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Review Article

Heliconia: diseases and integrated management

Helicônias: doenças e manejo integrado

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Abstract: Heliconia cultivation faces challenges due to diseases that lead to depreciation in flower quality, decrease in yield, and increase in management costs. Quality standards require heliconias to be visually attractive and healthy. The primary causes of these diseases include fungi, nematodes, bacteria, and viruses. Fungal diseases are the most prevalent, causing damage to leaves, bracts, and rhizomes. Nematode-induced diseases affect both underground and above-ground plant organs. Among bacterial diseases, wilt caused by *Ralstonia solanacearum* is the most damaging to the crop, while viral diseases are relatively rare. Integrated disease management is the best strategy to control diseases in heliconias. This strategy combines preventive, curative, and eradication measures. This study describes the main diseases affecting heliconias, highlighting their primary occurrence sites, host range, as well as the description of disease symptoms and pathogens. Additionally, information on the cycle, epidemiology, and management of the major diseases is provided. The aim is to contribute to the sustainability and efficiency of heliconia cultivation.
Keywords: leaf spots, phytopathogens, rot, tropical flowers, wilt.

Resumo: O cultivo de helicônias enfrenta desafios devido a doenças que causam depreciação na qualidade das flores, redução na produção e aumento de custos de manejo. As principais causas dessas enfermidades são fungos, nematoides, bactérias e vírus. As doenças fúngicas são as mais prevalentes, causando danos nas folhas, brácteas e nos rizomas. As doenças causadas por nematoides afetam os órgãos subterrâneos e a parte aérea das plantas. Entre as bacterioses, a murcha bacteriana, causada pela *Ralstonia solanacearum*, é a doença que causa os maiores danos à cultura, já as doenças virais são relativamente raras. Para atender aos padrões de qualidade do mercado, é essencial que as helicônias sejam visualmente atraentes e saudáveis. O manejo integrado de doenças é a melhor estratégia para controlar as doenças em helicônias. Essa estratégia combina medidas preventivas, curativas e de erradicação. Neste trabalho estão descritas as principais doenças incidentes nas helicônias, ressaltando os principais locais de ocorrência, a gama de hospedeiros, bem como a descrição das enfermidades e dos patógenos, além de informações sobre o ciclo, a epidemiologia e o manejo das principais doenças.
Palavras-chave: flores tropicais, fitopatógenos, manchas foliares, murchas, podridões.

Introduction

In the cultivation of heliconias (*Heliconia* spp.), the conditions that favor their development, such as warm, humid and shaded environments with organic matter-rich soils, also favor the emergence of phytopathogens (López-Vásquez et al., 2013). Diseases cause spots, rot and wilt, and the main causal agents are fungi, nematodes, bacteria and viruses (Cardona and Zapata, 2012).

Fungi cause the most significant damage to heliconias, mainly on leaves (73.46%) and bracts (22.37%), which are more susceptible to anthracnose, rust, powdery mildew and leaf spots. Damage to rhizomes (4.17%) is more caused by rots (Bedendo, 1995, Mattos Sobrinho et al., 2015).

About 10 genera of phytonematodes have been reported in association with heliconias, although the pathogenicity of some has not been proven (Cardona and Zapata, 2012, Sardinha et al., 2012). Nematodes mainly parasitize roots and rhizomes, also affecting shoots, which results in reduced quality and production, in addition to increased costs with phytosanitary control (Mattos Sobrinho et al., 2013).

Bacterial wilt caused by *Ralstonia solanacearum* is the most prevalent bacteriosis in heliconia plantations in Brazil (Warumby et al., 2004). This bacterium causes damage such as wilting, yellowing and drying of plants and, for being present in the soil, its management is very complex, highlighting the importance of preventive measures.

In the production of heliconias, it is crucial to ensure good appearance and health of the product. To achieve this goal, it is essential to adopt integrated disease management tactics and sustainable control measures. Next, we will discuss the main diseases and occurrences, hosts, symptoms of these diseases, as well as information about their cycle, epidemiology and management.

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1. Fungal diseases

Disease	Etiology (E), occurrence (O) and hosts (H)	Disease symptoms and pathogen signs	Epidemiology
Rhizoctonia rot	E: *Thanatephorus cucumeris* (A.B. Frank) Donk (*Rhizoctonia solani* J.G. Kühn); O: Pernambuco and Maranhão (Lins and Coelho, 2004, Sardinha et al., 2012); H: *H. bihai*, *H. rauliniana*, *H. psittacorum* cv. Alan Carle and *H. chartacea* cv. Sex Pink (Lins and Coelho, 2004, Sardinha et al., 2012).	**Symptoms**: darkened and depressed lesions on plant collar. Rots in rhizome and roots, at the seedling stage. **Signs:** whitish, cottony mycelium. **Signs**: sclerotia (resistance structure) (Fig. 1A).	Soil-borne, necrotrophic and polyphagous pathogen; **Penetration**: directly to the host surface, or through wounds; **Dissemination**: infected seedlings and contaminated soils, rainwater or irrigation water, and agricultural implements; **Survival**: mycelium and/or sclerotia in the soil, host plants, and crop residues; high soil moisture, planting density, successive heliconia cultivation, temperatures between 15 and 25 °C, and non-decomposed organic matter (Fig. 1A).
Cylindrocladium rot	E: *Calonectria spathiphylli* El-Gholl, J.Y. Uchida, Alfenas, T.S. Schub., Alfieri & A.R. Chase 1992 (*Cylindrocladium spathiphylli* f. sp. *heliconiae* Aragaki, Yahata & J.Y. Uchida); O: São Paulo (Coutinho, 2006) and Pernambuco (Assis et al., 2002); H: *H. bihai*, *H. caribaea*, *H. psittacorum* x *H. marginata*, *H. psittacorum* cvs. Strawberries and Lady Di (Assis et al., 2002).	**Symptoms**: rots in the vascular system and rhizomes. Dwarfism, production of few flowers, which may result in the death of the clump. Necrotic brownish oval-shaped spots with a grayish center and yellowish halo. These spots can coalesce and scorch the margins and sheaths of the leaves. **Signs**: cylindrical conidia, with conidiophores with phialides. Microsclerotia (resistance structure) (Fig. 1B and Fig. 2).	**Dissemination**: infected plant material (rhizomes), contaminated irrigation water, and agricultural tools; **Survival**: long periods in the soil, and in crop residues. High air humidity and temperatures of 25 to 30 °C (Fig. 1B).
Pythium and Phytophthora rots	E: *Pythium splendens* Hans Braun, *P. aphanidermatum* (Edson) Fitzp. and *P. myriotylum* Drechsler. *Phytophthora nicotianae* Breda de Haan; O: São Paulo (Coutinho, 2006); H: papaya, tomato, pineapple, peace lilies, hibiscus, gerberas and several species of heliconias (Sewake and Uchida, 1995).	**Symptoms**: *Pythium*: root rot and plant decline. *Phytophthora:* rotting of roots and rhizomes. Infected flower stems and pseudostem become darkened. Plants show reduced growth, loss of vigor and low flower production; **Signs**: cottony mycelium, sporangia with flagellated zoospores, and oospore (Fig. 1E).	**Dissemination**: rainwater or irrigation water, infected seedlings, agricultural implements, and contaminated soils; **Survival**: in soil, in organic matter, for long periods; high soil moisture, temperatures between 15 and 22 °C, and compacted and overwatered soils (Fig. 1E).
Anthracnose	E: *Glomerella cingulata* (Stoneman) Spauld. & H. Schrenk (*Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc); O: Pernambuco (Lins and Coelho, 2004), Maranhão (Sardinha et al., 2012, Gusmão et al., 2018), Ceará (Freire and Mosca, 2009), Bahia (Santos et al., 2009, Mattos Sobrinho et al., 2015), Paraíba (Barguil et al., 2009), Minas Gerais (Sologuren and Juliatti, 2007), Mato Grosso (Silva et al., 2015) and Pará (Ferreira et al., 2022); H: *H. bihai*, *H. rostrata*, *H. psittacorum* cvs. Red Opal and Golden Torch, *H. psittacorum* x *H. spathocircinata* vars. Alan Carle and Adrian, *H. stricta* cv. Las Cruzes, *H. augusta*, *H. chartacea* cv. Sex Pink, *H. densiflora*, *H. episcopalis*, *H caribaea* x *H. bihai* var. Jaquini, *H. latispatha*, *H. orthotricha* cvs. She and Total Eclipse (Lins and Coelho 2004, Barguil et al., 2009, Santos et al., 2009, Sardinha et al., 2012, Mattos Sobrinho et al., 2015, Silva et al., 2015, Gusmão et al., 2018, Alves et al., 2020, Ferreira et al., 2022). It occurs frequently in other flowers and ornamental plants, such as anthuriums, begonias, cacti, areca bamboo, among others (Pitta, 1995).	**Symptoms**: brownish necrotic lesions of circular or elliptical shapes on the leaves and bracts, surrounded by dark brown or yellowish halos. These lesions can occur throughout the leaf blade. Inflorescences show necrotic, depressed, irregular spots, with a light color in the center and presence of conidia. In the postharvest period, the lesions necrotize and coalesce, causing significant damage and loss of the inflorescences. On pseudostems, the lesions are necrotic and elongated; **Signs**: whitish to grayish mycelium, setaceous acervuli, conidiophores with hyaline, unicellular, elliptical to cylindrical conidia. Appressoria with dark brown color (Fig. 1C and Fig. 3).	**Dispersal of conidia**: through splashes of rainwater or irrigation water by sprinklers, cultivation practices or insects. Conidia reach host surface, germinate and form appressoria. Appressoria are used by the fungus to penetrate the host. Penetration via wounds may also occur. Pathogen propagules survive in crop residues. Dispersal of propagules over long distances occurs mainly via infected seedlings; high temperatures (above 25 °C) and relative humidity; presence of densely grown plants with nutritional stress favors infections (Fig. 1C).

Rust	E: *Puccinia heliconiae* Arthur (*Uredo heliconiae* Dietel); O: Pernambuco (Lins and Coelho, 2004), Ceará (Freire and Mosca, 2009) and Pará (Poltronieri et al., 2013); H: *H. psittacorum* cvs. Sassy and Vicent Red, *H. psittacorum* x *H. spathocircinata* var. Golden Torch (Lins and Coelho, 2004, Poltronieri et al., 2013). It also affects acacias, anthuriums, carnations, chrysanthemums, geraniums, roses, among others (Pitta, 1995).	**Symptoms**: oval chlorotic spots, with a reddish-brown center. Lesions coalesce and dry out the leaf blade. Abaxial surface of the leaf shows powdery pustules of orange yellow to reddish-brown color; **Signs**: uredospores and teliospores (Fig. 1D).	Urediniospores are dispersed through splashes of rainwater or irrigation water, and wind; mild temperatures and high relative humidity, especially dew (Fig. 1D).
Powdery mildew	E: *Oidium* sp.; O: Pernambuco (Assis et al., 2002) and Ceará (Freire and Mosca, 2009); H: *H. collinsiana*, *H. caribaea* cvs. Gold and Purpurea (Assis et al., 2002). It affects azaleas, begonias, chrysanthemums, dahlias, hydrangeas, roses, among others (Pitta, 1995).	**Symptoms**: necrosis in leaves, sheaths and bracts. Leaves in an advanced stage of infection are grayish, coalesce and may even fall off; **Signs**: Powdery, superficial whitish mycelial growth on the adaxial surface of leaves. Presence of conidiophores with cylindrical, unicellular and hyaline conidia. Formation of haustoria (Fig. 1F).	Mild temperatures and relative humidity around 80%. **Survival**: host plant or weed. They produce conidia that are carried by wind, water splashes, or other media to healthy plant tissue, where they infect the adaxial and abaxial surfaces of leaves. To date, development of the perfect form of the fungus has not been observed in heliconias (Fig. 1F).
Leaf spots Pestalotiopsis spot	E: *Pestalotiopsis pauciseta* (Sacc.) Y.X. Chen; O: Sergipe (Serra and Coelho, 2007), Maranhão (Sardinha et al., 2012), Bahia (Mattos Sobrinho et al., 2015) and Distrito Federal (Costa, 2007); H: *H. psittacorum* x *H. spathocircinata* var. Golden Torch, *H. stricta* cv. Las Cruzes, *H. wagneriana* (Serra and Coelho, 2007), *H. rostrata*, *H. psittacorum* cvs. Alan Carle and Golden Torch, *H. latispatha* (Sardinha et al., 2012) and *H. bihai* cv. Chocolate (Mattos Sobrinho et al., 2015).	**Symptoms:** Depressed, oval to elliptical spots on the bracts. Center of lesions with grayish-white color and dark points (acervuli). Lesion edges with reddish brown color. On the leaves, the spots are brownish, oval, with regular edges and chlorotic halos. In the center of the lesions: acervuli; **Signs:** whitish, cottony mycelium; conidiophores with fusiform conidia. Dark acervuli (Fig. 1G).	**Penetration**: through natural openings and wounds; **Dissemination**: wind, insects and splashes of water (rainwater or irrigation water); high temperatures and relative humidity (Fig. 1G).
Bipolaris spot	E: *Cochliobolus cynodontis* R.R. Nelson (*Bipolaris cynodontis* (Marignoni) Shoemaker); O: Bahia (Santana et al., 2009a, Mattos Sobrinho et al., 2015), Pernambuco (Lins and Coelho, 2004), Mato Grosso (Nascimento et al., 2015), São Paulo (Coutinho, 2006) and Distrito Federal (Costa, 2007); H: *H. rostrata*, *H. caribaea* (Assis et al., 2002), *H. psittacorum* cvs. Golden Torch and Suriname Sassy, *H. bihai* cv. Jacquinni (Santana et al., 2009), *H. augusta*, *H. tagami* (Costa, 2007), *H. bihai cv.* transamazonica, *H. stricta* (Lins and Coelho, 2004), *H. psittacorum* x *H. spathocircinata* var. Alan Carle and *H. psittacorum* cv. Red Opal (Mattos Sobrinho et al., 2015). It also occurs in carnations, roses, chrysanthemums and palm tree species (Pitta, 1995).	**Symptoms:** mainly on the leaves, possibly extending to the inflorescences. Necrotic spots of varying shapes and sizes are observed on the leaves, mainly rounded or oval, with a whitish-brown center and a chlorotic halo. Lesions may coalesce, possibly perforating the leaves. On sheaths and bracts, spots of purplish-brown color; **Signs:** grayish and cottony mycelium. Presence of conidia in conidiophores (Fig. 1G).	**Dissemination**: by splashes of rainwater or irrigation water, and by wind. Presence of continuous humidity. Pathogen disperses mainly through cultural practices (Fig. 1G).

Curvularia spot	E: *Curvularia brachyspora* Boedijn; O: Mato Grosso (Nascimento et al., 2015), Maranhão (Sardinha et al., 2012), Distrito Federal (Costa, 2007), Pará (Benchimol et al., 2005), Bahia (Santos et al., 2009; Mattos Sobrinho et al., 2015), Pernambuco (Lins and Coelho, 2004) and Ceará (Freire and Mosca, 2009). H: *H. rostrata*, *H. bihai*, *H. rauliniana*, *H. latispatha* (Sardinha et al., 2012), *H. psittacorum* cvs. Golden Torch, Sassy, Red Opal, Vicent Red (Lins and Coelho, 2004) and Alan Carle (Sardinha et al., 2012), *H. densiflora*, *H. psittacorum* (Nascimento et al., 2015), *H. episcopalis* (Assis et al., 2002) and *H. orthotricha* cv. She (Mattos Sobrinho et al., 2015).	**Symptoms**: irregularly shaped, brownish necrotic spots on older leaves, extending to the inflorescences. Lesions start at the margins of the leaves, coalescing and necrotizing them. Symptomatic leaves have a "scorched" appearance; **Signs**: brownish to black and cottony mycelium. Fusiform conidia in brownish conidiophores (Fig. 1G).	**Dissemination**: wind; continuous high humidity and wide temperature range (18 to 32 °C) (Fig. 1G).
Cercospora spot	E: *Cercospora* spp.; O: Mato Grosso (Nascimento et al., 2015) and Pernambuco (Assis et al., 2002); H: *H. densiflora*, *H. psittacorum* (Nascimento et al., 2015) and *H. psittacorum* cv. Lady Di (Assis et al., 2002). It also affects carnations, chrysanthemums, roses and palm trees (Pitta, 1995).	**Symptoms**: Irregular small brown spots on the leaves. Lesions start at the leaf margins and expand to the center. They are similar to those of physiological and nutritional disorders. Individualized greenish to brownish lesions with a chlorotic halo may occur on the leaf veins. Lesions may expand, leaving the plant with a "scorched" appearance. **Signs:** brownish to black and cottony mycelium; brownish conidiophores, and hyaline, fusiform, or cylindrical conidia (Fig. 1G).	**Dissemination**: by wind or by insects; High humidity. Important for sporulation and dispersal of pathogen propagules (Sewake and Uchida, 1995) (Fig. 1G).
Alternaria spot	E: *Alternaria solani* (Ellis & G. Martin) L.R. Jones & Grout and *Alternaria alternata* (Fr.) Keissl; O: Maranhão (Sardinha et al., 2012), Bahia (Santana et al., 2009) and Distrito Federal (Costa, 2007); H: *H. psittacorum* cvs. Golden Torch and Suriname Sassy, *H. rostrata*, *H. bihai* cv. Jacquinii (Costa, 2007; Santana et al., 2009b) and *H. colisiana* (Sardinha et al., 2012). It affects carnation, chrysanthemum, rose and palm trees (Pitta, 1995).	**Symptoms:** brownish spots with concentric circles of different sizes on the leaf blade. Spots are visible on the margins and centers of the leaves. Lesions may coalesce; **Signs:** grayish and cottony mycelium; with brownish conidiophores and conidia (Fig. 1G).	**Dissemination**: by wind or splashes of water (rainwater or irrigation water). Conidia and mycelium can survive in crop residues and soil; high temperatures and humidity (Fig. 1G).

Cladosporium spot	E: *Mycosphaerella tassiana* (De Not.) Johanson (*Cladosporium herbarum* (Pers.) Link); O: Bahia (Santos et al., 2009; Mattos Sobrinho et al., 2015), Pernambuco (Assis et al., 2002), Mato Grosso (Nascimento et al., 2015) and Distrito Federal (Costa, 2007); H: *H. latispatha* (Mattos Sobrinho et al., 2015), *H. psittacorum* cvs. Golden Torch and Red Opal (Santos et al., 2009), *H. densiflora* (Nascimento et al., 2015), *H. psittacorum* (Costa, 2007), *H. psittacorum* x *H. spathocircinata* vars. Alan Carle, Golden Torch and Adrian (Mattos Sobrinho et al., 2015).	**Symptoms**: Circular necrotic brownish spots of varying sizes with chlorotic halos on leaves. These spots occur especially on the abaxial surface. Lesions may coalesce and cause a "scorched" appearance on the leaf blade. On the inflorescences, the spots are dark and irregularly shaped. **Signs:** green to olive-brown mycelium on the abaxial surface, with conidiophores and conidia of the same color (Fig. 1G).	**Dissemination**: by infected seedlings, wind and agricultural implements. Mild temperatures and high relative humidity. **Survival**: mycelium, in or on the seed surface and diseased plant residues that remain on the soil (Fig. 1G).
Panama disease	E: *Fusarium oxysporum* f. sp. *cubense* (Foc) (E.F. Smith) Sn & Hansen; O: Maranhão (Sardinha et al., 2012), Distrito Federal (Costa, 2007), Pernambuco (Assis et al., 2002, Lins and Coelho, 2004), Ceará (Freire and Mosca, 2009), Bahia (South Coast) (Mattos Sobrinho et al., 2015), Alagoas and Sergipe (Castro et al., 2008); H: *H. latispatha*, *H. bihai*, *H. caribaea*, *H. wagneriana*, *H. chartacea* cv. Sexy Pink, *H. rostrata*, *H. stricta* cvs. Capri and Fire Bird, *H. psittacorum* cvs. Golden Torch, Golden Torch Adrian, Sassy and Alan Carle (Assis et al., 2002, Castro et al., 2010; Sardinha et al., 2012), *H. densiflora* (Silva et al., 2015), *H. orthotricta* cv. Eclipse Total (Castro et al., 2008), *H. pseudoaemygdiana* (Costa, 2007) and *H. chartacea* cv. Sexy Scarlet (Mattos Sobrinho et al., 2015).	**Symptoms:** progressive yellowing from the lower leaves to the younger ones, rupture of the sheath near the pseudostem (typical "closed umbrella" appearance) and wilting of the plant. In cross-sections of the pseudostem and rhizome, vascular discoloration in the form of concentric rings is observed (Cordeiro et al., 2005, Pereira et al., 2005). Rhizomes and inflorescences show dry rot. Central leaves may also show symptoms of necrosis; **Signs:** unicellular hyaline microconidia and fusiform hyaline macroconidia. Presence of chlamydospores (resistance structures) is noticeable (Fig. 1H).	Soil-dwelling pathogen with a high saprophytic capacity, it survives with chlamydospores. In the absence of the host, it can survive for up to 40 years. It has four races that infect different hosts: a) race 1, related to the banana varieties of the Prata and Gros Michel subgroups; b) race 2, with bananas of the Bluggoe subgroup; and c) race 4, with bananas of the Cavendish subgroup. This race has not yet been found in Brazil. In the case of species of the Heliconiaceae family, the Foc race responsible for the disease is race 3 (Pereira et al., 2005; Cordeiro et al., 2005); **Dissemination**: contaminated propagative material. The fungus is dispersed in the crop by irrigation water, as well as by humans, animals and agricultural implements (Cordeiro et al., 2005); water and nutritional stresses. Greater severity of the disease is also observed in the presence of acidic soils, with inadequate drainage and nematode infestation (Warumby et al., 2004) (Fig. 1H).

2. Diseases caused by nematodes

Disease	Etiology (E), occurrence (O) and hosts (H)	Symptoms and signs	Epidemiology
Root knot	E: *M. incognita* Chitwood; O: Pernambuco, Ceará, Maranhão and Bahia (Lins and Coelho, 2004, Freire and Mosca, 2009, Sardinha et al., 2012, Mattos Sobrinho et al., 2013); H: *H. rostrata*, *H. bihai*, *H. rauliniana*, *H. latispatha*, *H. wagneriana*, *H. rivularia*, *H. angusta* and *H. psitacorum* cvs. 'Red Opal', 'Golden Torch', 'Golden Torch Adrian' and 'Alan Carle' (*H. psittacorum* x *H. spathocircinata*), 'Sassy' (*H. psittacorum*), 'She' (*H. orthotricha*), 'Jacquinii' (*H. bihai* x *H. caribaea*), 'Fire bird' (*H. stricta*) and 'Splash' (*H. champneiana*) (Lins and Coelho, 2004, Freire and Mosca, 2009, Sardinha et al., 2012, Mattos Sobrinho et al., 2013).	**Symptoms** wilt in the hottest hours of the day and scorching of older leaves and underdeveloped plants (Lins and Coelho, 2004, Warumby et al., 2004, Oliveira et al., 2007, Freire and Mosca, 2009); **Signs**: Males are vermiform and adult females have a piriform globose body. They form galls in the root system. They compromise the absorption of water and nutrients (Fig. 1J and Fig. 4).	Life cycle: 3-4 weeks; **Dispersal**: infected seedlings, soil adhered to agricultural implements, irrigation water or rainwater, and animals; **Survival**: host plants and eggs. Quiescence occurs under stress conditions (McSorley, 2003) (Fig. 1J).
Burrowing nematode	E: *Radopholus similis* (Cobb) Thorne; O: São Paulo and Pernambuco (Zem and Lordello, 1983, Assis, 2006); H: Wide range of hosts.	**Symptoms:** Reddish necrotic lesions on roots and rhizomes. On primary roots: cracks that extend into the cortex. In the aerial part, yellowing, wilting and damping-off of plants occur (Warumby et al., 2004). Reduction in leaf size and scorching on the margins of older leaves, observed when there is interaction between nematodes and other soil pathogens; **Signs:** migratory endoparasite, vermiform in the larval and adult stages, with sexual dimorphism (Sipes et al., 2001) (Fig. 1L and Fig. 5).	Obligate parasite, although in its various stages it can move from the root of the infected plant to the soil and vice versa. Females and juvenile stages are infectious. Eggs are deposited on the roots, which decompose quickly. Females can reproduce sexually or asexually (parthenogenesis), and recent studies suggest hermaphroditism; Life cycle: 25-30 days, 24 to 32 °C (Luc et al., 1990). **Dissemination**: by infected seedlings, adhered soil, contaminated agricultural implements, transit of workers, animals, and irrigation water or rainwater. **Survival in soil**: six months or less (Fig. 1L).
Spiral nematode	E: *Helicotylenchus* spp. Steiner, 1945; O: Pernambuco, Maranhão, Bahia and São Paulo (Zem and Lordello, 1983, Lins and Coelho, 2004, Assis, 2006, Sardinha et al., 2012); H: *Heliconia* sp., *H. psittacorum* 'Golden Torch', (Oliveira et al., 2007; Mattos Sobrinho et al., 2013).	**Symptoms:** reduced growth of the plant and root system, wilting in the hottest hours of the day, and symptoms of nutritional deficiency. Root rot when secondary infections occur, as well as shoot symptoms such as scorching of margins on older leaves and more intense wilting (Warumby et al., 2004); **Signs:** ectoparasite and migratory endoparasites (Lordello, 1994, Warumby et al., 2004, Mattos Sobrinho et al., 2012) (Fig. 1M).	Females lay their eggs in the soil. **Life cycle**: 35 to 37 days at temperature of 23-33 °C, and humidity of 40 to 60% (Laughlin and Lordello, 1977). **Dissemination**: planting material, contaminated agricultural implements, animals and waterlogged soils. **Survival**: several months in soil and in tissues remaining from previous plantations (Fig. 1M).
Dagger nematode	E: *Xiphinema* spp.; O: Generalized geographical distribution (Tenente et al., 2002); H: *H. rostrata* and *H. latispatha* (Assis, 2007).	**Symptoms:** swelling in root tips, similar to the galls of *Meloidogyne*. In monocots, there is an excessive amount of secondary roots (Warumby et al., 2004). In the shoot: underdevelopment and yellowing. For some plant species, infected root tips may have galls; **Signals:** Migratory ectoparasites (Fig. 1N).	They transmit viruses and remain infectious for two to four months. They live in deep soil and migrate from one root to another to feed. Life cycle length can range from a month to a year. Most prefer light-textured soils. **Dissemination**: by infected seedlings, instruments used in soil preparation, and humans. **Survival**: crop residues and extreme temperature (freezing) conditions in the soil (Fig. 1N).

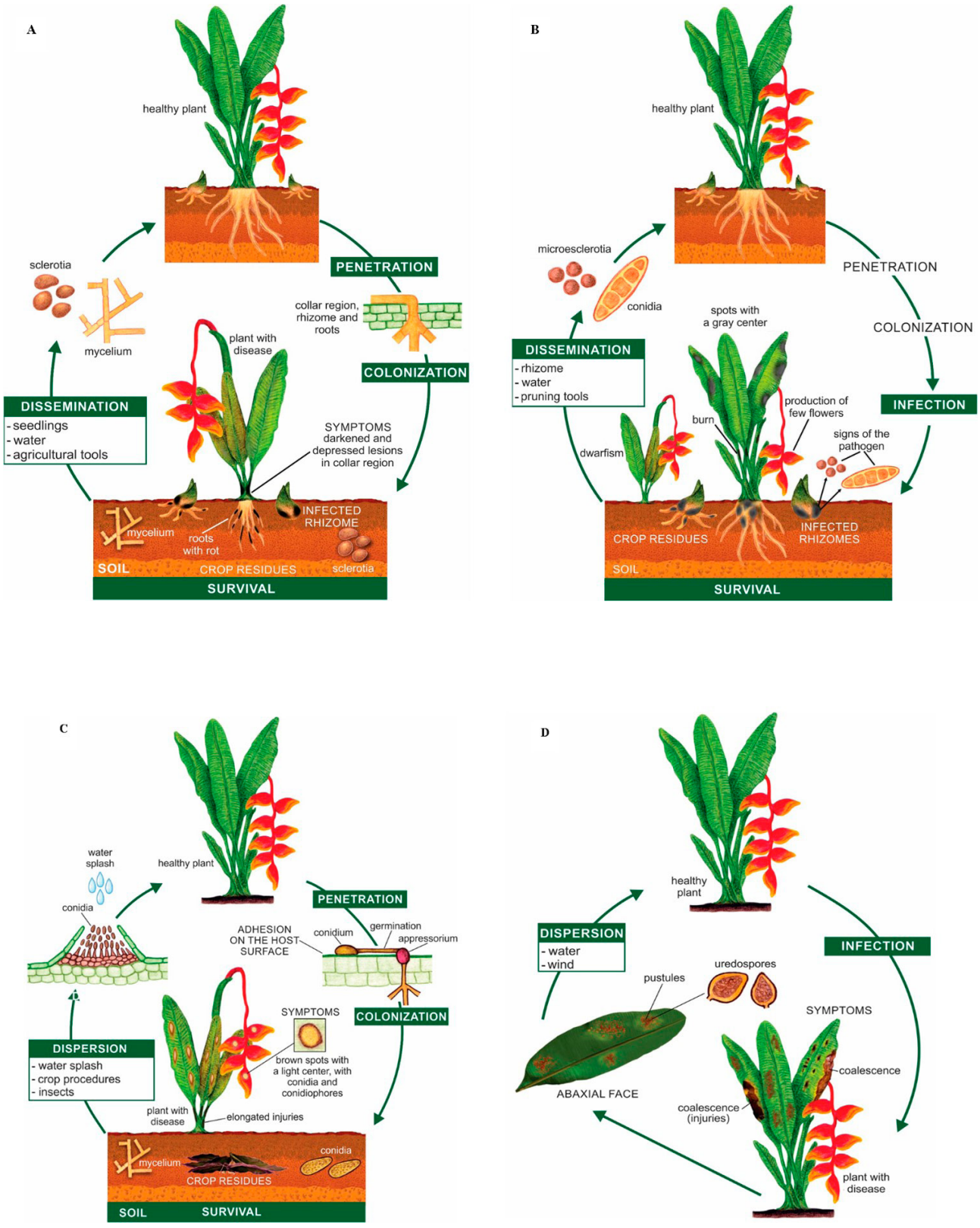

Fig. 1. Disease cycles in heliconias. (A) Rhizoctonia Rot, (B) Cylindrocladium Rot, (C) Anthracnose, (D) Rust, (E) Oomycete Rot, (F) Powdery mildew, (G) Leaf spots, (H) Panama Disease, (I) Moko, (J) Root knot, (L) Burrowing Nematode, (M) Spiral nematode, and (N) Dagger nematode. Arts: Paulo R. V. S. Pereira.

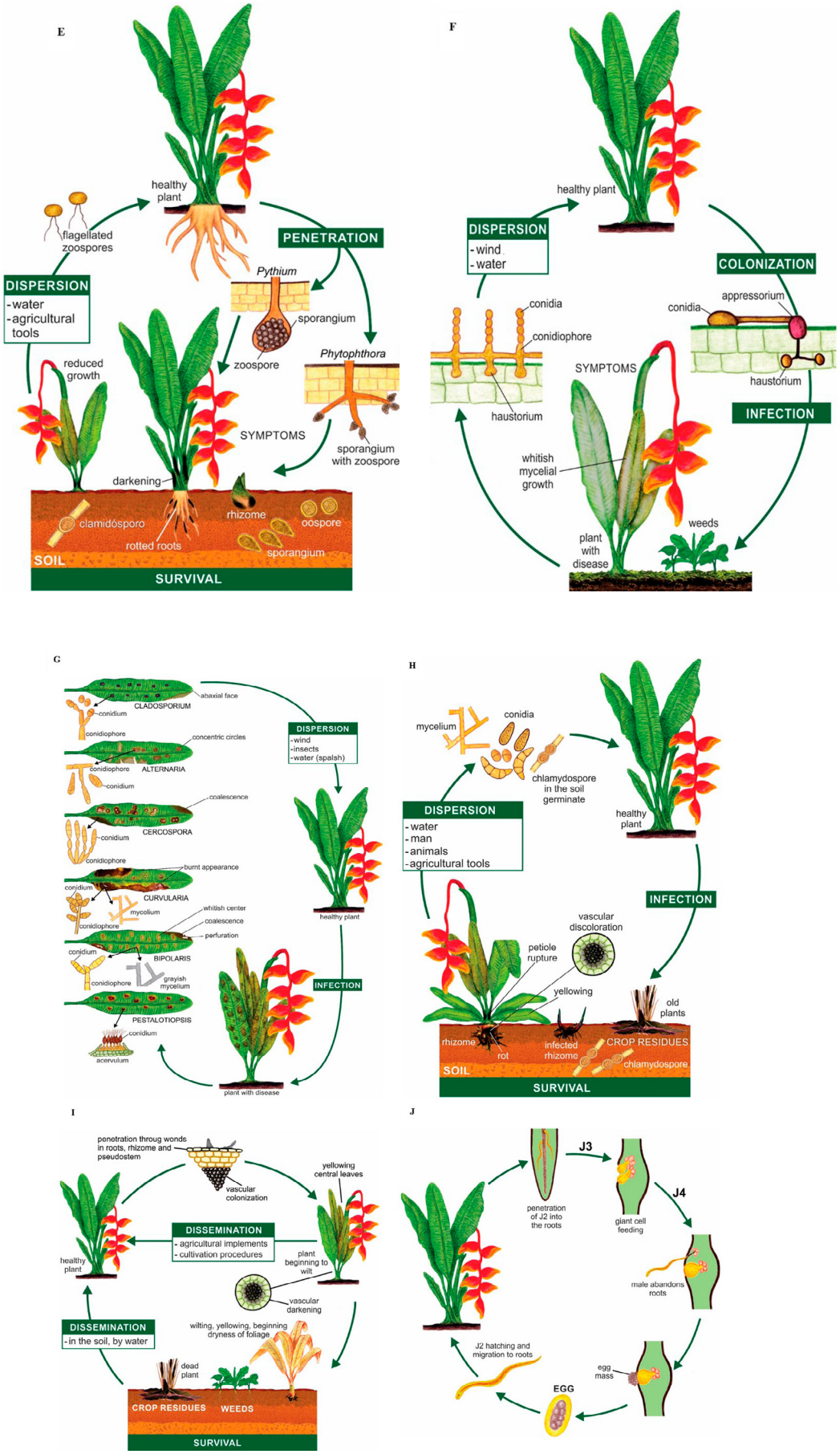
E
healthy plant
flagellated zoospores
DISPERSION
-water
-agricultural tools
PENETRATION
Pythium
sporangium
zoospore
Phytophthora
sporangium with zoospore
reduced growth
SYMPTOMS
darkening
clamidósporo
rotted roots
rhizome
oospore
sporangium
SOIL
SURVIVAL
F
healthy plant
DISPERSION
-wind
-water
COLONIZATION
conidia
conidiophore
haustorium
conidia
appressorium
haustorium
SYMPTOMS
INFECTION
whitish mycelial growth
plant with disease
weeds
G
CLADOSPORIUM
abaxial face
conidium
conidiophore
concentric circles
ALTERNARIA
CERCOSPORA
coalescence
burnt appearance
CURVULARIA
mycelium
whitish center
perfuration
BIPOLARIS
grayish mycelium
PESTALOTIOPSIS
acervulum
DISPERSION
-wind
-insects
-water (spalsh)
healthy plant
INFECTION
plant with disease
H
mycelium
conidia
chlamydospore in the soil germinate
healthy plant
DISPERSION
-water
-man
-animals
-agricultural tools
INFECTION
vascular discoloration
petiole rupture
yellowing
old plants
rhizome rot
infected rhizome
CROP RESIDUES
chlamydospore
SOIL
SURVIVAL
I
penetration throug wonds in roots, rhizome and pseudostem
vascular colonization
yellowing central leaves
DISSEMINATION
- agricultural implements
- cultivation procedures
healthy plant
plant beginning to wilt
vascular darkening
DISSEMINATION
-in the soil, by water
wilting, yellowing, beginning dryness of foliage
dead plant
CROP RESIDUES
WEEDS
SURVIVAL
J
J3
penetration of J2 into the roots
giant cell feeding
J4
male abandons roots
egg mass
EGG
J2 hatching and migration to roots

Fig. 1. Cont.

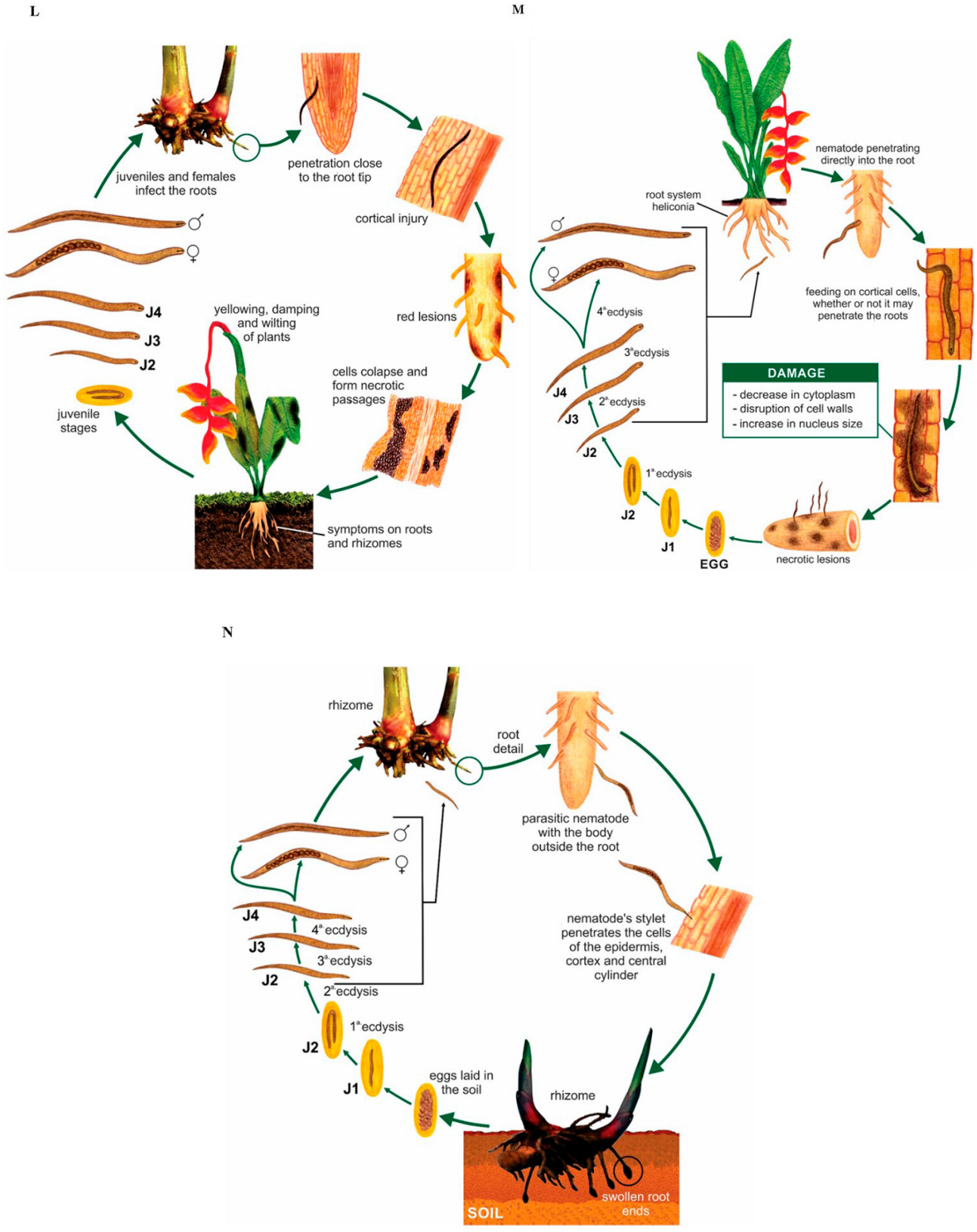
L
juveniles and females infect the roots
penetration close to the root tip
cortical injury
red lesions
cells colapse and form necrotic passages
symptoms on roots and rhizomes
yellowing, damping and wilting of plants
juvenile stages
J4
J3
J2
M
nematode penetrating directly into the root
root system heliconia
feeding on cortical cells, whether or not it may penetrate the roots
DAMAGE
- decrease in cytoplasm
- disruption of cell walls
- increase in nucleus size
4ª ecdysis
3ª ecdysis
2ª ecdysis
1ª ecdysis
EGG
necrotic lesions
N
rhizome
root detail
parasitic nematode with the body outside the root
nematode's stylet penetrates the cells of the epidermis, cortex and central cylinder
eggs laid in the soil
SOIL
swollen root ends

Fig. 1. Cont.

Fig. 2. Symptoms of Cylindrocladium rot in heliconia rhizome (A) and conidiophores, phialides and conidia of *Cylindrocladium spathiphylli* f. sp. *heliconiae* (B). Photos: Tereza Cristina de Assis.

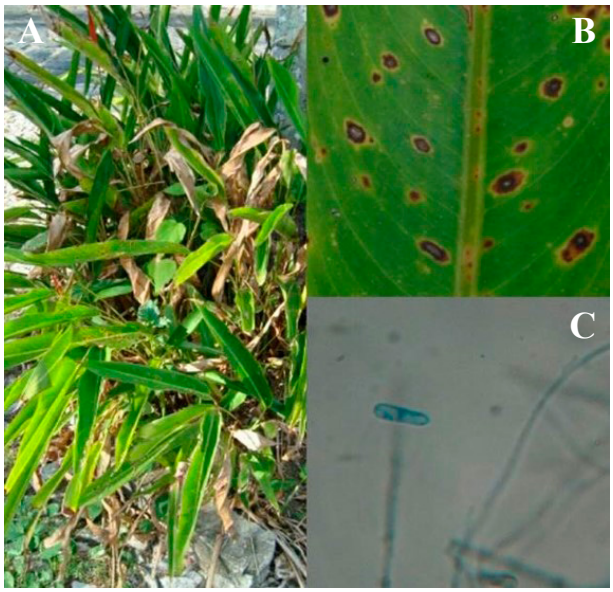

Fig. 3. Symptoms of anthracnose in heliconia leaves (A, B) and conidia of *Colletotrichum gloeosporioides* (C). Photos: Regina Ceres Torres Rosa.

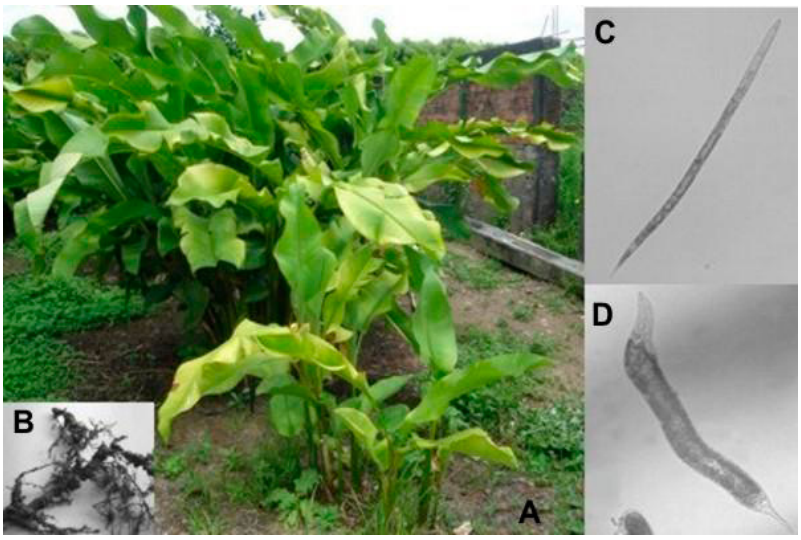

Fig. 4. Symptomatology of root knot in heliconia causing symptoms in patches, with underdeveloped plants (A) and galls in the root system (B) and the forms shown by *Meloidogyne* spp., juvenile (C) and female (D). Photos: Regina Ceres Torres Rosa.

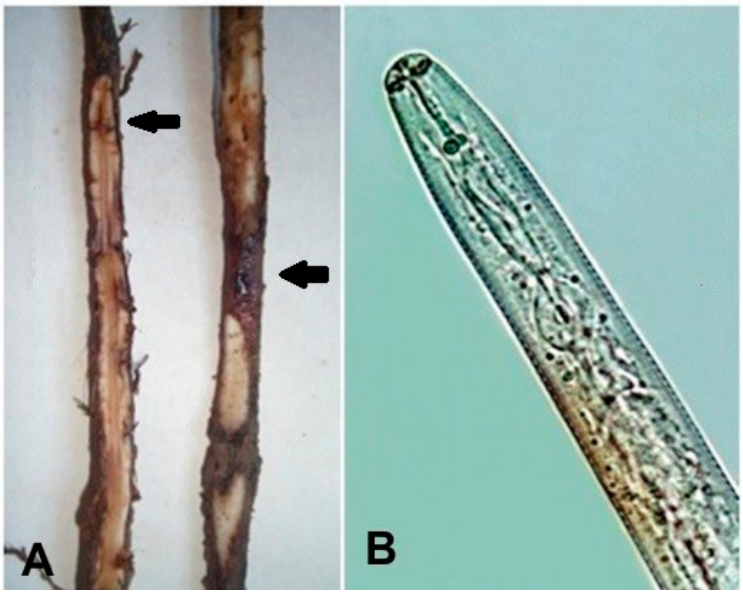

Fig. 5. Symptoms of burrowing nematode infestation in heliconia, (A) reddish necrotic lesions on the roots, and (B) cephalic region of *Radopholus similis*. Photos: (A) Regina Ceres Torres Rosa, (B) Graham and Jackson.

3. Bacterial disease

Disease	Etiology (E), occurrence (O) and hosts (H)	Symptoms and signs	Epidemiology
Bacterial wilt	E: *Ralstonia solanacearum* (Smith) Yabuuchi et al; O: Pernambuco, Sergipe, Amapá, Pará, Amazonas, Roraima, Rondônia and Distrito Federal (Assis et al. 2002, Zoccoli et al. 2009, Conaban, 2012); H: *H. bihai*, *H. caribaea*, *H. humilis*, *H. x nickeriensis* (*H. psittacorum* x *H. marginata*), *H. stricta*, *H. wagneriana*, *H. rauliniana*, *H. acuminata* and *H. psittacorum* 'Lady Di', 'Sassy', 'Strawberries', 'Red opal', 'Red gold' (Assis et al., 2002, Warumby et al., 2004, Zoccoli et al., 2009).	**Symptoms and signs**: yellowing, starting with the central leaves, progressing to wilting and drying. On the pseudostem: discoloration of xylem vessels, followed by darkening of the central part. Presence of bacterial exudation (sign). Leaf deformation occurs in tillers, with leaf curling, yellowing and necrosis (Fig. 1I and Fig. 6).	Only race 2 infects heliconias (Hernández, 2022). The race is a soil dweller and penetrates the plant through wounds. Then, it multiplies towards the xylem, reaching all parts of the plant and obstructing the vessels (Hikichi et al., 2007, Amorim et al., 2011). **Dissemination**: by soil, by dew or irrigation water, by contact between roots, by cultivation practices, infected seedlings, agricultural implements, insects, nematodes and humans (Kelman et al., 1994, Warumby et al., 2004). **Survival:** soil, host weeds, and volunteer plants (Jabuonski and Hidalgo, 1987) (Fig. 1I).

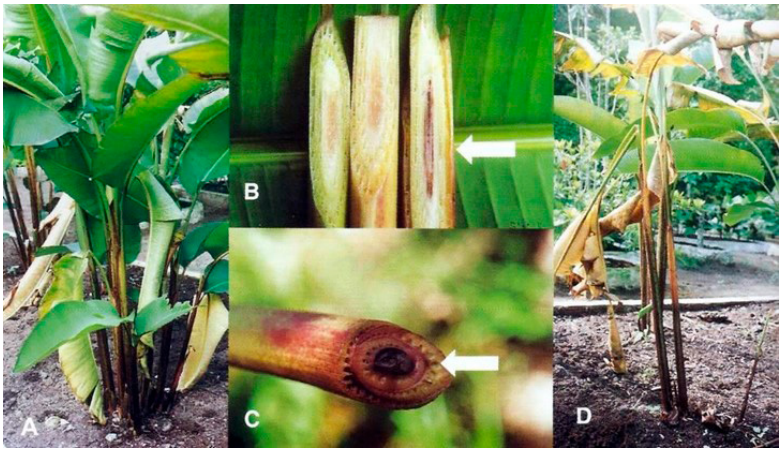

Fig. 6. Symptoms of bacterial wilt in heliconia, (A) plant showing yellowing, wilting, and drying; (B) pseudostem with darkening in the central part; (C) bacterial exudation; (D) Plant collapse and death. Photos: Sayonara M. P. Assis.

4. Viral diseases

In tropical ornamental flowers, especially those of the order Zingiberales, few occurrences of viral diseases have been observed. However, the viruses that stand out in prevalence are the Cucumber Mosaic Virus – CMV and the Banana Streak Virus – BSV (CABI, 2020, Muhammad et al., 2021). These viruses have been reported in Colombia and the United States infecting *H. bihai* 'Orange' and *H. psittacorum* cultivars 'Andromeda' and 'Golden Torch', respectively (Warumby et al., 2004; Cardona and Zapata, 2012). The Banana Bunchy Top Virus (BBTV) has been detected in *Heliconia* spp. in the United States and Indonesia, a worrying fact for banana growers because the disease caused by this virus is a threat to the banana crop and heliconia would be a host plant (Hamim et al., 2017, Arimbawa et al., 2022).

The first occurrence of virus in the genus *Heliconia* was described in Brazil in 2013, being detected in the State of São Paulo in *H. stricta* plants, caused by the genus *Potyvirus*. The plants showed symptoms of chlorotic 'pin points' between the veins and yellowish spots with reddish necrotic areas (Rivas et al., 2013). The genus *Potyvirus* is the most studied among those in the family *Potyviridae*, with 146 species already characterized. They are viruses composed of positive-sense single-stranded RNA that, when translated, generates a polyprotein that self-cleaves into 10 mature proteins (King et al., 2012). Due to the recent detection of this virus, further studies are needed on its etiology, epidemiology (type of virus, source of inoculum, vector, virus-vector relationship, vector population fluctuation etc.), symptoms and cycle, as well as evaluations of the economic damage of the disease to the crop. Identification of new viruses, even if they do not cause economic damage to agriculture, is important due to the increasing presence of emerging virus populations.

5. Disease management in heliconias

Control measures	Diseases
1. Use certified seedlings and healthy rhizomes.	Rots, anthracnose, rust, powdery mildew, Panama disease, leaf spots, bacterial wilt, root knot, burrowing nematode, spiral nematode and dagger nematode and plant viral disease.
2. Avoid planting plant species susceptible to hosts.	Rots, anthracnose, rust, powdery mildew, Panama disease and leaf spots.
3. Destroy and eliminate inoculum sources.	Rots, anthracnose, rust, powdery mildew, Panama disease and leaf spots, bacterial wilt and plant viral disease.
4. Avoid planting in contaminated soils.	Rots, anthracnose, rust, powdery mildew, Panama disease and leaf spot, root knot and dagger nematode.
5. Avoid successive cultivation. Crop rotation is recommended when possible.	Rots, anthracnose, rust, powdery mildew, Panama disease and leaf spots, root knot, burrowing nematode, spiral nematode and dagger nematode.
6. Carry out organic fertilization	Rots, anthracnose, rust, powdery mildew, Panama disease and leaf spots, burrowing nematode, spiral nematode and dagger nematode.
7. Increase spacing between clumps, allowing for better aeration between plants.	Rots, anthracnose, rust, powdery mildew, Panama disease and leaf spots.
8. Carry out irrigation management, avoiding excess moisture in the soil and plants.	Rots, anthracnose, rust, powdery mildew, Panama disease and leaf spot, bacterial wilt, burrowing nematode, and spiral nematode.
9. Resistance inductors for reducing severity (GURGEL et al., 2014).	Anthracnose.
10. Carry out balanced fertilization on plants.	Rots, anthracnose, rust, powdery mildew, Panama disease and leaf spots, bacterial wilt, root knot, burrowing nematode, spiral nematode and dagger nematode.
11. Selection of resistant or tolerant heliconia species/hybrids.	Leaf spots, Panama disease.
12. Quarantine seedlings and rhizomes of any origin.	Bacterial wilt.
13. Avoid planting near banana trees.	Panama disease and bacterial wilt.
14. Sanitize agricultural equipment, especially pruning and cleaning equipment.	Panama disease, bacterial wilt, burrowing nematode, spiral nematode and plant viral disease.
15. Avoid injuries during planting and cultural practices.	Bacterial wilt.
16. Monitor plantations.	Bacterial wilt and plant viral disease.
17. Fallow the area.	Bacterial wilt.
18. Intercropping of antagonistic plants (*Crotalaria spectabilis* and *Tagetes* sp.)	Root knot and burrowing nematode.
19. Heat treatment of infested rhizomes.	Root knot, burrowing nematode and spiral nematode.
20. Avoid water stress.	Root knot and dagger nematode.
21. Soil solarization.	Root knot, burrowing nematode and spiral nematode.
22. Biological control with fungi and antagonistic bacteria.	Burrowing nematode, spiral nematode and Panama disease.
23. Use arbuscular mycorrhizal fungi (AMF).	Burrowing nematode and spiral nematode.
24. Use cover crops.	Dagger nematode.
25. Control insect vectors.	Plant viral disease.
26. Chemical control with fungicides registered by MAPA.	Panama disease

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Author contribution

CFBS: Supervision, Conceptualization, Resources, Writing – Original Draft, Writing – Review & Editing. **RCTR:** Data curation, Writing – Original Draft, Writing – Review & Editing. **PRVSP:** Data curation, Writing – Review & Editing. **ACRC:** Data curation, Conceptualization, Resources, Writing – Original Draft, Writing – Review & Editing. **ACPPC:** Writing – Review & Editing.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

All the research data is contained in the manuscript.

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