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Risk analysis and phytosanitary measures to prevent the introduction of the quarantine pest Huanglongbing (HLB) of citrus into Ecuador

Análisis de riesgo y medidas fitosanitarias para evitar la introducción de la plaga cuarentenaria Huanglongbing - HLB de los cítricos en Ecuador

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ABSTRACT

Citrus Huanglongbing (HLB) is considered the most devastating disease of citrus plants because of the damage it causes, its difficulty in diagnosis, and its speed of dissemination, mainly due to the international trade in plant propagation material and its vectors *Diaphorina cilri* and *Trioza erylreae*. Nowadays, there is no effective treatment for HLB, so early detection is necessary to mitigate its spread to eradicate infected trees. In 2016, Colombia confirmed the presence of HLB in its territory, so there is a need to prepare this research to determine the risk level and the options for adequate phytosanitary measures to exclude the introduction of the HLB to Ecuador; the study with documentary bibliographic methodology uses an adaptation to "Work Guide for the preparation of Pest Risk Analysis (PRA) studies per Pest" established by "Agrocality" under Resolution 0002 of January 03, 2020, which comprises three stages supported by scientific-technical information that allowed to identify a high-risk level of introduction of HLB to Ecuador and the options of phytosanitary measures to avoid the introduction and dispersion of HLB; among these are the prohibition of importing citrus propagating material from countries with HLB, production of certified plants, strengthening border control s, to control the vector.

Keywords: Huanglongbing (HLB); citrus plants; dissemination; phytosanitary measures; exclusion.

RESUMEN

El Huanglongbing (HLB) de los cítricos se considera la enfermedad más devastadora de las plantas cítricas debido al daño que causa, la dificultad de su diagnóstico y su rápida diseminación, principalmente por el comercio internacional de material vegetal de propagación y por sus vectores *Diaphorina citri* y *Trioza erytreae*. En la actualidad no existe un tratamiento efectivo para el HLB, por lo que la detección temprana es necesaria para mitigar su propagación y erradicar los árboles infectados. En 2016, Colombia confirmó la presencia del HLB en su territorio, lo que generó la necesidad de desarrollar esta investigación para determinar el nivel de riesgo y las opciones de medidas fitosanitarias adecuadas que excluyan la introducción del HLB en Ecuador. El estudio, con metodología documental y bibliográfica, utiliza una adaptación de la “Guía de trabajo para la elaboración de estudios de Análisis de Riesgo de Plagas (ARP) por plaga” establecida por Agrocalidad mediante la Resolución 0002 del 3 de enero de 2020. Esta guía comprende tres etapas sustentadas en información científico-técnica, lo que permitió identificar un alto nivel de riesgo de introducción del HLB en Ecuador y las opciones de medidas fitosanitarias para evitar su introducción y diseminación, entre ellas la prohibición de importar material de propagación de cítricos de países con HLB, la producción de plantas certificadas y el fortalecimiento de los controles fronterizos para el control del vector.

Palabras clave: Huanglongbing (HLB) de los cítricos; plantas cítricas; diseminación; medidas fitosanitarias; exclusión.

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1. Introduction

Citrus huanglongbing (HLB) is a disease affecting plants of the family Rutaceae, mainly sweet orange, mandarin, and tangelo. Other species within this family exhibit less pronounced symptoms, such as lime (*Citrus aurantifolia*), which is less susceptible than sweet orange and mandarin (CAB International, 2020). HLB is a bacterial complex composed of Candidatus Liberibacter asiaticus, Candidatus Liberibacter africanus, and Candidatus Liberibacter americanus (Mora-Aguilera et al., 2014). Candidatus Liberibacter asiaticus and C. L. americanus are transmitted by the insect vector Diaphorina citri, whereas C. L. africanus is transmitted by Trioza erytreae (Garza-Saldaña et al., 2017). C. Liberibacter asiaticus (CLas) is a biotrophic bacterium transmitted by the Asian citrus psyllid, which feeds primarily on young flushes of host plants. Psyllids acquire the pathogen while feeding on infected citrus shoots and subsequently disperse it to susceptible trees, thereby facilitating the spread of HLB (Yan et al., 2025). Once transmitted to the plant by the insect vector, these bacteria move through the phloem, systemically colonizing the plant and causing tree death within approximately two to three years (Garza-Saldaña et al., 2017). Infected citrus trees exhibit symptoms such as leaf yellowing, curling, and defoliation, which reduce tree vigor and lead to malformed fruits, ultimately decreasing yield and fruit quality (Zhang et al., 2025). Additional symptoms include blotchy mottling of leaves and yellowing of veins, which may be confused with nutrient deficiency symptoms. Fruits exhibit abnormal coloration and deformation, seed abortion, and bitter juice (Garza-Saldaña et al., 2017). A characteristic symptom of HLB is the inversion of fruit color from yellow or orange to green, which is why the disease is also known as citrus greening. Other fruit symptoms include thickening and deformation of the central columella. Fruit peduncles also exhibit color inversion, with the proximal end turning yellow to orange while the stylar end remains green. Additionally, vascular bundles within the fruit axis at the peduncular end show brownish discoloration (Soto-Plancarte et al., 2024). Huanglongbing is considered the most devastating disease affecting citrus worldwide. It is estimated to have caused the death of approximately 63 million trees, mainly impacting South Africa, Asia, and Brazil. Due to its high capacity for dissemination, the disease has rapidly spread across multiple continents. In 2004, HLB was detected for the first time in the Western Hemisphere in Brazil, followed by its identification in Florida, USA, in 2005, where citrus-growing area declined by approximately 28%, largely due to the disease. Subsequently, HLB was reported in Mexico in 2009 in the Yucatán Peninsula and in 2010 in Colima (Garza-Saldaña et al., 2017). Globally, HLB has shown a high epidemic impact, with an incidence of 26% in Brazil and up to 100% in China, where the disease is presumed to have originated. Reported yield losses vary among citrus species, reaching 42% in sweet orange, 62% in key lime, and 17.3% in Persian lime (Álvaro et al., 2017). Currently, HLB is present in Burundi, Cameroon, Central African Republic, Comoros, Eswatini, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Réunion, Rwanda, Saint Helena, Somalia, South Africa, Tanzania, Uganda, Zimbabwe, Bangladesh, Bhutan, Cambodia, China, Hong Kong, India, Indonesia, Iran, Japan, Laos, Malaysia, Myanmar, Nepal, Oman, Pakistan, the Philippines, Saudi Arabia, Sri Lanka, Taiwan, Thailand, Vietnam, Yemen, Barbados, Belize, Costa Rica, Cuba, Dominica, the Dominican Republic, El Salvador, and Guadeloupe (Figure 1). HLB disease currently has no effective treatment; therefore, it is essential to have an early detection procedure in order to eliminate infected trees, mitigating the spread of HLB to the rest of the crop and surrounding areas (Garza-Saldaña et al., 2017).

For integrated disease management, several measures have been proposed, including:

• Physical control: identification and timely removal of infected trees (Zhang et al., 2025).

• Chemical control: application of appropriate pesticides to reduce the spread of HLB (Zhang et al., 2025). Albrecht et al. (2025) indicate that recent studies have identified trunk injection of oxytetracycline (OTC) as an effective method to reduce pathogen titters and restore the health and productivity of citrus trees.

• Biological control: introduction of natural enemies such as lady beetles and parasitic wasps that prey on the Asian citrus psyllid (ACP), the vector of HLB. Tamarixia radiata is a parasitoid wasp (Hymenoptera: Eulophidae) that parasitizes nymphs of Diaphorina citri (mainly the 4th and 5th instars). The female oviposits on the nymph and feeds on nymphs (host-feeding), increasing mortality. This significantly reduces vector populations, thereby decreasing the transmission of Candidatus Liberibacter asiaticus. By reducing the vector, the incidence and spread of HLB are reduced (Parra et al., 2016).

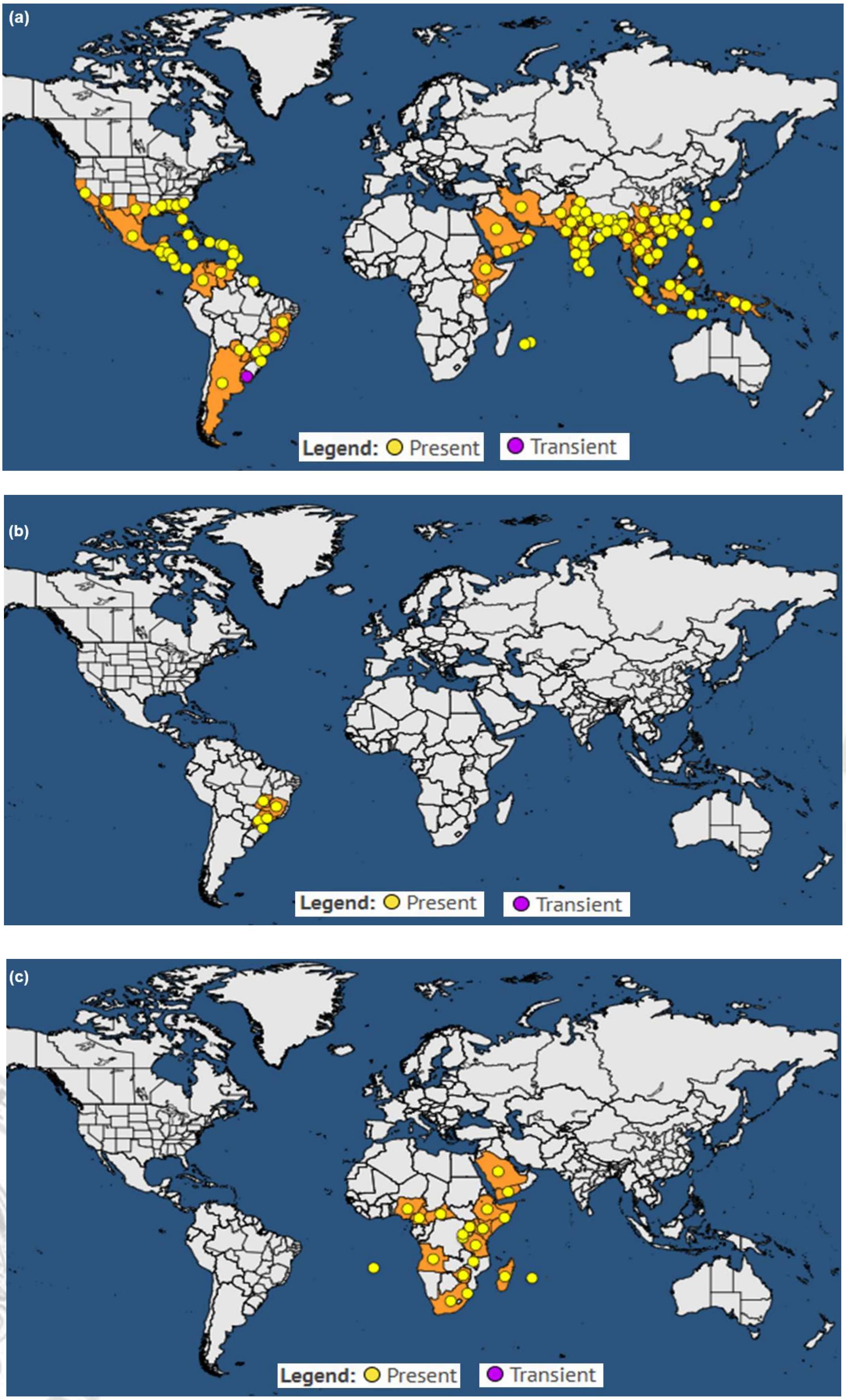

Figure 1. Distribution of (a) Candidatus Liberibacter asiaticus, (b) Candidatus Liberibacter americanus, and (c) Candidatus Liberibacter africanus. Source: EPPO (2025).

• Breeding of resistant varieties: development of citrus varieties resistant to HLB to increase tree tolerance to the disease (Zhang et al., 2025). Most commercial citrus cultivars are susceptible to HLB. However, Citrus australis and other native Australian species such as C. australasica, C. glauca, and C. inodora, as well as their hybrids, have been reported to exhibit varying degrees of tolerance to HLB (Ramekar et al., 2025).

• Cultural control: Yan et al. (2025) mention that intercropping involves the simultaneous cultivation of two or more crops in the same field and offers advantages such as increased yield and reduced pest and disease pressure. Trap cropping is an integrated pest management (IPM) strategy that consists of planting a crop that is more attractive to the pest than the main crop, in order to attract and concentrate the pest and reduce pressure on the commercial crop. Eduardo et al. (2025), in field trials, demonstrated that when Murraya paniculata was planted as a trap crop along field borders and treated with insecticides, average psyllid captures were reduced by approximately 30% compared to plots without trap crops. Smaller-scale studies showed reductions of 40–83% in psyllid settlement on citrus when M. paniculata borders were used instead of grass borders. Psyllids are first attracted to M. paniculata before entering citrus orchards; because the trap crop is treated with insecticides, the insects die before colonizing citrus trees.

• Legal control: On January 1, 1995, the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) entered into force with the establishment of the World Trade Organization (WTO). The purpose of this agreement is to regulate food safety, animal health, and plant protection measures applied by member countries (Heit et al., 2016). This agreement authorizes each member country to establish its own standards; however, these must be based on scientific principles and applied only to the extent necessary to protect human and animal health and to preserve plant health. The International Standards for Phytosanitary Measures (ISPMs) compile phytosanitary measures that have been agreed upon and adopted by consensus among member countries through the Commission on Phytosanitary Measures (CPM). ISPMs therefore facilitate safe agricultural trade by providing guidance on procedures to be followed; these standards are recognized by the WTO for managing trade-related risk (Urbaneja et al., 2015). In Ecuador, the Organic Law on Agricultural Health, issued through Official Gazette Supplement No. 27 of July 3, 2017, and its regulations, issued through Executive Decree No. 919, Official Gazette Supplement No. 91 of November 29, 2019, are harmonized with ISPM guidelines in order to align procedures related to the trade of plants, plant products, and regulated articles (Soto-Plancarte et al., 2024).

Currently, HLB has spread to several countries on the continent. In 2016, Colombia confirmed the presence of this bacterial complex within its territory, becoming a phytosanitary alert and a source of introduction pressure for Ecuador. Therefore, it is essential to develop an Introduction Risk Analysis study to identify the level of risk posed by this pest and thus define appropriate phytosanitary measure options. The implementation of these measures, according to the identified risk level, will help prevent the introduction of HLB into the country (Pérez-Zárate et al., 2024), thereby safeguarding national citrus production and reducing the economic impact on producers.

Ecuador does not have an Introduction Risk Analysis study for citrus Huanglongbing (HLB), which constitutes the necessary technical-scientific tool, in accordance with the International Standards for Phytosanitary Measures (ISPMs), to determine the level of risk posed by quarantine pests and, based on this risk, to identify appropriate phytosanitary measures to exclude, contain, or suppress the pest (Segnana et al., 2020).

The Introduction Risk Analysis of citrus Huanglongbing (HLB) will make it possible to identify the level of risk required to define appropriate phytosanitary measure options that mitigate the risk of pest introduction into the country. To this end, several parameters are analyzed to assess the probability of introduction and spread, as well as the potential economic consequences of citrus Huanglongbing (Cagua et al., 2024), determining the level of risk and, based on this, identifying appropriate phytosanitary measures during the risk management stage, in order to carry out pest exclusion actions in Ecuador (Gochez et al., 2018). The Introduction Risk Analysis of citrus Huanglongbing (HLB) constitutes the necessary technical-scientific tool for the adoption of phytosanitary measures aimed at preventing the entry of this pest into the country, benefiting both the citrus and floriculture sectors, as the pest also affects other ornamental species belonging to the family Rutaceae (Monge et al., 2024), such as myrtle used as foliage in floral arrangements.

2. Methodology

The methodology to develop the Introduction Risk Analysis and Phytosanitary Measures to Prevent the Introduction of the Quarantine Pest Huanglongbing (HLB) of Citrus into Ecuador has been adapted to the Working Guide for the development of Pest Risk Analysis (PRA) studies by pest, of Agrocalidad, which is harmonized to the guidelines issued by the International Standards for Phytosanitary Measures (ISPM) of the International Plant Protection Convention (IPPC) and has been established by Agrocalidad through Resolution No. 0002 of January 3, 2020. 0002 of January 03, 2020; therefore, this study uses this guide as a development tool to determine the level of risk of introduction of HLB to Ecuador and the options for phytosanitary measures to exclude the introduction of the pest to our country, contain the spread of the insect vector to areas of the national territory where it is not present and in case HLB is introduced to the country, determine the options for phytosanitary measures to eradicate and prevent its spread (D'Alessandro & Junior, 2018).

The Introduction Risk Analysis study is justified in its three stages by reliable scientific technical support, obtained from the search and analysis of research, studies published in scientific journals, journals, phytosanitary databases, field and laboratory investigations and other scientific sources available at national and international level that are related to the subject (González, 2015), so that when an examination is raised or a controversy arises, the sources of the information and the principles used to make the decision on phytosanitary measures related to risk management can be clearly demonstrated (Stage III); In this sense, the study consists of a documentary analysis of each parameter evaluated, establishing a rating range between 1 and 3, where 1 is low, 2 is medium and 3 is a high risk level. In this way, the level of risk of introduction of the pest is determined and, based on these results, the necessary phytosanitary measures to prevent the introduction and spread of Huanglongbing of citrus to Ecuador and the control options for the insect vector are identified (Urbaneja et al., 2015).

2.1. Stage I. Initiation of the PRA Process

2.1.1. Initiating event

The process of Pest Risk Analysis by Pest will be initiated from the identification of any of the following situations:

- Emergence of an emergency situation upon discovery of an established infestation or outbreak of a new pest.
- Emergence of an emergency situation upon interception of a new pest in an imported commodity.
- Identification of the risk of a new pest through scientific research.
- Pressure for introduction of a pest into an area.
- Identification that a pest is more damaging in an area other than its area of origin.
- Repeated interception of a pest.
- Identification of an organism as a vector of other pests.

According to the phytosanitary condition of HLB in the world, including the American continent, which shows a rapid dissemination in countries where it was not previously present, and given the introduction of HLB to the Colombian territory and its subsequent dissemination, the risk analysis developed in this study corresponds to the pressure of introduction of the bacterial complex to our country (Rodríguez et al., 2016).

2.1.2. Identification of the PRA area

The area contemplated for the risk analysis is the continental territory of Ecuador, where the level of risk of the pest and the options for phytosanitary measures that could be adopted to prevent its introduction into Ecuadorian territory will be identified.

2.1.3. Analysis of established phytosanitary requirements or previous PRAs

Ecuador has not conducted a Pest Risk Analysis study for Huanglongbing of citrus, where the level of risk of introduction of the pest is determined, as well as identifying the options for phytosanitary measures to mitigate the introduction and, if it enters the country, the options for phytosanitary measures to mitigate its spread (Soto-Plancarte et al., 2024).This study is also the necessary technical tool required to scientifically support the measures to be taken. At the national level, our country has an action plan "National Action Plan for the management of Diaphorina citri and prevention of the introduction of HLB", which has been developed with experts from different countries with the support of FAO and in conjunction with countries in Latin America and the Caribbean; Ecuador also has an "Andean Prevention and Contingency Plan for the 'Huanglongbing' citrus disease", prepared and agreed by the member countries of the Andean Community, which specifies the actions and commitments to be fulfilled for HLB and its vectors (Orozco-Santos et al., 2023).

Finally, Ecuador is a member of the Inter-American Plant Health Coordination Group (GICSV), made up of countries of the American continent and a group of experts on HLB and its vectors, currently organized by the Inter-American Institute for Cooperation on Agriculture (IICA). The purpose of this group is to harmonize phytosanitary actions to mitigate the spread or prevent the introduction of HLB and its vectors, depending on the current situation of the countries.

2.2. Stage II. Pest risk assessment

According to ISPM No. 11, countries should decide what level of risk is acceptable to them, considering for example the estimated economic losses, the level of risk accepted by other countries, among others.

Before starting Stage II, it is necessary to mention the considerations for issuing a risk rating for each of the parameters to be evaluated in this stage, so that, according to the reliable technical-scientific information gathered, a Low (1), Medium (2) and High (3) risk level should be assigned for each of them. In the case of not obtaining all the necessary information for the analysis and evaluation of the parameters indicated below, the risk level will be considered High (3). The ratings corresponding to each of the evaluated parameters will be presented in the results session of this development study (Álvaro et al., 2017).

2.2.1. Evaluation of introduction and dispersion probability

The main way of transmission of citrus Huanglonbing in the field is through the insect vector (*Diaphorina citri*), it has been proven that in a time of 5 to 7 hours the insect can acquire and transmit the bacterial complex. In addition, the insect vector has the capacity to be simultaneously infected with the bacteria that make up the HLB complex. Through their salivary secretion, the fourth, fifth instar and adult insects are effective in transmitting HLB to a healthy host. It is not known whether this vector can sexually transmit HLB to other healthy insects, and no studies have been conducted to show that the parasitoids used for its control can infect the bacterial complex to healthy hosts (Stansly, 2016).

Another mode of transmission of HLB is through contaminated grafts, for which depends on the part of the plant used, the amount of tissue and the isolation of the pathogen. Regarding transmission by seeds, there is not much information on the transmission of HLB through this propagative material, since most of the fruits of an infected plant fall prematurely to the ground and those that remain on the plant have a high percentage of aborted seeds.

It has been shown that in a crop area infected with HLB and with the presence of the vector, in 30 healthy plants there would be 57% of infection at six months, in one year 73% of diseased plants and at two years 100% of the infected crop (Tena et al., 2019).

2.2.2. Probability of pest entry

The probability of entry of a pest depends on the pathways followed from the exporting country to the place of destination, the frequency and quantity of the pests associated with them. The more pathways there are, the greater the probability of the pest entering the PRA area (Ecuadorian territory) (Pérez-Zarate et al., 2024).

To evaluate the probability of entry of a pest into the PRA area, the following parameters will be considered:

Identification of pathways for a pest-initiated PRA: According to the latest updates of September 4, 2020, corresponding to CAB International 2021, citrus Huanglongbing is present in four of the five continents; thus, in Asia where it is presumed to originate, it is present in 22 countries (Bangladesh, Bhutan, Cambodia, China, Hong Kong, India, Indonesia, Iran, Japan, Laos, Malaysia, Myanmar, Nepal, Oman, Pakistan, Philippines, Saudi Arabia, Sri Lanka, Taiwan, Thailand, Vietnam and Yemen); in Africa, it is present in 18 countries (Burundi, Cameroon, Central African Republic, Comoros, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Reunion, Rwanda, St. Helena, Somalia, South Africa, Tanzania, Uganda and Zimbabwe); (United States, United States, Argentina, Brazil, Colombia, Paraguay and Venezuela.

Probability that the pest is associated with the pathway in the place of origin: A study carried out in Ciego de Avila in Cuba, shows the behavior and favorable factors for the development of Huanglongbing of citrus, for this purpose bioclimatic scenarios are proposed based on the requirements of HLB and *Diaphorina citri* as insect vector, in this study it is evident that HLB (Candidatus Liberibacter asiaticus) has an optimal development between 27 to 32 °C; In the case of Diaphorina citri, temperature indices between 22 to 29 °C were identified that allow optimal development of the insect vector, limiting its life cycle to 10 and 33 °C. According to this biological model established in Ciego de Avila, the female of the insect vector could have a longevity between 39.6 and 47.5 days, being able to live for several months until the sprouting period of the host crop begins.

Probability of survival during transport or storage: HLB is transmitted by insect vectors Diaphorina citri and *Trioza erytreae*; however, it is also transmitted by infected budwood that could be traded. Infected propagative material will not always contain the bacteria in its entirety, i.e. the more phloem tissue is immersed in the inoculum, the greater the probability of HLB transmission by this route. On the other hand, there is no evidence that the disease is transmitted by seed.

Probability that the pest will survive pest management procedures: Currently, there are no standardized phytosanitary measures for the bacterial complex, countries such as Ecuador prohibit, through phytosanitary regulations, imports of citrus propagative material from countries where HLB is present; in the case of Mexico, for the commer-cialization of orange budwood originating from the United States, the phytosanitary measures established are the prohibition of importing this plant material from the state of Florida and require bacteriological examinations, in addition to a Certificate of Bacteriology, In the case of Mexico for the marketing of orange sticks or buds originating in the United States, phytosanitary measures include the prohibition of importing this plant material from the state of Florida and require bacteriological examinations, in addition to a Phytosanitary Certificate issued by the phytosanitary authority, a phytosanitary inspection at the point of entry into the country. Even if HLB is present in both countries.

Probability of transfer to a suitable host: Dispersal of Huanglongbing of citrus is spread mainly through two vectors: *Diaphorina citri* (Kuwayama) for C. L. asiaticus and C. L. africanus, and *Trioza erytreae* (Del Guercio) for C. L. africanus. The bacterial complex is also spread over long distances through the movement of infected propagative material, which is one reason why one of the most effective measures to mitigate the spread of HLB is the production of certified plants, thus ensuring the healthy production and marketing of citrus plants and other citrus propagative material.

2.2.3. Probability of establishment

In order to estimate the probability of establi-shment of a pest, reliable biological information (developmental stage, host range, epidemiology, survival, among others) should be obtained from the areas where the pest is currently present and compare the situation with the PRA area, For this it is necessary to consider the availability, quantity and distribution of host species in the PRA area, adaptability to the environment in the PRA area, pest adaptation potential, pest reproductive strategy, pest survival method, cultivation practices and control measures (Lara, 2020).

Availability of Suitable Hosts in the PRA Area: Citrus Huanglongbing affects the following species of the Rutaceae family: Citrus aurantiifolia, Citrus limon, Citrus reticulata, Citrus reticulata x paradisi, Citrus sinensis, Calodendrum capense, Clausena sp., Fortunella sp., Fortunella sp, Limonia acidissima, Murraya paniculata, Poncirus sp., Toddalia lanceolata, citrus, are distributed throughout the country, so there is a probability of finding a suitable host for its establishment.

Adaptability in the environment: Within the bacterial complex, species have temperature requirements for establishment: Ca. L. asiaticus is heat adapted to temperatures exceeding 30 °C (32 to 35 °C), however, it does not exceed 38 °C; Ca. L. africanus, has an infective capacity at milder temperatures, between 20 and 25 °C and Ca. L. americanus is less heat tolerant, being infective in a range of 24 to 30 °C, but not at higher temperatures. These temperature requirements of the bacterial complex allow us to identify that HLB could become established in 10 of the 13 ecological zones established in the country (Cagua et al., 2024).

Cultivation practices and control measures: Mexico is an important country in terms of citrus production; it is the fourth largest producer of oranges in the world, producing more than 6 million tons of fruit. It is currently seeking to mitigate the damage caused by the presence of Huanglongbing in its country; despite investing millions of dollars to counteract HLB in the areas of control, research, production and training, it has not managed to eradicate the disease and it continues to spread throughout its territory; Given this scenario, Mexico, together with the rest of the countries that make up the OIRSA region, based on its experience and that of other countries, has implemented integrated management of HLB, including the elimination of diseased plants, the control of Diaphorina citri as the insect vector and the development of a program aimed at the production of certified nurseries where healthy plants are produced (Gochez et al., 2018).

Other pest characteristics that influence the likelihood of establishment: HLB clogs the phloem of the plant interfering with sap circulation, causing symptoms on leaves and fruit. Leaf mottling, yellowing and thickening of veins, yellowing branches, deformed, small, asymmetric fruits with sour and acid juice are present. Leaf symptoms resemble nutritional zinc deficiencies. Other symptoms that may occur due to HLB infection are the appearance of flowering out of season, fruit abortion or fruit drop and dieback of plants as the pathogen causes the gradual and regressive death of branches.

2.2.4. Probability of dispersion after establishment

Ecuador's agroclimatic conditions for citrus production are very favorable, especially in the coastal region, which has 10219 hectares of orange, lemon and mandarin monoculture; 58219 hectares as an associated crop, with the provinces with the highest citrus production being Manabí, Los Ríos, Bolívar, Guayas, Pichincha and Tungurahua. For development and fruiting, these citrus species differ in temperature requirements, with a range between 19 and 40°C and an optimum range between 24 and 32°C (D'Alessandro & Junior, 2018). On the other hand, regarding the difficulties of citrus cultivation in our country, which could be identified as a favorable factor for the spread of HLB, there is a deficient marketing system for fruits, plants and propagative material. This situation is due to the lack of organizations of citrus producers, which causes the excessive existence of intermediaries, before reaching the consumer.

2.2.5. Assessment of potential economic consequences

To determine the potential economic importance of the pest, qualitative information on the pest and its potential host plants may be obtained. In many cases, a detailed analysis of the estimated economic consequences is not necessary if there is sufficient evidence or, in general opinion, the introduction of a pest would have unacceptable economic consequences (including environmental consequences). In such cases, risk assessment will focus primarily on the probability of introduction and spread (Alvarenga, 2017).

Direct effects of the pest: Worldwide, HLB has become a serious threat to citrus production in the world; currently, countries have registered very high economic losses due to the presence of HLB. Countries that are major producers and marketers of citrus such as Mexico, the United States and Brazil have obtained losses of approximately 3 billion dollars of their annual production.

Indirect effects of the pest: Citriculture is considered one of the most important activities in the world, due to the economic income generated in the countries by the commercialization of fruit, as well as by the commercialization of its derivatives. The most important producing countries worldwide are China, United States, Brazil, Mexico and Spain; these countries strive to supply a demand of 65.6 million tons of fruit per year that are marketed as fresh fruit 38.5 million and the remaining is industrialized.

2.3. Stage III. Risk management

Once Stage II, Pest Risk Assessment, is completed, this stage evaluates and selects options for phytosanitary measures that will reduce the risk of introduction of HLB and mitigate the spread of the pest if it is introduced into the country. The guiding principle for risk management should be to manage the risk to achieve the necessary degree of safety, which should be justified and feasible within the limits of available options and resources.

2.3.1. Identification and selection of appropriate risk management options

The appropriate phytosanitary measures selected should be effective in reducing the probability of pest introduction (Urbaneja et al., 2015). This selection should be made considering the following phytosanitary principles: (a) Phytosanitary measures of demonstrated efficacy and feasibility; (b) minimal impact; (c) Re-evaluation of previous requirements; (d) equivalence; and (e) non-discrimination.

2.3.2. Shipping options

The appropriate phytosanitary measures selected should be effective in reducing the probability of pest introduction. This selection should be made considering the following phytosanitary principles (Munoz 2019):

The establishment of phytosanitary measures directed at shipments that are imported into our country can be taken as a whole in order to guarantee the phytosanitary status of the imported product; these options of measures can be the following:

- Inspection or testing to verify the absence of a pest or tolerance of a given pest; the sample size should be adequate to result in an acceptable probability of detection of the pest.
- Prohibition of parts of the host species.
- Post-entry quarantine system, this should be considered the most intensive form of inspection or testing when appropriate facilities and resources are available and may be the only option for certain pests that cannot be detected at entry.
- Specified conditions of shipment preparation (e.g., handling to prevent infestation or re-infestation).
- Specified treatment of the consignment, such treatments are applied after harvest and may include chemical, thermal, irradiation, or other physical methods.
- Restrictions on end-use, distribution and commodity entry periods.

2.3.3. Options to prevent or reduce the original infestation in the crop

These phytosanitary measure options are applied at origin and may include the following measures:

- Treatment of the crop, field or place of production.
- Restricting the composition of a consignment so that it is composed of plants belonging to resistant or less susceptible species.
- Growing plants in specially protected environments (greenhouses, isolation).
- Harvesting plants at a certain age or at a specific time of the year.

2.3.4. Options for other track types

For various types of pathways, the measures considered above can also be used or adapted for plants and plant products to detect the pest in the consignment or to prevent infestation of the consignment, so the following factors should be considered:

- Natural spread of a pest includes movement of the pest through flight, wind dispersal, carried by vectors such as insects or birds, and natural migration. If the pest enters the PRA area through natural spread or has the potential to enter in the immediate future, phytosanitary measures may have little effect. Control measures applied in the area of origin could be considered. Similarly, containment or eradication, supported by suppression and surveillance, could be considered in the PRA area after pest entry (Rodríguez et al., 2016).
- Measures for travelers and their baggage may include targeted inspections, publicity, and fines or incentives. In rare cases, treatments may be possible.
- Contaminated machinery or conveyances (ships, trains, aircraft, road transport) may be subject to cleaning or disinfestation.

3. Results and discussion

He results of the present pest risk analysis indicate that Candidatus Liberibacter spp. (the causal agents of Huanglongbing, HLB) represent a high phytosanitary risk for Ecuador. This finding is consistent with studies conducted in other citrus-producing regions, where the introduction of HLB has caused significant ecological and economic impacts (Bassanezi et al., 2020; Gottwald, 2010).

The high-risk level obtained (total score: 36) reflects both the biological characteristics of the pathogen and its efficient transmission by *Diaphorina citri* and *Trioza erytreae*, two highly adaptable vectors capable of surviving under diverse climatic conditions (Bové, 2006; Hall et al., 2016).

3.1. Probability of introduction and establishment

The analysis determined a maximum risk level for the probability of pest entry (A = 15; Table 1) and establishment (A = 12; Table 2). This outcome aligns with the current regional context of the Andean countries, where *D. citri* is already present in Colombia and Peru (Colmenárez et al., 2023; Duran-Vila et al., 2021). The 2016 detection of HLB in La Guajira (Colombia) represents a critical alert for Ecuador, given the high connectivity across borders and the continuous movement of propagative material and fruit.

From a biological perspective, Candidatus Liberibacter asiaticus is particularly difficult to detect in asymptomatic stages, and its latent infection period favors undetected transport through vegetative material (Ghosh et al., 2020). This justifies the high risk assigned to the parameters "probability of pest association with the pathway" and "survival during transport". Moreover, the absence of effective curative treatments or thermal disinfection methods (Cifuentes-Arenas et al., 2019) confirms that phytosanitary certification alone is insufficient, and stricter import protocols are required.

3.2. Potential for dispersion and economic consequences

The total risk of introduction and dispersion (A = 30; Table 3) reflects the high mobility of *D. citri*, whose adults can disperse over distances greater than 2 km (Lewis-Rosenblum et al., 2015). Once established, vector populations expand rapidly during flushing periods, increasing the probability of secondary spread within orchards (Sétamou & Bartels, 2015).

The economic assessment (A = 6; Table 4) further supports the high-risk classification. International experiences show that HLB can cause losses exceeding US$ 3 billion annually, with the death of more than 116 million citrus trees worldwide (Bassanezi et al., 2020). For Ecuador, where citrus production is mainly carried out by small and medium-sized farmers, such impacts would directly threaten rural livelihoods, employment, and food security.

Table 3
Probability of introduction and dispersion

Parameters	Risk Level
Probability of pest entry	A (15)
Probability of establishment	A (12)
Probability of dispersion after establishment	A (3)
Total	A (30)

Table 1
Assessment of the probability of pest entry

Parameters	Risk Level	Justification of risk level
Identification of pathways for a pest-initiated PRA	A (3)	The main entry route for HLB is citrus propagative material imported into the country.
Probability that the pest is associated with the pathway at the place of origin	A (3)	Propagative material has the risk of being infected at the place of origin by vectors that feed on it.
Probability of survival during transport or storage	A (3)	Since the propagative material is a perishable plant product, it must be transported in the shortest possible time while maintaining its physiological quality, which favors the survival of the pest.
Probability of pest surviving pest management procedures	A (3)	There are no effective phytosanitary measures or chemical treatments to manage the pest, and it cannot be detected with the naked eye.
Probability of transferring to a suitable host	A (3)	As propagating plant material used for planting, it has a high probability of finding a suitable host.
Total	A (15)	

Table 2
Evaluation of the probability of establishment

Parameters	Risk Level	Justification of risk level
Availability of suitable hosts in the PRA area	A (3)	The main citrus hosts of HLB are found throughout the country, which favors the availability of suitable hosts for the pest.
Adaptability to the environment	A (3)	The bacterial complex that makes up the HLB can be established in 10 of the 13 ecological zones established in the country.
Cultivation practices and control measures	A (3)	To date, there are no effective management practices for the control of HLB, the countries apply as a measure the eradication of plants.
Other pest characteristics that influence the likelihood of establishment	A (3)	HLB concentrates in the phloem of the host and through vector feeding is likely to become established in an area of the host.
Total	A (12)	

Table 4
Evaluation of economic consequences

Parameters	Risk Level	Justification of risk level
Direct effects of the pest	A (3)	Death of more than 116 million citrus trees in the world, large citrus producers, losses of more than 3 billion dollars per year.
Indirect effects of the pest	A (3)	Closure of markets for the commercialization of citrus propagative material and restrictions on trade of fruit from countries where HLB is present.
Total	A (6)	

3.3 Evaluation of phytosaniary measures

The proposed phytosanitary measures are consistent with the principles of the International Standards for Phytosanitary Measures (ISPM No. 11 and 14), which emphasize prevention at the source, early detection, and containment. The differentiation of measures between the country of origin and Ecuadorian territory represents a comprehensive and scientifically based approach. In the country of origin, mandatory phytosanitary certification, verification of pest-free areas, and pre-shipment inspections are essential. In other regions, such as Australia and the Mediterranean Basin, similar strategies have been effective in preventing the introduction of HLB (Beattie et al., 2021). Within Ecuador, post-entry quarantine, vector monitoring, and inspections at entry points (ports, airports, and borders) are crucial, considering the current distribution of D. citri in neighboring countries.

In the event of introduction, the proposed contingency plan—which includes the creation of buffer zones, eradication of infected trees, vector management, and rotation of insecticides with different modes of action—is aligned with the most successful containment strategies documented in São Paulo (Bassanezi et al., 2020) and Florida (Miranda et al., 2021). However, for long-term sustainability, these chemical strategies should be complemented with biological control (e.g., Tamarixia radiata). Parra et al. (2016) mention that Tamarixia radiata is the main biological control agent of Huanglongbing, as it parasitizes nymphs of the Asian citrus psyllid (*Diaphorina citri*), reducing vector populations and, consequently, the transmission of Candidatus Liberibacter asiaticus.

Trap crops (*Murraya paniculata*, Bergera koenigii) and public awareness programs also reduce vector density and slow epidemic progression (Tomaseto et al., 2019). Psyllids are first attracted to M. paniculata before entering the citrus crop; when the trap crop is treated with insecticides, the insects die before colonizing the citrus trees. This reduces the population pressure of Diaphorina citri on citrus and can significantly decrease HLB incidence when properly managed. It works best as part of an integrated pest management strategy. In studies where M. paniculata was used as a trap crop and insecticides were applied, the number of trees showing HLB symptoms was 31% lower compared to plots without trap crops (Eduardo et al., 2025).

3.4 Implications for national citriculture

In Ecuador, during the first half of 2025, it was confirmed that both Huanglongbing (HLB) and Trioza erytreae remain absent from Ecuadorian territory. However, the presence of the vector Diaphorina citri was recorded from January to June 2025 in seven of the country's 23 provinces (Manabí, Imbabura, Bolívar, Carchi, Santa Elena, Cañar, and Pichincha) (Comunidad Andina, 2025).

Given Ecuador's favorable agroecological conditions and the current absence of HLB, the country is at a strategic advantage to establish strong preventive and diagnostic systems before the pathogen's arrival. The implementation of a national early warning system for HLB, integrating molecular diagnostics (PCR, LAMP) and vector population monitoring, is recommended. Strengthening research and inter-institutional cooperation with regional networks (IICA, OIRSA, and COSAVE) will also be key to prevent HLB introduction and protect national citrus productivity.

According to the results obtained in the Analysis of the Risk of Introduction of Huanglongbing of citrus - HLB, quarantine pest (absent) for Ecuador, it is evident that this bacterial complex has a high level of risk of introduction to the country, so it is necessary to strengthen phytosanitary actions and in other cases to establish them in order to prevent entry into our country; It is also necessary to strengthen and continue with surveillance and control actions for *Diaphorina citri* by the competent entity to mitigate its dispersion and reduce populations in areas where it is present.

Finally, according to the above, it is important to promote the development of our citriculture due to the potential and favorable conditions that our country has; on the other hand, based on experiences in countries where HLB is present, the alternative that exists once the pest is present is to evolve and develop new production technologies, otherwise producers should seek to change their crops for others or change their activity.

4. Conclusions

This study on the and Phytosanitary Measures to Prevent the Introduction of the Quarantine Pest Huanglongbing (HLB) of Citrus into Ecuador has determined a high level of risk for the introduction and spread of this quarantine pest, as well as assessed its potential economic consequences, highlighting the vulnerability of the national citrus sector due to the presence of the vector *Diaphorina citri* and the lack of effective control measures once the pest is introduced.

The findings provide a technical and scientific tool for phytosanitary decision-making, allowing for (a) the definition and implementation of preventive and surveillance measures to exclude HLB from the country; (b) the establishment of vector control strategies to mitigate its spread in areas where it is already present; (c) guidance for public policies and import protocols for vegetative material and citrus fruits, reducing the likelihood of entry of quarantine pests.

The results of this analysis can serve as a basis for additional research on the spread of other quarantine pathogens of importance to Ecuadorian agriculture, the effectiveness of implemented phytosanitary measures, through follow-up evaluations and risk modeling, and the development of early warning and monitoring systems integrating climatic factors, vector distribution, and international trade routes.

Finally, this study not only confirms the urgent need to strengthen agricultural biosecurity in Ecuador but also establishes a practical framework that can guide phytosanitary planning and future research on the prevention of quarantine pests, contributing to the sustainability of the national citrus industry.

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