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Status and Significance of Citrus Greening (Huanglongbing) Disease in Ethiopia

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Abstract
The huaglongbing (HLB) is the most feared disease and cause total yield loss citrus orchards under favorable environmental conditions. The Candidatus Liberibacter species is the cause of citrus greening which is carried on Diaphorina citri during feeding of leaves. In Ethiopia citrus are produced in large commercial and small scale farmers. However, the status of yield reduction has no more attention were given. The critical diagnosis is important task either the citrus tree has blotchy mottle or leaf yellowing due the deficiency of nutrient or HLB. The asymmetric mottle is produced when HLB affects the plant, which can be shown as atypical patches of light green or yellow in contrast to the normal green color of the leaf. When once infected the field the disease control is impossible rather than removing infected trees. Therefore, the government is better to establish strong quarantine policy for the inspection of exchanging materials from abroad or even within country exchanging citrus stocks or scions for breeding purpose without certification.
Keywords: Blotchy mottle, Candidatus Liberibacter, Citrus greening, Diaphorina citri, Huanglongbing
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Introduction

Citrus greening (huaglongbing, HLB) is the most epidemic disease of citrus trees in the world. In the last few years, more than 58 nations including tropics and subtropics of Africa, Asia, India and Bangladesh have been reported occurrence of disease (Braswell *et al*., 2020; Vashisth and Kadyampakeni, 2020). It is difficult to determine where HLB originated. However, there is information suggesting that HLB was responsible for India's citrus dieback during the eighteenth century (da Graça, 2008). Initially, researchers believed that the tristeza virus was the leading cause of the citrus dieback in India, but after a thorough survey, HLB was determined to be the primary cause (da Graça, 2008). In China, HLB has been reported since 1919 and described as the citrus yellow shoot disease (Bové, 2014). In 1937, the first time report has been made in South Africa (Garnier *et al*., 2000)

The presence of *Diaphorina citri* (Vector for HLB) has been reported in 21 countries out of 54 African countries (Ajene, 2020) and detected in Tanzania, Kenya during 2016 and 2017 respectively (Shimwela *et al*., 2016; Rwomushana *et al*., 2017). In Ethiopia the distribution of African citrus triozid (ACT) showed an irregular pattern (Hailu and Wakgari, 2019). The highest infestation of ACT has been reported on White sapota (*Casimiroa edulis*) in Oromia and Dire Dawa (Hailu and Wakgari, 2019) which is among the alternative host plants. The yield reduction of citrus due to the bacteria disease is does not given attention in social community in spite of the constraint might be caused nutrient deficiency. Therefore, the present review is focused on the social awareness, early warning and the way of control method for minimizing the risk caused by citrus greening in Ethiopia.

Distribution of citrus greening

The putative dispersal patterns of Asian citrus Phsyllid suggest that it may have spread from the regions of the initial detection into other countries. The natural movement of Phsyllid may be an unlikely route of long-distance dispersal, but the free flow of plant products such as bud wood and root stock seedlings through trade within the eastern African region could assist the long-distance dispersal of the eggs and nymphs (Rwomushana *et al*., 2017).Citrus greening disease is naturally disseminated by insect vector *Diaphorina citri* (Hemiptera:Liviidae) and Trioza eryt- reae (Del Guercio) from diseased plant to healthy during insect feeding. HLB bacteria can also be spread through plant grafting and movement of infected plant material (Lin, 1956). Even though the pathogens are bacteria, the disease does not spread by casual contamination of personnel and tools or by wind and rain. The widespread presence of ACT in Ethiopia, as well as the presence of '*Candidatus Liberibacter asiaticus'* associated HLB already present a significant risk to citrus production in Ethiopia (Dessie *et al*., 2022). The presence of the *Ca. L. asiaticus* in Ethiopia, recent detection of ACP in the African continent, free trade movement, presence of reservoir hosts plants and similar climatic patterns, there is a need to confirm the presence and status of ACP in the country. The three species of bacteria associated with HLB: '*Ca. Liberibacter asiaticus', 'Ca. L. africanus'*, and '*Ca. L. americanus', 'Ca. L. africanus'* and its vector, *Trioza erytreae*, are both heat sensitive, and when present, occur in citrus when temperatures remain below 30 to 32°C. In Africa, '*Ca. L. africanus*' and *T. erytreae* have been reported in South Africa, Zimbabwe, Malawi, Burundi, Kenya, Somalia, Ethiopia, Cameroon, and Madagascar (Bove, 2014). However, Dessie et al.2022 reported the HLB bacteria species *Ca. Liberibacter asiaticus* which is transmitted by vector *Diaphorina citri* in Upper Awash citrus farm in Ethiopia, which is also possible the vector live above 30 ºC and the bacteria strain is adapt those temperature fluctuation (Hall *et al*., 2013).

Limitations and constraints for identification of citrus greening

Citrus greening is serious problems for citrus crops in the world (Wang, 2020). The HLB disease is threating citrus fields in Ethiopia. However, the actual yield reduction data were not established. Naturally, HLB disease is confusion for diagnosis easily, resemblance of nutrient deficiency (Abate, 1988). The strain of HLB in recent years has made the situation more complex in the country (Saponari *et al*., 2010; Ajene *et al*., 2019). The majority of growers or even experts are neither aware of HLB presence nor acquainted with efficient control options in Ethiopia. Some farmers manage these trees by applying farmyard manure and plant residues. The major problem related to HLB is that it interacts with soil nutrient amendments (Zhang *et al*., 2016). Ajene et al. 2019 described the field investigation of the disease confirmed the presence HLB with significant damage on citrus orchards located in different parts of northern Ethiopia. The visual diagnosis of HLB in citrus is difficult as some cases it might be looks like zinc or manganese deficiency and some growers supply nutrient (Dessie *et al.,* 2022).

Disease epidemiology

Citrus greening is an obligate bacterial disease that was serious in many citrus planting. The African citrus psyllid (*Trioza ertreae)* is common insect vector and transmits huaglongbing, also called citrus greening while feeding on the saps of the phloem. Hence, the disease could be transmitted from infected trees to a healthy one with the help of the vector so-called citrus Psyllid. According to the report the specific cause of the disease and its vector were identified in Ethiopia in 2016 (Atsbha, 2081). The presence of the disease and the natural vector may lead to rapid spread of the diseases to many parts of citrus growing region. The bacteria also transmitted through grafting if the grafting tools have been taken from infected plant tissue (Garces-Giraldo, 2012; León and Kondo, 2018).

The bacteria disease cannot be spread by wind, rain, or contact with contaminated personnel, unlike other infectious diseases. In the citrus growing areas of the world, its insect vectors have been most observed, and this may occur due to gigantic movements of plants and insects around the globe (Tolba and Soliman, 2015) as well as some calamities such as hurricanes or storms that have played an important role in expanding the Asian citrus Phsyllid over vast distances (Gottwald 2010; Wang *et al*., 2017). Among the three Candidatus Liberibacter species, there is the fact that their ecological adaptation is not the same to each other considering temperature. If we represent CLas, which fosters when the temperature is over 30 ºC, which manifests as a heat-tolerant species (Hall et al., 2013), and the CLaf species, adaptation is closely associated when the temperature is below 30 ºC. That's why in the case of altitudinal distribution of the two pathogen species, ecological preferences are first (Jagoueix *et al*., 1994).

HLB symptoms and nutrient deficiency problems

Citrus leaves infected with citrus greening showed a characteristic symptom of blotchy mottled and yellowing discolorations (Catara *et al*., 1988; Rasowo ,2019). Symptoms are many and variable: yellow shoots, twig dieback, leaf drop, leaves with blotchy yellow/green coloration similar to the symptoms of zinc nutritional deficiency, enlarged veins that appear corky, excessive fruit drop, small and misshapen fruit, fruit that remains green at one end (the stylar end) after maturity, fruit with mottled yellow/ green coloration, small dark aborted seed inside fruit, discolored vascular bundles in the pithy center of the fruit, bitter tasting fruit, and silver spots left on fruits that are important for visual diagnosis of fruits infected for HLB (Dala--Paula *et al*., 2019).

Examining the deficiency of nutrient elements from citrus greening symptoms is important role because it is also responsible for leaf yellowing due to the absence of a few nutrients like manganese, magnesium, iron, zink, and calcium resulting from the mineral deficiencies, which are also similar to greening symptoms. Diffuse asymmetric mottle is produced when HLB affects the plant, which can be shown as atypical patches of light green or yellow in contrast to the normal green color of the leaf. It has been difficult to distinguish between HLB symptoms and nutrient deficiency symptoms, but a cautious and precise identification could isolate them (fig1). At the later stages of the disease, nutrient deficiency symptoms are often exposed, and for each symptom, it will have different patterns, but one thing is certain: patterns always occur across the mid-vein.

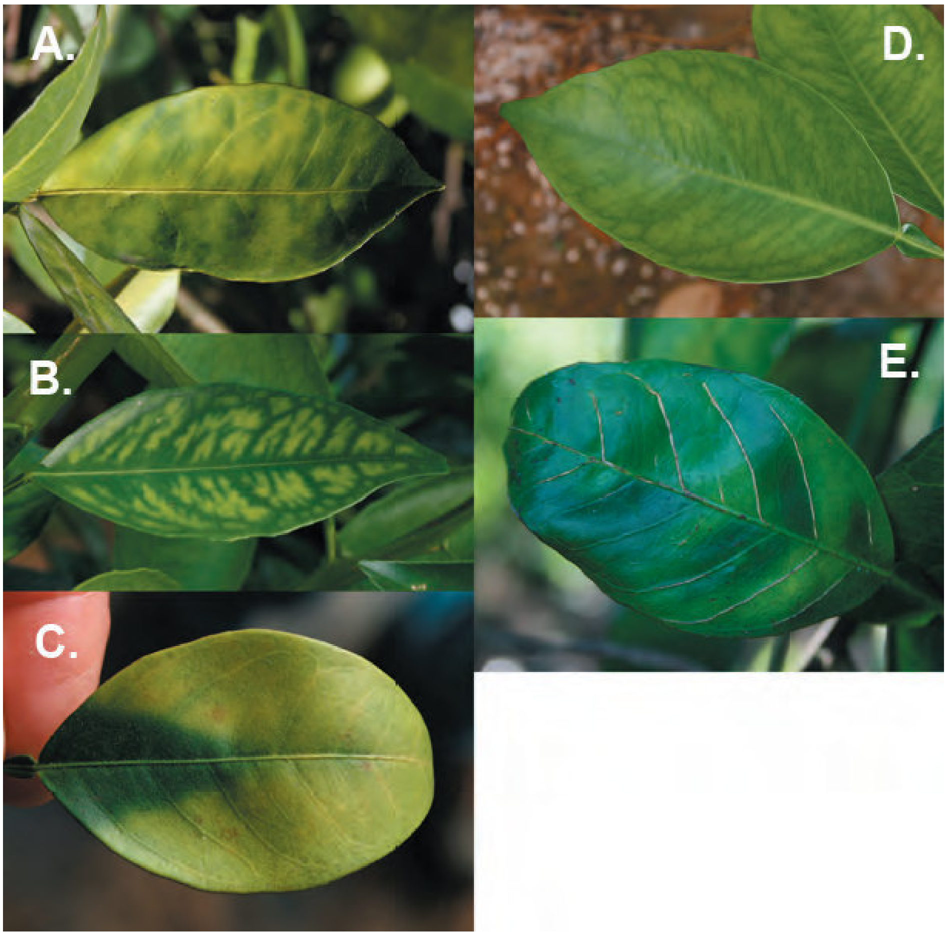

Figure 1. Citrus Leaves showing the blotchy mottle symptom of (**A**) HLB, (**B**) Zn deficiency, (**C**) Mg deficiency, (**D**) Mn deficiency, and vein corking associated with HLB, but also indicative of (**E**) B deficiency. Note the lack of symmetry about the mid-vein in the blotchy mottle leaf compared to the nutrient deficient leaves.


Figure 2.Huanglongbing-infected orange trees bear fruits that are small and lopsided (right) compared with healthy fruit (left).

Symptomatic trees display excessive starch accumulation in the aerial plant parts, one of the predominant biochemical responses to HLB, due to the up regulation of glucose-phosphate transport, which is involved with the increased entrance of glucose into this pathway (Martinelli and Dandekar, 2017). It has been suggested that accumulation of starch in the leaves is also the result of decreased degradation and impaired transport which results in an inefficient partitioning of photo assimilates among mature citrus leaves, roots, and young leaves. This unbalance in sugar transport and accumulation would affect sugar content in fruit. The starch indefinitely remains in the aerial plant parts; it does not degrade, even during the night cycles, resulting in root starvation, severe health decline, and death of trees (Zheng *et al*., 2018).

HLB symptomatic fruit from infected trees are smaller in diameter compared to asymptomatic fruit from infected and healthy trees (fig. 2). Even though most of these symptomatic fruit do not make it to processing due to premature drop or elimination by sizing equipment (Baldwin *et al*., 2018), more are entering the processing stream as there is not enough normal sized fruit. The weight and juice content of symptomatic oranges are diminished compared to asymptomatic and healthy oranges (Baldwin *et al*., 2018).

Yield reduction

The evolution of symptom severity can be very fast, resulting in a rapid prevalence of severe symptoms distributed throughout the tree canopy. Severe symptoms in trees have been observed one to five years after onset of the first symptoms, depending on the age of the tree at the time of infection, but also on the number of infections per tree, which are often multiple (Schwarz *et al*., 1973). As disease severity increases, the yield is reduced and fruit quality degrades. Yield reduction is mainly due to early abortion of fruits from affected branches and can reach 30% to 100%, depending on the proportion of the canopy affected (Catling and Atkinson, 1974).

The despite of premature drop, some fruit from diseased trees can be harvested and have fair quality. However, as the HLB severity increases, the percentage of affected fruit that remains on the tree increases as well and can reach more than 40% of the fruit harvested (Bassanezi *et al.*,2008).These affected fruit are smaller, lighter, very acidic, and have a reduced Brix ratio. As HLB severity increases, the percentage of juice and soluble solids per box also decreases, and juice quality can become affected (Bassanezi *et al*., 2009). Because of this rapid disease progress, combined with yield and quality reduction, an affected orchard can become economically infeasible within seven to ten years after planting (Bassanezi *et al.,*2005).

Field monitoring of citrus greening vectors

Daily monitoring of citrus orchards is the one of approaches that contributes to Phsyllid prevention. Monitoring Phsyllid can be conducted by visual inspection of eggs and nymphs on flush shoots (Sétamou *et al.,* 2008), and monitoring of adult populations using sticky traps and stem tap sampling (Stansly *et al.,* 2009; Sétamou *et al.,* 2014). Among them, yellow or lime-green sticky cards are currently the most sensitive and effective method for detecting adult citrus Phsyllid and monitoring their populations (Hall and Hentz 2010; Monzo *et al.,* 2015). Immediate detection and correct diagnosis of HLB after introduction, followed by eradication measures, are critical to prevent its further spreading. Making discussion/ education of the stakeholders, including growers and regulatory agents are critical for prevention in Ethiopian condition.

Management of citrus greening

A valid reason for losing the commercial value of fruits affected by HLB is that, along with the yield reduction, falling market price, and management of disease and production is very costly, which severely affects the economic condition. Also, citrus greening deteriorates the marketability of fruits in the agricultural field (Inoue *et al.,* 2020). When a tree begins to be infected, it is totally a loss project to apply chemical pesticides because they cannot be cured completely with pesticides. In addition, young plants are more susceptible to this disease, and it is therefore a very laborious job for farmers to replace the young plants that have been affected so far. The first line of defense for HLB has always been quarantines to ensure the bacteria is not introduced and established. However, with ever-increasing international trade and immigration, the probability of unintentional introduction continues to rise and even strong quarantine policy of the country is established. Recently, no fruitful method has been developed to cure this deadliest disease, except to remove all infected plants from good ones to eliminate the spread of the pathogen (Inoue *et al*., 2020) and the use of insecticides to reduce the numbers of vectors are possible.

Conclussion

Citrus greening is the world feared disease in citrus orchards and epidemics of African countries produced in citrus fruits. In Ethiopia the crop is produced both commercial and small scale farms. The major symptoms are blotchy mottle leaves, small fruit sizes, miss happen fruit, color inversion, bitter fruit taste are typical symptoms. The Phsyllid vectors are the carriers of HLB causing bacteria species which can transmit from infected to healthy through feeding and grafting materials. In the nature, actual disease identification based on the symptom is very difficult task however the symptom is confused with nutrient deficiency and growers are supplement nutrient as solution. The confirmation of citrus greening disease is using molecular diagnosis. No fruitful methods of HLB bacteria control rather than removing infected orchards for limiting transmission of disease from infected orchard to healthy and even, daily monitoring for the presence or absence of insect vectors and using insecticides are possible.

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Declaration of interest

No conflict of interest for any authors