBS) (Akosah *et al*., 2021).

Citrus Black Spot is prevalent globally in most tropical and subtropical regions, especially in warm and humid climates. It is a fungal foliar and fruit disease caused by the *Phyllosticta citricarpa* (previously known as *Guignardia citricarpa*) (Baldassari *et al*., 2008; Guarnaccia *et al*., 2017; Kotzé, 1981; Urbina *et al*., 2021; USDA, 2021). The pathogen affects the fruits and foliage of many citrus hosts, generating a variety of symptoms. on Susceptibility to the disease has been reported to vary among different varieties of lemons, limes, mandarins and late-maturing sweet oranges (Guarnaccia *et al*., 2019; Kiely, 1948a, 1948b; Kotzé, 1981; Snowdon, 1990). In Ghana, CBS is known to affect almost all citrus species and varieties in commercial groves, except for sour orange (*C. aurantium*) and its hybrids and Tahiti lime (*C. latifolia*) (Brentu *et al*., 2012). The first documented instance of CBS can be traced to 1897 in Australia (Cobb, 1897) and 1999 in Ghana in the Eastern Region., in that instance, several citrus species showed several typical symptoms. It has since become one of the most important citrus diseases of economic importance in the country, causing about 22% crop loss (Brentu *et al*., 2012).

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Symptoms of CBS

Symptoms of the CBS disease include a hard spot, which is identified by sunken lesions on the fruit rind with reddish-brown raised borders that may contain pycnidia of the asexual stage of *P. citricarpa*. The virulent spot is characterized by a sunken necrotic lesion that spreads without well-defined borders on mature fruits, while false melanose appears as small black pustules arranged in a tear-stain pattern, freckle, cracked, or speckled spot (Fig 1). Symptoms for leaves and twig infections are not commonly seen on commercial citrus species such as oranges and mandarins but are frequently observed on lemons. These symptoms typically manifest as small, round, sunken necrotic lesions with a yellow halo (Kotzé, 1981). CBS also causes fruit drop and aesthetic degradation, with a resulting financial loss for the sale of the fruit in its natural state (Kupper *et al*., 2020). Fruit can be infected for up to 6 months (24 weeks) after petal fall, whereas leaves can be infected for up to 10 months from flush (Baldassari *et al*., 2006; Truter *et al*., 2004, 2007). Infected fruit symptoms become copious, usually at the same time as the fruit is ripening. However, the magnitude of these symptoms is influenced by various physiological and environmental factors such as temperature, rain, light and the age of the tree (Frare *et al*., 2019; Kotzé, 1981). In most instances, infected fruits that are asymptomatic during harvesting and packing show visible symptoms of the disease during transport or storage, reducing their salability and market value (Brentu *et al*., 2012).

The hard spot symptom of black spot on mature fruit (*Citrus Industry*, no date).

Fig 1: Citrus black spot symptoms caused by *Phyllosticta citricarpa*.

Etiology and epidemiology

Phyllosticta citricarpa has exclusively been detected on plant species belonging to the Rutaceae family and can be obtained from asymptomatic citrus tissues (Baldassari *et al*., 2008). The life cycle of *P. citricarpa* consists of both a sexual phase (with ascospores as inoculum) and an asexual phase (with conidia as inoculum) (Fig 2). For sexual reproduction, ascospores are formed in the fungal structures (pseudothecia) which contain ascospores. This type of reproduction is particularly important for long-range dissemination (Guarnaccia *et al*., 2019; Parnell *et al*., 2020; Spósito *et al*., 2007; Truter *et al*., 2004, 2007). This method of production normally occurs in the decaying leaf litter on the orchard floor and develops 40-180 days after infection in infected leaf litter. The infected leaf litter provides suitable conditions for pseudothecia to establish, grow and reproduce. These pseudothecia then release ascospores as primary inoculum, starting new infections (Dummel *et al*., 2015; Fourie *et al*., 2013; Guarnaccia *et al*., 2017; Huang and Chang, 1972; Kotzé, 1963). The release of mature ascospores from the asci of pseudothecia is triggered by rainfall, irrigation, or heavy dew (Baldassari *et al*., 2006), excessive rainfall, however, will disrupt ascospore discharge and cause the dead leaves to decompose, destroying the *P. citricarpa* substrate (Kotzé, 1963, 1981; Lee and Huang, 1973). The ascospores are then disseminated by air currents

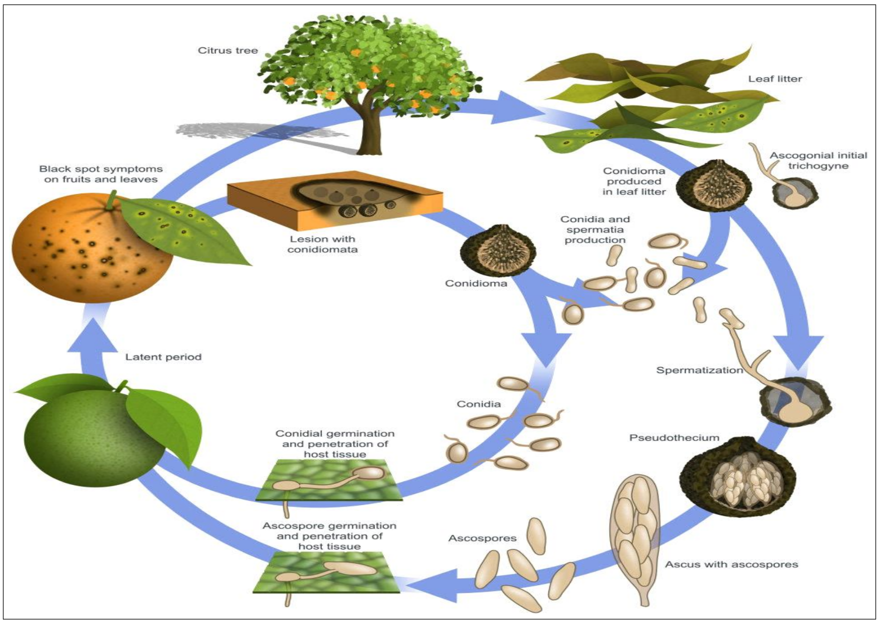

Fig 2: Cycle of citrus black spot disease, caused by *Phyllosticta citricarpa* (Guarnaccia *et al*., 2019).

over long distances and deposited on the surfaces of leaves and fruits, where they subsequently germinate and penetrate to create quiescent infections (Huang and Chang, 1972; Lee and Huang, 1973; McOnie, 1967). On the other hand, conidia are formed within specific types of lesions on fruit, twigs and leaves from pycnidia (Kiely, 1948a; Kotzé, 1981). Conidia play a significant role in situations where mature infected fruit coexists with young growing fruit on the same tree, in areas with a high number of dead twigs and in citrus varieties that develop hard spots with pycnidia on leaves. While ascospores are only found on fallen leaves (leaf litter). Conidia can be found on diseased fruit, green leaves (primarily lemons), dead twigs (not on green twigs) and green leaves (Baldassari *et al*., 2006; Kiely, 1948a; Kotzé, 1963). Primarily, conidia were thought to play a less significant role in disease transmission than ascospores due to their shorter dispersal distance by splash and lesser viability. However, recent studies suggest that water and wind may spread conidia over wider distances than previously thought (Perryman *et al*., 2014).

During infection, the spores germinate and form appressoria in the presence of moisture. The pathogen starts infection by penetrating the cuticle and expanding into a small mass of mycelium between the cuticle and the epidermis wall, resulting in a latent infection (McOnie, 1967). The length of the latent period can be influenced by various factors, including the concentration of the inoculum and the diameter of the fruit (Frare *et al*., 2019). During the fruit's maturation stage, a temperature increase from 20 to 27°C can cause CBS symptoms to manifest and lead to the growth of a significant number of fruit lesions. High levels of light illuminations have been linked to an increase in fruit lesions, with symptoms being more pronounced on the side of the canopy that receives higher illuminations of light. Additionally, increased CBS symptom expression may result from dry conditions. The development of CBS is also influenced by stress and aging, as symptoms are typically more severe in older trees than in healthy, young trees (Kotzé, 1981).

Climate has a significant impact on the epidemiology of the disease; mild to warm temperature swings and a cycle of wetting and sun-drying of the leaves are favorable conditions for pseudothecia maturation and ascospore release (Dummel *et al*., 2015; Fourie *et al*., 2013; Huang and Chang, 1972; Kotzé, 1963; Lee and Huang, 1973; Reis *et al*., 2006). Furthermore, these conditions must occur repeatedly in subsequent years for the organism to persist in disease manifestation (Yonow *et al*., 2013). These weather conditions are predominant in most parts of Asia, Africa, South America and Australia where CBS has been known to occur. However, the disease in recent times has been detected in Florida, North America. (Schubert, *et al*., 2010). Yonow *et al*. (2013) utilized CLIMEX modeling to predict the potential worldwide distribution of *P. citricarpa* and their findings corresponded to the known areas or regions where the disease has been reported (Fig 3). According to their findings, *P. citricarpa* had a high ecoclimatic index (EI) in areas where the disease is prevalent, including Ghana.

Impacts of cbs on citrus production in Ghana

Orange is an essential component of the tree-crop-based farming system in western Africa's semi-deciduous forest agroecological zone, where it is commonly cultivated. Over 1.3 million tons of orange fruits are produced in the region, with Ghana producing over 53% of that total (Akosah *et al*., 2021; Ofosu-Budu *et al*., 2007). More than 20,000 producers are employed by the citrus industry in Ghana. Therefore, even though citrus does not constitute a food security crop, it provides a significant source of income for small-scale farmers and is of particular importance for women who market the fruit nationally (Akosah *et al*., 2021; Ofosu-Budu *et al*., 2007). Orange is mostly grown by smallholder farmers in Ghana's forested regions, primarily in the Eastern, Ashanti and Central regions, where annual rainfall surpasses 1000 mm and is distributed bimodal (Ofosu-Budu *et al*., 2007). In 2021, Ghana's citrus production reached approximately 743,263 tons (knoema, 1961-2022). Citrus black spot is a major production constraint affecting orange farming in the country (Akosah *et al*., 2021).

According to a 2012 study, that investigated the impact of CBS on citrus yield, which included field and market surveys, CBS is at its epidemical levels in citrus-producing

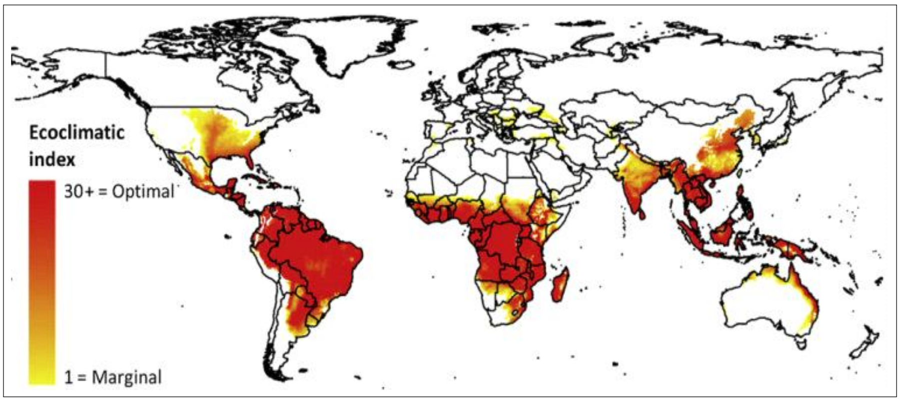

Fig 3: Potential global distribution of *P. citricarpa* (Yonow, Hattingh and de Villiers, 2013).

areas of Ghana's Eastern and Ashanti regions and is spreading rapidly to other regions (Brentu *et al*., 2012). The study also identified CBS as the most significant fruit disease affecting citrus in Ghana, resulting in a crop loss of about 22%. This high rate of crop loss has led to the discarding of a significant amount of blemished fruit, resulting in reduced income generation, with possible unstudied human and animal, as well as environmental health implications in the country. country.

Management strategies for cbs disease

Various management approaches have been employed over time to curtail the menace of the CBS. In many instances, these strategies include chemical, cultural and a hybrid of the two.

Cultural method

Culture control methods basically have to do with carefully choosing or combining various farm operations and practices to manage or prevent the prevalence of the disease. *Eg*. The use of clean planting materials usually seeds and seedling stocks for grafting. Pruning has also been postulated to be one of the very useful practices in managing the disease. This approach focuses on removing diseased branches and leaves from the standing tree to remove or reduce the inoculum load in the farm, or the removal of excess branches and leaves to enhance aeration on the far. Well-aerated fields have been reported to have created unfavorable conditions for the development of the pathogen by reducing the level of humidity on the farm. Also, other practices such as timely weed management, among other practices such as removal of other host plants enhance the rate of success in not only managing the disease but preventing it (Dewdney and Yates, 2010).

Host-plant resistance

Host-Plant resistance has been one of the effective methods to manage the disease. This has to do with using resistant citrus varieties as planting materials which can still strive, even in the presence of the disease with minimal impacts. According to a 2000 study, *Citrus aurantium* (sour orange) is one of the well-known varieties that is resistant to the disease. The same study also revealed that some species such as *C. limo* (lemons). And *C. paradisi* (grapefruit) is the most susceptible species to disease (Dewdney *et al*., 2022). As much as this has proven to have a promising future in the management of the disease, it is also important to acknowledge that the journey will face a lot of inconsistencies and setbacks. This is because outright resistance is not easy to come by and the fact that genetic resistance in most instances breaks with time. For commercial usefulness, a step ahead with genetic modification looks like a sure way to develop more sustainable cultivars that are resistant to the disease.

Chemical method

Chemical control, as one of the undoubtable approaches to managing crop disease has been a phenomenal method of managing the CBS over the period. Mainly, many studies have postulated the use of benzimidazoles, copper-based fungicides, benzimidazoles, strobilurins and dithiocar bamates as one of the effective ways of managing the disease. Unfortunately, it was reported later that some strains of *Phyllosticta citricarpa* have developed resistance to benzimidazoles in some regions of higher epidemics (Goes *et al*., 2000). The implication of this could be that fungicides and their combinations should be chosen carefully, to minimize the risk of pathogens developing resistance to the active ingredients. To achieve this, it is also important to apply fungicides, complemented with other cultural practices to enhance the level of success in the control of the disease (Korf *et al*., 2001).

Postharvest management

Oftentimes, freshly harvested fruits usually portray latent infections. These infections usually manifest during transport or storage, sometimes even on the shelves in the market. This implies that there must be very critical postharvest measures to curtail symptoms that may not show while the fruits are on the field or at harvest time. In most instances, the ideal case is to create an unfavourable environment for the development of the pathogen. For example, fresh fruits can be refrigerated (usually at 27°C and under spontaneous light) to slow down the development of the pathogen. It has also been reported that hot water treatment and waxing reduce the virulence of the pathogen even when lesions have already been formed (Korf *et al*., 2001).

Current status and prospects

In recent times, many studies have focused on localized the relationship between climate and geographic location on the incidence, severity and management of the CBS. This has brought to light the distribution pattern of the disease (Hendricks *et al*., 2020). To this, one of the focal points of discussion on achieving optimum levels of management of the CBS is the identification and usage resistance varieties. To this, (Miles *et al*., 2019) studied the efficacy of some 49 citrus cultivars by introducing them to in-field novel inoculation assays. Apart from this, current studies have also focused on the use of clean. and healthy planting materials, as to prevent the introduction and spread of pathogens to previously uninfected sites and regions (CDFA, 2023; Dewdney *et al*., 2022; Miles *et al*., 2019).

In as much as many studies have been conducted in several directions, there are still several ongoing. The future of the various studies may still have to focus on discovering and developing a variety of effective management strategies to manage the disease. In this stance, there is a high chance of reducing the menace caused by the disease. This may be seen in the improvement of the quality and quantity of yield. Many studies may also delve into the investigation to develop site-specific management practices, including application time and frequency and planting and harvesting time, among other farm management practices. In summary, phytopathological studies are critical in discovering and developing new and highly efficient and environmentally benign approaches to combating the impacts of the disease (CDFA, 2023; Dewdney *et al*., 2022; Miles *et al*., 2019).

CONCLUSION

CBS is one of the most important economic diseases affecting the production of citrus across many citrus production regions. It is responsible for about 22 % of the general yield loss in citrus production annually. Its mode poof yield reduction is seen both in the quality and quantity of the produce. The *Phyllosticta citricarpa* is a fungus that is favored by a wide range of environmental conditions. This makes it strive well in various regions, causing various levels of economic constraints if not managed properly. Due to its adaptability to a wide range of environmental conditions, it also makes it quite difficult to manage. Management methods such as fungicide applications have been reported in some studies to be effective. However, this has dwindled with the rising development of fungicide resistance. On the other hand, the use of resistant cultivars, coupled with careful selection of cultural practices has been mentioned as one of the effective ways of managing the disease. Postharvest practices such as temperature management and waxing have also been proposed to be effective in the management of the CBS. It is advisable that even though research has advanced on the disease, no sole method or approach has been identified to have absolute control or manage the disease. It is recommended to combine two or more methods to effectively manage the disease.

Conflict of interest

All authors declared that there is no conflict of interest.

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