





Review

A Survey of Endophytic Fungi Associated with High-Risk Plants Imported for Ornamental Purposes

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Abstract: An extensive literature search was performed to review current knowledge about endophytic fungi isolated from plants included in the European Food Safety Authority (EFSA) dossier. The selected genera of plants were *Acacia*, *Albizia*, *Bauhinia*, *Berberis*, *Caesalpinia*, *Cassia*, *Cornus*, *Hamamelis*, *Jasminus*, *Ligustrum*, *Lonicera*, *Nerium*, and *Robinia*. A total of 120 fungal genera have been found in plant tissues originating from several countries. *Bauhinia* and *Cornus* showed the highest diversity of endophytes, whereas *Hamamelis*, *Jasminus*, *Lonicera*, and *Robinia* exhibited the lowest. The most frequently detected fungi were *Aspergillus*, *Colletotrichum*, *Fusarium*, *Penicillium*, *Phyllosticta*, and *Alternaria*. Plants and plant products represent an inoculum source of several mutualistic or pathogenic fungi, including quarantine pathogens. Thus, the movement of living organisms across continents during international trade represents a serious threat to ecosystems and biosecurity measures should be taken at a global level.

Keywords: endophytic fungi; crop protection; *Acacia*; *Albizia*; *Bauhinia*; *Berberis*; *Caesalpinia*; *Cassia*; *Cornus*; *Hamamelis*; *Jasminus*; *Ligustrum*; *Lonicera*; *Nerium*; *Robinia*; EFSA; high-risk plants

1. Introduction

Endophytic fungi are ubiquitous to plants, and are mainly members of Ascomycota or their mitosporic stage, but they also include some taxa of Basidiomycota, Zygomycota, and Oomycota. Endophytes are organisms living within the tissues of plants [1] establishing stable relationships with their host, ranging from non-pathogenic to beneficial [2,3]. The endophytic fungi communities represent an enormous reserve of biodiversity and constitute a rich source of bioactive compounds used in agriculture [4,5]. For these reasons, they have attracted the attention of the scientific community worldwide. By definition, all or at least a significant part of the endophytic fungi life cycle occurs within the plant tissues without causing symptoms to their host [6–8]. A wide range of fungi, including pathogens and saprophytes, may be endophytes. Several pathogens live asymptotically within plant tissues during their latency or quiescent stage, while some saprobes can also be facultative parasites [1,8,9]. Fungal endophytes are influenced by abiotic and biotic factors, occupying different habitats and locations during their life cycle phases. Even if host plants do not show any symptoms, they may represent a source of inoculum for other species [10–13]. Furthermore, changes in environmental conditions or species hosts may modify the fungal behavior, thus producing

disease symptoms [8,11,14]. Large quantities of plants and plant material that are globally traded might contain asymptomatic infections of these fungi. It is generally accepted that the movement of plants and plant products by global trade and human activities is the most common way to introduce exotic pathogens and pests in non-endemic countries. Plant health is increasingly threatened by the introduction of emerging pests and/or pathogens [15,16]. Noticeable examples are represented by the invasion of alien plant pathogens into new areas [17–19]. Generally, biological invasions are the main threat to biodiversity [20], causing a decrease in species richness and diversity [20,21] or affecting local biological communities [22], as well as changing ecosystem processes [23–25].

In this scenario, the European Food Safety Authority (EFSA) Panel on Plant Health is responsible for the risk assessment, evaluations of risk reduction options, as well as guidance documents [26] in the domain of plant health for the European Union (EU) [26,27]. Commission Implementing Regulation (EU) [28] prohibits the importation of 35 so-called ‘High-Risk Plants, plant products and other objects’ from all third (non-EU) countries as long as no full risk assessment has been carried out. The EFSA Panel on Plant Health was requested to prepare and deliver risk assessments for these commodities [27,28], to evaluate whether the plant material will remain prohibited or removed from the list, with or without the application of additional measures [27,29]. The Commodity Risk Assessment has to be performed on the basis of technical dossiers provided by National Plant Protection Organizations of third countries. Information required for the preparation and submission of technical dossiers includes data on the pests potentially associated with the plant species or genera and on phytosanitary mitigation measures and inspections [30,31].

These plants have been identified as ‘High-Risk Plants’ by the EU since they ‘host commonly hosted pests known to have a major impact on plant species which are of major economic, social or environmental importance to the Union’ [28]. However, among these 35 plant genera, within the meaning of Art. 42 of Regulation (EU) 2016/2031, a list of only 13 taxa have been selected by the EFSA as plants mostly traded for ornamental purposes. According to this list, we have reviewed the following genera: *Acacia* Mill., *Albizia* Durazz., *Bauhinia* L., *Berberis* L., *Caesalpinia* L., *Cassia* L., *Cornus* L., *Hamamelis* L., *Jasminus* L., *Ligustrum* L., *Lonicera* L., *Nerium* L., and *Robinia* L. In this article, as much as possible, we highlight the potential risks associated with the movement of plants or materials among nations. Although other plant species may also have a significant impact, this review is limited to plants included in EU regulation [28] that do not originate within Europe. Thus, given these perspectives for future assessments, the present investigation offers an up-to-date snapshot of endophytic fungi associated with the so-called ‘High-Risk Plants for ornamental purpose’. The aim is to facilitate the information required for technical dossiers, needed by the EFSA to perform the Commodity Risk Assessment of 13 plants mandated on an EU import list.

2. Endophytic Fungi Occurring in Selected Plants

Table 1 summarizes the abundance of endophytic fungi reported in association with High-Risk Plants for ornamental purposes. Herein, the number of endophytic species found in association with the examined plant genera has been taxonomically grouped by fungal genus. There are important differences in terms of fungi recovered per specific plant genus (SP) as well as in the frequency of a specific fungal genus (SF). These discrepancies could be explained by the different availability of literature data on these specific plants.

Table 1. Endophytic fungi isolated from *Acacia* (AC), *Albizia* (AL), *Bauhinia* (BA), *Berberis* (BE), *Caesalpinia* (CP), *Cassia* (CS), *Cornus* (CO), *Hamamelis* (HA), *Jasminus* (JA), *Ligustrum* (LI), *Lonicera* (LO), *Nerium* (NE), *Robinia* (RO). Columns report the number of isolated fungal species. The total number of records calculated per fungal genus is indicated as Tot. SF. The total number of records per plant genera is indicated as Tot. SP. Fungal genera are sorted by alphabetic order.

Fungi Genera	Plant Genera													Tot SF
	AC	AL	BA	BE	CP	CS	CO	HA	JA	LI	LO	NE	RO	
<i>Acremonium</i>		1	3											4
<i>Albifimbria</i>			1											1
<i>Alternaria</i>	1		1	4	1		3			2		2		14
<i>Anguillospora</i>				1										1
<i>Ascochyta</i>							1							1
<i>Ascotricha</i>			2											2
<i>Aspergillus</i>	3	8	11	1	9	2	3					3		40
<i>Aureobasidium</i>	2						4							6
<i>Bacillispora</i>				1										1
<i>Beauveria</i>													1	1
<i>Bipolaris</i>		1			2							1		4
<i>Botryosphaeria</i>	1						2							3
<i>Botrytis</i>			1				1							2
<i>Campylospora</i>				1										1
<i>Cercospora</i>				1										1
<i>Chaetomium</i>	2		1									3		6
<i>Chrysosporium</i>					1									1
<i>Cladosporium</i>			4		1		5			1		3		14
<i>Clonostachys</i>				1						1			1	3
<i>Cochliobolus</i>	1		3									1		5
<i>Colletotrichum</i>	2	1	3	4	1		2	1	7	3		3		27
<i>Coprinus</i>						1								1
<i>Cordyceps</i>							1							1
<i>Corynespora</i>			1											1
<i>Cryptodiaporthe</i>							1							1
<i>Cryptodiaporthe</i>							1							1
<i>Curvularia</i>		1	5		2							2		10
<i>Cylindrocarpon</i>												1		1
<i>Cyrtosporiopsis</i>							1							1
<i>Daldinia</i>						1								1
<i>Diaporthe</i>		1	1	2			2						1	7
<i>Didymella</i>							2							2
<i>Diplococcium</i>			2											2
<i>Diplodia</i>	1									1				2
<i>Discula</i>							1							1
<i>Dothiorella</i>	6		2											8
<i>Drechslera</i>												1		1
<i>Drepanopeziza</i>							1							1
<i>Elsinoe</i>							1							1
<i>Epicoccum</i>					1		1							2
<i>Eupenicillium</i>	1													1
<i>Eutiarosporella</i>	1													1
<i>Exserohilum</i>			1											2
<i>Fusarium</i>	1	4	4	4	4		4			2	1	4	1	29
<i>Fusidium</i>			1											1
<i>Geomyces</i>												1		1
<i>Geotrichum</i>			1		1					1				3
<i>Gibberella</i>			2											2
<i>Glomerella</i>			1											1
<i>Gloniopsis</i>													1	1
<i>Guignardia</i>						1				1	1			3

Table 1. Cont.

Fungi Genera	Plant Genera														Tot SF
	AC	AL	BA	BE	CP	CS	CO	HA	JA	LI	LO	NE	RO		
<i>Heliscus</i>				1										1	
<i>Helminthosporium</i>					1		1							2	
<i>Hypoxylon</i>						1								1	
<i>Khuskia</i>			1											1	
<i>Kiflimonium</i>			1											1	
<i>Lasiodiplodia</i>	6	1	1		1					2		1		12	
<i>Lasmenia</i>			2											2	
<i>Lecanicillium</i>							1							1	
<i>Leptosphaerulina</i>							1							1	
<i>Libertella</i>										1				1	
<i>Lophiostoma</i>							1							1	
<i>Microsphaeropsis</i>				1										1	
<i>Moesziomyces</i>	1												1	2	
<i>Myrmecridium</i>			2											2	
<i>Myrothecium</i>				1										3	
<i>Nectria</i>					2									2	
<i>Nemania</i>						1								1	
<i>Neocosmospora</i>		1		1						1				3	
<i>Neofabraea</i>							1							1	
<i>Neofusicoccum</i>	6													6	
<i>Neonectria</i>							2							2	
<i>Nigrospora</i>			4			1	1	1				1		8	
<i>Nodulisporium</i>			2			2								4	
<i>Oblongocollomyces</i>	1													1	
<i>Paecilomyces</i>		2												2	
<i>Papulospora</i>						1								1	
<i>Paraboeremia</i>			1											1	
<i>Paraphaeosphaeria</i>	1			1										2	
<i>Penicillium</i>	2	3	7		3	2	8			1		4		30	
<i>Periconia</i>						1								1	
<i>Peroneutypa</i>										1				1	
<i>Pestalotia</i>	1		1											2	
<i>Pestalotiopsis</i>			2				4			1				7	
<i>Peyronellaea</i>	1													1	
<i>Pezicula</i>								1						1	
<i>Phaeobotryosphaeria</i>	1													1	
<i>Phoma</i>	2		3				1					1		7	
<i>Phomopsis</i>			3	1		2	3			3				12	
<i>Phyllosticta</i>	1		1	1	1		1	1		1	1	1		9	
<i>Phytophthora</i>							1							1	
<i>Pithomyces</i>			1											1	
<i>Pleuroceras</i>							1							1	
<i>Prathoda</i>				1										1	
<i>Preussia</i>	1													1	
<i>Psathyrella</i>							1							1	
<i>Pseudopithomyces</i>			1											1	
<i>Pseudothielavia</i>												1		1	
<i>Puccinia</i>				1										1	
<i>Pycnidiella</i>										1				1	
<i>Rhizopus</i>	1									1				2	
<i>Rosellinia</i>		1												1	
<i>Sarocladium</i>							1							1	
<i>Scedosporium</i>			1											1	
<i>Sclerotinia</i>							1							1	
<i>Scopulariopsis</i>					1									1	
<i>Septoria</i>							1							1	

Table 1. Cont.

Fungi Genera	Plant Genera													Tot SF
	AC	AL	BA	BE	CP	CS	CO	HA	JA	LI	LO	NE	RO	
<i>Simplicillium</i>							1							1
<i>Spegazzinia</i>			2											2
<i>Spencermartinsia</i>	1													1
<i>Sphaeria</i>			1											1
<i>Sporormiella</i>			1											1
<i>Stenella</i>							1							1
<i>Talaromyces</i>			3		2		3							8
<i>Theliovopsis</i>						1								1
<i>Thelonectria</i>							1							1
<i>Torula</i>												1		3
<i>Trichoderma</i>	1	1	2		6		1			2		1		14
<i>Tubakia</i>							2							2
<i>Verticillium</i>		1					1							2
<i>Xylaria</i>	1				2	1	1			2		1		8
<i>Wickerhamomyces</i>	1													1
Tot. SP	51	27	94	29	42	19	78	4	7	29	3	37	6	

2.1. Acacia

The *Acacia*, commonly known as wattle, belongs to the family Mimosaceae. The genus comprises more than 1350 species found throughout the world: almost 1000 are native of Australia, up to 140 species occur in Africa, 89 from Asia, and about 185 species are found in North and South America. Some Australian wattles are naturalized beyond their native range and have become invasive in many parts of Europe, South Africa, and Florida, especially in conservation areas [32]. Aboriginal communities use some *Acacia* species as sources of food and medicine. Australian acacias are widely used as wood products, ornamental plants, commercial cut flowers, and perfume crops [33].

Endophytic occurrence (Table 2) has been reported for 61 fungal isolates belonging to genera *Lasioidiplodia* (7 isolates), *Dothiorella* (8 isolates), *Neofusicoccum* (9 isolates), *Aspergillus* (3 isolates), *Chaetomium* (3 isolates), *Botryosphaeria* (1 isolate), *Colletotrichum* (2 isolates), *Aureobasidium* (2 isolates), *Spencermartinsia* (2 isolates), *Alternaria* (1 isolate), *Cochliobolus* (1 isolate), *Diplodia* (2 isolates), *Eupenicillium* (1 isolate), *Fusarium* (1 isolate), *Moesziomyces* (1 isolate), *Paraphaeosphaeria* (1 isolate), *Penicillium* (2 isolates), *Eutiarosporella* (2 isolates), *Pestalotia* (1 isolate), *Peyronellaea* (1 isolate), *Phaeobotryosphaeria* (1 isolate), *Phoma* (2 isolates), *Phyllosticta* (1 isolate), *Wickerhamomyces* (1 isolate), *Preussia* (1 isolate), *Rhizopus* (1 isolate), *Oblongocollomyces* (1 isolate), *Trichoderma* (1 isolate), and *Xylaria* (1 isolate). Plant host tissues were collected in Egypt, China, India, Australia, South Africa, La Réunion (France), France, USA, and Hawaii.

Table 2. Endophytic fungi isolated from *Acacia* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Phyllosticta</i> sp.	<i>A. amara</i>	leaf	Masinagudi, India	[34]
<i>Xylaria</i> sp.	<i>A. amara</i>	leaf	Masinagudi, India	[34]
<i>Aspergillus niger</i>	<i>A. arabica</i>	leaf	Punjab, India	[35]
<i>Aspergillus</i> sp.	<i>A. auriculaeformis</i>	root	Guangdong, China	[36]
<i>Trichoderma</i> sp.	<i>A. auriculaeformis</i>	root	Guangdong, China	[36]
<i>Aureobasidium pullulans</i>	<i>A. baileyana</i>	phyllode	Melbourne, Australia	[37]
<i>Alternaria</i> sp.	<i>A. decurrens</i>	leaf, stem	Yunnan, China	[38]
<i>Penicillium</i> sp.	<i>A. decurrens</i>	leaf, stem	Yunnan, China	[38]
<i>Peyronellaea</i> sp.	<i>A. decurrens</i>	leaf, stem	Yunnan, China	[38]

Table 2. Cont.

Species	Host Plant	Plant Part	Country	Reference
<i>Phoma</i> sp.	<i>A. decurrens</i>	leaf, stem	Yunnan, China	[38]
<i>Rhizopus</i> sp.	<i>A. decurrens</i>	leaf, stem	Yunnan, China	[38]
<i>Aureobasidium pullulans</i>	<i>A. floribunda</i>	phyllode	Melbourne, Australia	[37]
<i>Chaetomium globosum</i>	<i>A. floribunda</i>	phyllode	Melbourne, Australia	[37]
<i>Dothiorella heterophyllae</i>	<i>A. heterophylla</i>	branch	La Réunion, France	[39]
<i>Dothiorella reunionis</i>	<i>A. heterophylla</i>	branch	La Réunion, France	[39]
<i>Lasiodiplodia iranensis</i>	<i>A. heterophylla</i>	branch	La Réunion, France	[39]
<i>Lasiodiplodia rubropurpurea</i>	<i>A. heterophylla</i>	branch	La Réunion, France	[39]
<i>Neofusicoccum parvum</i>	<i>A. heterophylla</i>	branch	La Réunion, France	[39]
<i>Cochliobolus geniculatus</i>	<i>A. hindsii</i>	leaf	Mexico	[40]
<i>Colletotrichum gloeosporioides</i>	<i>A. hindsii</i>	leaf	Mexico	[40]
<i>Colletotrichum truncatum</i>	<i>A. hindsii</i>	leaf	Mexico	[40]
<i>Eupenicillium javanicum</i>	<i>A. hindsii</i>	leaf	Mexico	[40]
<i>Fusarium oxysporum</i>	<i>A. hindsii</i>	leaf	Mexico	[40]
<i>Moesziomyces bullatus</i>	<i>A. hindsii</i>	leaf	Mexico	[40]
<i>Paraphaeosphaeria</i> sp.	<i>A. hindsii</i>	leaf	Mexico	[40]
<i>Phoma</i> sp.	<i>A. hindsii</i>	leaf	Mexico	[40]
<i>Wickerhamomyces anomalus</i>	<i>A. hindsii</i>	leaf	Mexico	[40]
<i>Botryosphaeria dothidea</i>	<i>A. karroo</i>	branch	South Africa	[41]
<i>Diplodia allocellula</i>	<i>A. karroo</i>	branch	South Africa	[41,42]
<i>Dothiorella brevicollis</i>	<i>A. karroo</i>	branch	South Africa	[41,42]
<i>Dothiorella dulcispiniae</i>	<i>A. karroo</i>	branch	South Africa	[42]
<i>Dothiorella pretoriensis</i>	<i>A. karroo</i>	branch	South Africa	[41,42]
<i>Eutiarospora urbis-rosarum</i>	<i>A. karroo</i>	branch	South Africa	[41,42]
<i>Lasiodiplodia pseudotheobromae</i>	<i>A. karroo</i>	branch	South Africa	[41]
<i>Lasiodiplodia theobromae</i>	<i>A. karroo</i>	branch	South Africa	[41]
<i>Lasiodiplodia gonubiensis</i>	<i>A. karroo</i>	branch	South Africa	[41]
<i>Neofusicoccum kwambonambiense</i>	<i>A. karroo</i>	branch	South Africa	[41]
<i>Neofusicoccum protearum</i>	<i>A. karroo</i>	branch	South Africa	[41]
<i>Neofusicoccum vitifusiforme</i>	<i>A. karroo</i>	branch	South Africa	[41,42]
<i>Neofusicoccum australe</i>	<i>A. karroo</i>	branch	South Africa	[41]
<i>Neofusicoccum parvum</i>	<i>A. karroo</i>	branch	South Africa	[41]
<i>Oblongocollomyces variabilis</i>	<i>A. karroo</i>	branch	South Africa	[41]
<i>Phaeobotryosphaeria variabilis</i>	<i>A. karroo</i>	branch	South Africa	[42]
<i>Spenceriartinsia viticola</i>	<i>A. karroo</i>	branch	South Africa	[41,42]
<i>Dothiorella koae</i>	<i>A. koa</i>	branch	Hawaii, USA	[39]
<i>Lasiodiplodia theobromae</i>	<i>A. koa</i>	branch	Hawaii, USA	[39]
<i>Lasiodiplodia exigua</i>	<i>A. koa</i>	branch	Hawaii, USA	[39]
<i>Neofusicoccum occulatum</i>	<i>A. koa</i>	branch	Hawaii, USA	[39]
<i>Neofusicoccum parvum</i>	<i>A. koa</i>	branch	Hawaii, USA	[39]
<i>Aspergillus ochraceus</i>	<i>A. nilotica</i>	stem	Al-Sharqia, Egypt	[43]
<i>Penicillium</i> sp.	<i>A. nilotica</i>	stem	Al-Sharqia, Egypt	[43]
<i>Pestalotia</i> sp.	<i>A. nilotica</i>	stem	Al-Sharqia, Egypt	[43]
<i>Chaetomium globosum</i>	<i>A. podalyriifolia</i>	phyllode	Melbourne, Australia	[37]
<i>Chaetomium</i> sp.	<i>A. podalyriifolia</i>	phyllode	Melbourne, Australia	[37]
<i>Preussia</i> sp.	<i>A. victoriae</i>	leaf	Arizona, USA	[44]

2.2. Albizia

The genus *Albizia* (Mimosaceae) comprises almost 150 species, mostly trees and shrubs native to tropical and subtropical regions of Asia and Africa. They are common components of timber plantations, cropping, and livestock production systems [45]. *Albizia* synthesizes numerous bioactive compounds with pharmacological properties such as saponins, alkaloids, flavonoids, and phenolics [45]. The species *A. lebeck* has been extensively introduced in seasonally dry tropical regions of Africa, Asia, the Caribbean, and South America, mainly as an ornamental plant, and has become naturalized in many areas [46].

Table 3 reports endophytes isolated from *Albizia* genera. These fungi belong to 14 different genera, most of them found in leaves and twigs of *A. lebeck* originating from Iraq, India, Indonesia, and Egypt. Isolated fungi included different species of *Aspergillus* (9 isolates), which are dominant in comparison to other genera, followed by *Fusarium* (4 isolates), *Penicillium* (3 isolates), and *Paecilomyces* (2 isolates). One isolate for each of the following genera *Neocosmospora*, *Bipolaris*, *Colletotrichum*, *Diaporthe*, *Lasioidiplodia*, *Rosellinia*, *Acremonium*, *Trichoderma*, *Verticillium*, *Curvularia*, and *Nigrospora* has been detected.

Table 3. Endophytic fungi isolated from *Albizia* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Acremonium</i> sp.	<i>A. lebeck</i>	-	Indonesia	[47]
<i>Aspergillus fumigatus</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Aspergillus fumigatus</i>	<i>A. lebeck</i>	leaf	Al-Sharqia, Egypt	[43]
<i>Aspergillus glaucus</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Aspergillus niger</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Aspergillus raperi</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Aspergillus sclerotioniger</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Aspergillus flavus</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Aspergillus</i> sp.	<i>A. lebeck</i>	-	Indonesia	[47]
<i>Aspergillus</i> sp.	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Bipolaris australiensis</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Colletotrichum</i> sp.	<i>A. amara</i>	leaf	Masinagudi, India	[34]
<i>Curvularia cymbopogonis</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Diaporthe</i> sp.	<i>A. amara</i>	leaf	Masinagudi, India	[34]
<i>Fusarium verticilloides</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Fusarium</i> sp.	<i>A. amara</i>	leaf	Masinagudi, India	[34]
<i>Fusarium</i> sp.	<i>A. lebeck</i>	-	Indonesia	[47]
<i>Fusarium oxysporum</i>	<i>A. julibrissin</i>	-	-	[49]
<i>Lasioidiplodia</i> sp.	<i>A. amara</i>	leaf	Masinagudi, India	[34]
<i>Neocosmospora solani</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Paecilomyces variotii</i>	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Paecilomyces</i> sp.	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Paecilomyces</i> sp.	<i>A. lebeck</i>	-	Indonesia	[47]
<i>Penicillium</i> sp.	<i>A. lebeck</i>	leaf	Al-Sharqia, Egypt	[43]
<i>Penicillium</i> sp.	<i>A. lebeck</i>	leaf and twig	Baghdad, Iraq	[48]
<i>Rosellinia sanctae-cruciana</i>	<i>A. lebeck</i>	leaf	Jammu, India	[50]
<i>Trichoderma</i> sp.	<i>A. lebeck</i>	-	Indonesia	[47]
<i>Verticillium</i> sp.	<i>A. lebeck</i>	-	Indonesia	[47]

2.3. Bauhinia

The genus *Bauhinia*, commonly known as the orchid tree, belongs to the family *Fabaceae*. It comprises more than 500 species of shrubs, and small trees mostly native to tropical countries (Africa, Asia, and South America). Many species are widely used as ornamental plants, forage, human food, and in folk medicine [51,52].

A total of 107 fungal endophytes have been found in *Bauhinia* plant tissues (Table 4). The most common fungi reported were: *Aspergillus* (13 isolates), *Curvularia* (8 isolates), *Penicillium* (7 isolates), *Nigrospora* (7 isolates), *Fusarium* (5 isolates), *Phoma* (3 isolates), *Cladosporium* (4 isolates), *Acremonium* (3 isolates), *Colletotrichum* (3 isolates), *Phomopsis* (3 isolates), *Cochliobolus* (3 isolates), and *Exserohilum* (3 isolates). Furthermore, other genera were found less frequently: *Myrothecium* (2 isolates), *Gibberella* (2 isolates), *Lasioidiplodia* (2 isolates), *Khuskia* (1 isolate), *Nodulisporium* (2 isolates), *Pestalotiopsis* (2 isolates), *Alternaria* (2 isolates), *Gibberella* (2 isolates), *Pithomyces* (1 isolate), *Diplococcium* (2 isolates), *Dothiorella* (2 isolates), *Ascotricha* (2 isolates), *Talaromyces* (2 isolates), *Trichoderma* (2 isolates), *Spegazzinia* (2 isolates), *Kiflimonium* (1 isolate), *Geotrichum* (1 isolate), *Corynespora* (1 isolate), *Diaporthe* (1 isolate), *Glomerella* (1 isolate), *Pestalotia* (1 isolate), *Scedosporium* (1 isolate), *Botrytis* (1 isolate), *Sporormiella* (1 isolate), *Phyllosticta* (1 isolate), *Lasmenia* (2 isolates), *Albifimbria* (1 isolate), *Myrmecridium* (2 isolates), *Sphaeria*

(1 isolate), *Paraboeremia* (1 isolate), *Pseudopithomyces* (1 isolate), *Chaetomium* (1 isolate), and *Torulomyces* (1 isolate). All host plants, namely *B. fortificata*, *B. brevipes*, *B. racemosa*, *B. guianensis*, *B. monandra*, *B. malabarica*, *B. phoenicea*, and *B. vahlii*, were from Brazil and India.

Table 4. Endophytic fungi isolated with *Bauhinia* species.

Species	Host Plant	Plant Part	Country	Reference
	<i>B. brevipes</i>	-	Brazil	[53]
<i>Acremonium</i> sp.	<i>B. forficata</i>	-	Brazil	[53]
	<i>B. brevipes</i>	leaf	Pirapitinga, Brazil	[54]
<i>Albifimbriaverrucaria</i>	<i>B. fortificata</i>	stem	Recife, Brazil	[55]
	<i>B. malabarica</i>	stem	Chennai, India	[56]
<i>Alternaria alternata</i>	<i>B. racemosa</i>	leaf	Mudumalai, India	[57]
<i>Ascotricha</i> sp.	<i>B. forficata</i>	-	Brazil	[53]
<i>Ascotricha chartarum</i>	<i>B. fortificata</i>	seed	Recife, Brazil	[55]
	<i>B. forficata</i>	-	Brazil	[53]
<i>Aspergillus</i> sp.	<i>B. monandra</i>	leaf	Recife, Brazil	[58]
	<i>B. guianensis</i>	-	Brazil	[53,59,60]
<i>Aspergillus flavus</i>	<i>B. malabarica</i>	leaf, root	Chennai, India	[56]
	<i>B. fortificata</i>	stem	Recife, Brazil	[55]
<i>Aspergillus niger</i>	<i>B. malabarica</i>	leaf, root, stem	Chennai, India	[56]
	<i>B. racemosa</i>	leaf	Mudumalai, India	[57]
<i>Aspergillus ochraceus</i>	<i>B. fortificata</i>	stem, seed	Recife, Brazil	[55]
<i>Aspergillus tamaritii</i>	<i>B. malabarica</i>	leaf, stem	Chennai, India	[56]
<i>Aspergillus terreus</i>	<i>B. malabarica</i>	leaf, root	Chennai, India	[56]
<i>Aspergillus versicolor</i>	<i>B. vahlii</i>	leaf	Chilkigarh, India	[61]
<i>Botrytis cinerea</i>	<i>B. racemosa</i>	leaf	Mudumalai, India	[57]
<i>Chaetomium globosum</i>	<i>B. malabarica</i>	leaf	Chennai, India	[56]
<i>Cladosporium sphaerospermum</i>	<i>B. fortificata</i>	leaf	Recife, Brazil	[55]
<i>Cladosporium</i> sp.	<i>B. forficata</i>	-	Brazil	[53]
<i>Cladosporium cladosporioides</i>	<i>B. racemosa</i>	leaf	Mudumalai, India	[57]
<i>Cladosporium oxysporum</i>	<i>B. fortificata</i>	sepal	Recife, Brazil	[55]
<i>Cochliobolus</i> sp.	<i>B. forficata</i>	-	Brazil	[53]
<i>Cochliobolus australiensis</i>	<i>B. fortificata</i>	leaf	Recife, Brazil	[55]
<i>Cochliobolus lunatus</i>	<i>B. fortificata</i>	leaf, stem	Recife, Brazil	[55]
<i>Colletotrichum</i> sp.	<i>B. forficata</i>	-	Brazil	[53]
<i>Colletotrichum coccodes</i>	<i>B. guianensis</i>	stem	Belem, Brazil	[62]
<i>Colletotrichum gloeosporioides</i>	<i>B. racemosa</i>	leaf	Mudumalai, India	[57]
<i>Corynespora cassiicola</i>	<i>B. racemosa</i>	leaf	Mudumalai, India	[63]
<i>Curvularia</i> sp.	<i>B. monandra</i>	leaf	Recife, Brazil	[58]
<i>Curvularia brachyspora</i>	<i>B. malabarica</i>	leaf	Chennai, India	[56]
	<i>B. guianensis</i>	stem	Belem, Brazil	[62]
<i>Curvularia clavata</i>	<i>B. phoenicea</i>	leaf	Kudremukh range, India	[64]
	<i>B. malabarica</i>	leaf	Chennai, India	[56]
<i>Curvularia lunata</i>	<i>B. racemosa</i>	leaf	Mudumalai, India	[57]
	<i>B. phoenicea</i>	bark, leaf	Kudremukh range, India	[64]
<i>Curvularia pallescens</i>	<i>B. phoenicea</i>	leaf	Kudremukh range, India	[64]
<i>Diaporthe</i> sp.	<i>B. brevipes</i>	leaf	Pirapitinga, Brazil	[54]
<i>Diplococcium</i> sp.	<i>B. forficata</i>	-	Brazil	[53]
<i>Diplococcium spicatum</i>	<i>B. fortificata</i>	leaf	Recife, Brazil	[55]
		-	Brazil	[53]
<i>Dothiorella</i> sp.	<i>B. brevipes</i>	leaf	Pirapitinga, Brazil	[54]
	<i>B. racemosa</i>	leaf, stem	Sathyamangalam, India	[65]
<i>Exserohilum rostratum</i>	<i>B. guianensis</i>	stem	Belem, Brazil	[62,66]
<i>Fusarium culmorum</i>	<i>B. malabarica</i>	leaf, stem	Chennai, India	[56]

Table 4. Cont.

Species	Host Plant	Plant Part	Country	Reference
<i>Fusarium verticillioides</i>	<i>B. malabarica</i>	root	Chennai, India	[56]
<i>Fusarium oxysporum</i>	<i>B. malabarica</i>	leaf, root, stem	Chennai, India	[56]
<i>Fusarium sp.</i>	<i>B. phoenicea</i>	leaf	Kudremukh range, India	[64]
<i>Fusidium viride</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Geotrichum candidum</i>	<i>B. vahlii</i>	petiole	Chilkiharh, India	[61]
<i>Gibberella fujikuroi</i>	<i>B. vahlii</i>	leaf, petiole	Chilkiharh, India	[61]
<i>Gibberella sp.</i>	<i>B. fortificata</i>	leaf, stem	Recife, Brazil	[55]
<i>Glomerella sp.</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Kliformonium curvulum</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Khuskia sp.</i>	<i>B. forficata</i>	sepal, stem	Recife, Brazil	[55]
<i>Lasiodiplodia theobromae</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Lasmenia sp.</i>	<i>B. racemosa</i>	leaf	Mudumalai, India	[57,63]
<i>Lasmeniabalansae</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Myrmecridium sp.</i>	<i>B. forficata</i>	stem	Recife, Brazil	[55]
<i>Myrmecridium schulzeri</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Nigrospora oryzae</i>	<i>B. forficata</i>	sepal	Recife, Brazil	[55]
<i>Nigrospora sacchari</i>	<i>B. phoenicea</i>	leaf	Kudremukh range, India	[64]
<i>Nigrospora sp.</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Nigrospora sphaerica</i>	<i>B. vahlii</i>	stem	Chilkiharh, India	[61]
<i>Nodulisporium sp.</i>	<i>B. racemosa</i>	leaf, stem	Sathyamangalam, India	[65]
<i>Paraboeremia putaminum</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Penicillium commune</i>	<i>B. forficata</i>	stem	Recife, Brazil	[55]
<i>Penicillium corylophilum</i>	<i>B. forficata</i>	sepal	Recife, Brazil	[55]
<i>Penicillium glabrum</i>	<i>B. forficata</i>	sepal	Recife, Brazil	[55]
<i>Penicillium implicatum</i>	<i>B. forficata</i>	seed	Recife, Brazil	[55]
<i>Penicillium sp.</i>	<i>B. forficata</i>	stem, seed	Recife, Brazil	[55]
<i>Penicillium aurantiogriseum</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Pestalotia sp.</i>	<i>B. monandra</i>	leaf	Recife, Brazil	[58]
<i>Pestalotiopsis sp.</i>	<i>B. forficata</i>	seed	Recife, Brazil	[55]
<i>Phoma sp.</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Phomopsis sp.</i>	<i>B. brevipipes</i>	leaf	Pirapitinga, Brazil	[54]
<i>Phomopsis diachenii</i>	<i>B. brevipipes</i>	-	Brazil	[53]
<i>Phyllosticta capitalensis</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Pithomyces sp.</i>	<i>B. forficata</i>	leaf	Recife, Brazil	[55]
<i>Pseudopithomycesatro-olivaceus</i>	<i>B. forficata</i>	leaf	Recife, Brazil	[55]
<i>Scedosporium apiospermum</i>	<i>B. forficata</i>	seed	Recife, Brazil	[55]
<i>Spegazzinia sp.</i>	<i>B. guianensis</i>	stem	Belem, Brazil	[62]
<i>Spegazzinia tessartha</i>	<i>B. forficata</i>	-	Brazil	[53]
<i>Sphaeria baccata</i>	<i>B. forficata</i>	leaf	Recife, Brazil	[55]
<i>Sporormiella minima</i>	<i>B. forficata</i>	sepal	Recife, Brazil	[55]
<i>Talaromyces sp.</i>	<i>B. racemosa</i>	leaf	Mudumalai, India	[57]
<i>Talaromyces funiculosus</i>	<i>B. forficata</i>	leaf	Brazil	[53]
<i>Torulomyces lagena</i>	<i>B. forficata</i>	leaf	Recife, Brazil	[55]
<i>Trichoderma piluliferum</i>	<i>B. racemosa</i>	leaf	Mudumalai, India	[57]
<i>Trichoderma sp.</i>	<i>B. forficata</i>	stem	Recife, Brazil	[55]
	<i>B. forficata</i>	-	Brazil	[53]

2.4. Berberis

The genus *Berberis* (Berberidaceae) comprises almost 500 species of deciduous or evergreen shrubs, which occur in the temperate and subtropical regions of Europe, Asia, Africa, and America [67]. This genus has remarkable pharmacological properties [68]. Berberine and Berbamine are the main compounds produced by these plants, together with alkaloids, tannins, phenolic compounds, sterols, and triterpenes [69].

Numerous endophytic fungi belonging to 19 genera have been isolated from tissues of *Berberis* from India, China, Kenya, and the USA (Table 5). Isolated fungi included different species of *Fusarium* (4 isolates) and *Colletotrichum* (4 isolates), followed by *Alternaria* (4 isolates), *Anguillospora* (1 isolate), *Phomopsis* (1 isolate), *Campylospora* (1 isolate), *Cercospora* (1 isolate), *Clonostachys* (1 isolate), *Heliscus* (1 isolate), *Diaporthe* (2 isolates), *Microsphaeropsis* (1 isolate), *Phyllosticta* (1 isolate), *Paraphalosphaera* (1 isolate), *Prathoda* (1 isolate), *Bacillispora* (1 isolate), *Neocosmospora* (1 isolate), *Aspergillus* (1 isolate), *Myrothecium* (1 isolate), and *Puccinia* (1 isolate).

Table 5. Endophytic fungi isolated from *Berberis* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Alternaria alternata</i>	<i>B. poiretii</i>	leaf, twig	Beijing, China	[70]
	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Alternaria macrospora</i>	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Alternaria solani</i>	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Anguillospora crassa</i>	<i>Berberis</i> sp.	root	Western Himalaya	[71]
<i>Aspergillus flavus</i>	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Campylospora parvula</i>	<i>Berberis</i> sp.	root	Western Himalaya	[71]
<i>Cercospora citrullina</i>	<i>B. aristata</i>	stem	Sial Sui, District Rajouri, J&K, India	[68]
<i>Clonostachys rosea</i>	<i>B. aristata</i>	root	Sial Sui, District Rajouri, J&K, India	[68]
<i>Colletotrichum coccodes</i>	<i>B. aristata</i>	root	Sial Sui, District Rajouri, J&K, India	[68]
<i>Colletotrichum coffeanum</i>	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Colletotrichum gloeosporioides</i>	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Colletotrichum kahawae</i>	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Bacillispora aquatica</i>	<i>Berberis</i> sp.	root	Western Himalaya	[71]
<i>Diaporthe</i> sp.	<i>B. vulgaris</i>	leaf, stem	Kenya	[72]
<i>Neocosmospora falciformis</i>	<i>B. aristata</i>	root	Sial Sui, District Rajouri, J&K, India	[68]
<i>Fusarium lateritium</i>	<i>B. aristata</i>	stem	Sial Sui, District Rajouri, J&K, India	[68]
<i>Fusarium nematophilum</i>	<i>B. aristata</i>	root	Sial Sui, District Rajouri, J&K, India	[68]
<i>Fusarium oxysporum</i>	<i>B. aristata</i>	stem	Sial Sui, District Rajouri, J&K, India	[68]
<i>Fusarium solani</i>	<i>B. aristata</i>	root	Sial Sui, District Rajouri, J&K, India	[68]
<i>Heliscus lugdunensis</i>	<i>Berberis</i> sp.	root	Western Himalaya	[71]
<i>Microsphaeropsis coniioides</i>	<i>B. poiretii</i>	twig	Beijing, China	[70]
<i>Myrothecium inundatum</i>	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Paraphalosphaera</i> sp.	<i>B. thunbergii</i>	stem	China	[73]
<i>Phomopsis</i> sp.	<i>B. poiretii</i>	twig	Beijing, China	[70]
<i>Diaporthe tersa</i>	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Phyllosticta capitalensis</i>	<i>B. aristata</i>	leaf	Sial Sui, District Rajouri, J&K, India	[68]
<i>Prathoda longissima</i>	<i>Berberis</i> sp.	root	Western Himalaya	[71]
<i>Puccinia graminis</i> f. sp. <i>tritici</i>	<i>B. vulgaris</i>	-	Pacific Northwest USA	[74]

2.5. Caesalpinia

The genus *Caesalpinia* (Fabaceae) includes approximately 200 species, mainly arboreal and shrubby species, distributed in seasonally dry tropical forests, as well as in tropical and warm temperate savannas, tropical wet forests, and tropical coastal habitats [75]. Several classes of compounds, mainly flavonoids, diterpenes, and steroids, have been isolated from *Caesalpinia* species, which have shown various medicinal properties [75]. The most common species cultivated as ornamental plants are *C. pulcherrima* and *C. echinata*.

A total of 44 fungal endophytes were isolated from leaves, stems, and bark of plants collected from India, Brazil, and Indonesia (Table 6). Fungal genera associated with different species of *Caesalpinia* were: *Aspergillus* (10 isolates), followed by *Trichoderma* (6 isolates) and *Fusarium* (4 isolates). Other isolated endophytes have been identified as *Penicillium* (3 isolates), *Curvularia* (2 isolates), *Nectria* (2 isolates), *Bipolaris* (2 isolates), *Xylaria* (2 isolates), and one isolate for the genera *Alternaria*, *Chrysosporium*, *Cladosporium*, *Colletotrichum*, *Epicoccum*, *Geotrichum*, *Helminthosporium*, *Lasiodiplodia*, *Talaromyces*, *Scopulariopsis*, and *Phyllosticta*, respectively.

Table 6. Endophytic fungi isolated from *Caesalpinia* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Alternaria alternata</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Aspergillus flavus</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Aspergillus fumigatus</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Aspergillus niger</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Aspergillus flavus var. oryzae</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Aspergillus rugulosus</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Aspergillus terreus</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Aspergillus</i> sp.	<i>C. pyramidalis</i>	leaf	Brazil	[53]
	<i>C. echinata</i>	leaf	Brazil	[53]
<i>Aspergillus nidulans</i>	<i>C. echinata</i>	stem, bark	Brazil	[77]
	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Bipolaris oryzae</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Bipolaris</i> sp.	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Chrysosporium</i> sp.	<i>C. sappan</i>	stem	Indonesia	[78]
<i>Cladosporium cladosporioides</i>	<i>C. echinata</i>	leaf	Brazil	[79]
<i>Colletotrichum gloeosporioides</i>	<i>C. echinata</i>	leaf	Brazil	[79]
<i>Curvularia lunata</i>	<i>C. sappan</i>	stem	Indonesia	[78]
<i>Curvularia pallescens</i>	<i>C. echinata</i>	leaf	Brazil	[79]
<i>Epicoccum</i> sp.	<i>C. echinata</i>	leaf	Brazil	[53]
		stem	Brazil	[77]
<i>Fusarium</i> sp.	<i>C. echinata</i>	stem, bark	Brazil	[77]
		leaf	India	[76]
<i>Geotrichum candidum</i>	<i>C. sappan</i>	stem	Indonesia	[78]
<i>Helminthosporium</i> sp.	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Lasiodiplodia theobromae</i>	<i>C. echinata</i>	leaf	Brazil	[79]
<i>Nectria</i> sp.	<i>C. echinata</i>	-	Brazil	[53]
<i>Nectria pseudotrachia</i>	<i>C. echinata</i>	stem, bark	Brazil	[77]
		stem		[80]
<i>Penicillium citrinum</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Penicillium chrysogenum</i>	<i>C. pulcherrima</i>	leaf	India	[76]
<i>Penicillium</i> sp.	<i>C. sappan</i>	stem	Indonesia	[78]
<i>Phyllosticta sorghina</i>	<i>C. echinata</i>	stem, bark	Brazil	[77]
<i>Scopulariopsis coprophila</i>	<i>C. echinata</i>	leaf	Brazil	[79]
<i>Talaromyces</i> sp.	<i>C. echinata</i>	stem, bark	Brazil	[77]
		leaf	Brazil	[53]
<i>Trichoderma atroviride</i>	<i>C. pyramidalis</i>	stem, bark	Brazil	[81]
<i>Trichoderma harzianum</i>	<i>C. pyramidalis</i>	stem, bark	Brazil	[81]
<i>Trichoderma koningiopsis</i>	<i>C. pyramidalis</i>	stem, bark	Brazil	[81]
<i>Trichoderma longibrachiatum</i>	<i>C. pyramidalis</i>	stem, bark	Brazil	[81]
<i>Trichoderma virens</i>	<i>C. pyramidalis</i>	stem, bark	Brazil	[81]
<i>Trichoderma</i> sp.	<i>C. sappan</i>	stem	Indonesia	[78]
<i>Xylaria</i> sp.	<i>C. echinata</i>	leaf	Brazil	[53]
<i>Xylaria berteri</i>	<i>C. echinata</i>	stem, bark	Brazil	[77]

2.6. Cassia

The genus *Cassia* (Fabaceae) comprises about 600 species native to tropical and subtropical regions of Southeast Asia, Africa, Northern Australia, and Latin America [82,83]. In particular, *C. fistula* and *C. alata* are distributed worldwide and used as ornamental and medicinal plants for their biological and pharmacological properties [82–84]. Some investigations on phytochemicals of *Cassia* revealed that it comprises compounds like anthraquinones, alkaloids, catechols, flavonoids, phenolic compounds, saponins, steroids, tannins, and triterpenoids [83–86].

Nineteen endophytic fungi have been isolated from different tissues of *Cassia* species from Thailand, India, Malaysia, and Brazil (Table 7): *Aspergillus* (2 isolates), *Nodulisporium* (2 isolates), *Penicillium* (2 isolates), *Phomopsis* (2 isolates), *Daldinia* (1 isolate), *Coprinus* (1 isolate), *Guignardia* (1 isolate), *Hypoxylon* (1 isolate), *Nemania* (1 isolate), *Nigrospora* (1 isolate), *Papulospora* (1 isolate), *Periconia* (1 isolate), *Xylaria* (1 isolate), *Psathyrella* (1 isolate), and *Thielaviopsis* (1 isolate).

Table 7. Endophytic fungi isolated from *Cassia* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Aspergillus flavus</i>	<i>C. siamea</i>	leaf	Malaysia	[87]
<i>Aspergillus</i> sp.	<i>C. fistula</i>	leaf, stem, fruit	India	[88]
<i>Coprinus</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]
<i>Daldinia</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]
<i>Guignardia</i> sp.	<i>C. occidentalis</i>	leaf	Brazil	[53]
<i>Hypoxylon</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]
<i>Nemania</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]
<i>Nigrospora</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]
<i>Nodulisporium</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]
<i>Papulospora</i> sp.	<i>C. fistula</i>	-	-	[90]
<i>Penicillium sclerotiorum</i>	<i>C. fistula</i>	bark	India	[91]
<i>Penicillium</i> sp.	<i>C. fistula</i>	-	India	[92]
<i>Penicillium</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]
<i>Periconia</i> sp.	<i>C. fistula</i>	bark	India	[91]
<i>Phomopsis cassiae</i>	<i>C. spectabilis</i>	-	Brazil	[52]
<i>Phomopsis</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]
<i>Psathyrella</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]
<i>Theliovopsis</i> sp.	<i>C. fistula</i>	leaf	India	[91]
<i>Xylaria</i> sp.	<i>C. fistula</i>	leaf	Bangkok, Thailand	[89]

2.7. Cornus

The genus *Cornus* (Cornaceae) consists of over 50 species of woody plants, many of which are cultivated as ornamental and medicinal trees [93]. The most widespread ornamental plants of the genus are *C. florida* and *C. stolonifera*, called the flowering dogwood, native to northern and central America [93]. The species *C. officinalis* is widely distributed in China, Korea, and Japan, and used for its several pharmacological activities. Among bioactive compounds, iridoids, tannins, and flavonoids are the major components [94].

About 90 fungal endophytes have been isolated and identified from *C. alba*, *C. alternifolia*, *C. stolonifera*, *C. controversa*, and *C. officinalis* collected in Canada, USA, Japan, China, and Korea (Table 8): *Penicillium* (8 isolates), *Fusarium* (4 isolates), *Cladosporium* (5 isolates), *Colletotrichum* (5 isolates), *Alternaria* (6 isolates), *Pestalotiopsis* (5 isolates), *Aureobasidium* (4 isolates), *Botryosphaeria* (3 isolates), *Cryptodiaporthe* (2 isolates), *Phomopsis* (3 isolates), *Talaromyces* (4 isolates), *Aspergillus* (3 isolates), *Discula* (4 isolates), *Diaporthe* (3 isolates), *Neonectria* (2 isolates), *Trichoderma* (2 isolates), *Tubakia* (2 isolates), and *Didymella* (3 isolates). Only one isolate of the following genera has been reported: *Ascochyta*, *Botrytis*, *Cyrtosporiopsis*, *Elsinoe*, *Epicoccum*, *Helminthosporium*, *Lecanicillium*, *Leptosphaerulina*, *Lophiostoma*, *Drepanopeziza*, *Nigrospora*, *Sarocladium*, *Cordyceps*, *Phyllosticta*, *Phytophthora*,

Phoma, *Pleuroceras*, *Thelonectria*, *Sclerotinia*, *Neofabraea*, *Septoria*, *Simplicillium*, *Stenella*, *Verticillium*, and *Xylaria*.

Table 8. Endophytic fungi isolated from *Cornus* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Alternaria alternata</i>	<i>Cornus</i> spp.	leaf	Japan, USA	[95]
<i>Alternaria</i> sp.	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Alternaria tenuissima</i>	<i>C. officinalis</i>	twig, leaf	China	[97]
	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Ascochyta medicaginicola</i>	<i>C. officinalis</i>	twig	China	[97]
<i>Aspergillus flavus</i> var. <i>oryzae</i>	<i>C. alba</i>	leaf	-	[98]
<i>Aspergillus</i> sp.	<i>Cornus</i> spp.	leaf	Japan, USA	[95]
<i>Aureobasidium pullulans</i>	<i>Cornus</i> spp.	leaf	USA	[95]
	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Aureobasidium</i> sp.	<i>Cornus</i> spp.	leaf	Japan, USA	[95]
	<i>C. officinalis</i>	twig, leaf	China	[97]
<i>Botryosphaeria dothidea</i>	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Botryosphaeria</i> sp.	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Botrytis</i> sp.	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Cladosporium cladosporioides</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Cladosporium herbarum</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Cladosporium</i> sp.	<i>C. stolonifera</i>	leaf	Canada	[96]
	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Cladosporium sphaerospermum</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Colletotrichum acutatum</i>	<i>Cornus</i> spp.	leaf	USA, Japan	[95]
	<i>C. officinalis</i>	twig, leaf	China	[97]
<i>Colletotrichum gloeosporioides</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Colletotrichum</i> sp.	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Cordycepsfarinose</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Cryptodiaporthe corni</i>	<i>C. alternifolia</i>	stem	USA	[99]
		bark, phloem	USA	[100]
<i>Cyrtosporiopsis</i> sp.	<i>Cornus</i> spp.	leaf	USA	[95]
<i>Diaporthe amygdali</i>	<i>Cornus</i> spp.	leaf	USA, Japan	[95]
<i>Diaporthe lagerstroemiae</i>	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Didymellapinodella</i>	<i>C. officinalis</i>	twig	China	[97]
<i>Didymella glomerata</i>	<i>Cornus</i> spp.	leaf	USA, Japan	[95]
	<i>Cornus</i> spp.	leaf	USA	[101]
		leaf	USA	[95]
<i>Discula destructiva</i>		leaf	Germany	[102]
	<i>C. florida</i>	leaf	Italy	[103]
<i>Drepanopeziza populi</i>	<i>C. officinalis</i>	twig	China	[97]
<i>Elsinoe fawcettii</i>	<i>Cornus</i> spp.	leaf	USA	[95]
<i>Epicoccum nigrum</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Fusarium lateritium</i>	<i>C. controversa</i>	stem	Korea	[104]
<i>Fusarium oxysporum</i>	<i>C. officinalis</i>	root	China	[97]
	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Fusarium</i> sp.	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Helminthosporium velutinum</i>	<i>C. officinalis</i>	twig	China	[97]
<i>Lecanicillium psalliotae</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Leptosphaerulina australis</i>	<i>C. officinalis</i>	twig	China	[97]
<i>Lophiostoma</i> sp.	<i>Cornus</i> spp.	leaf	USA	[95]
<i>Neofabraea</i> sp.	<i>Cornus</i> spp.	leaf	USA	[95]
<i>Neonectria</i> sp.	<i>Cornus</i> spp.	leaf	USA, Japan	[95]
<i>Nigrospora sphaerica</i>	<i>C. florida</i>	stem	Tennessee, USA	[105]
<i>Penicillium brevicompactum</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Penicillium chrysogenum</i>	<i>Cornus</i> spp.	leaf	USA	[95]
<i>Penicillium citrinum</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Penicillium miczynskii</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Penicillium simplicissimum</i>	<i>Cornus</i> spp.	leaf	USA	[95]
<i>Penicillium</i> sp.	<i>C. stolonifera</i>	leaf	Canada	[96]

Table 8. Cont.

Species	Host Plant	Plant Part	Country	Reference
<i>Penicillium spinulosum</i>	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Penicillium thomii</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Phytophthora palmivora</i>	<i>C. florida</i>	leaf, shoot	USA	[106]
<i>Pestalotiopsis mangiferae</i>	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Pestalotiopsis microspora</i>	<i>Cornus</i> spp.	leaf	USA, Japan	[95]
<i>Pestalotiopsis monochaeta</i>	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Pestalotiopsis</i> sp.	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Phoma moricola</i>	<i>C. officinalis</i>	twig	China	[97]
<i>Phomopsis</i> sp.	<i>C. stolonifera</i>	leaf	Canada	[96]
	<i>Cornus</i> spp.	leaf	USA, Japan	[95]
<i>Phyllosticta fallopiae</i>	<i>C. officinalis</i>	leaf	China	[97]
<i>Phytophthora nicotianae</i>	<i>C. florida</i>	leaf, shoot	USA	[106]
<i>Pleuroceras tenellum</i>	<i>Cornus</i> spp.	leaf	USA	[95]
<i>Sarocladiumkiliense</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Sclerotinia sclerotiorum</i>	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Septoria</i> sp.	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Simplicillium lanosoniveum</i>	<i>C. officinalis</i>	fruit	China	[97]
<i>Stenella</i> sp.	<i>C. stolonifera</i>	leaf	Canada	[96]
<i>Talaromyces assiutensis</i>	<i>C. officinalis</i>	root	China	[97]
<i>Talaromycescecicicola</i>	<i>Cornus</i> spp.	leaf	USA, Japan	[95]
<i>Talaromyces trachyspermus</i>	<i>C. officinalis</i>	root	China	[97]
<i>Thelonectriadiscophora</i>	<i>Cornus</i> spp.	leaf	Japan	[95]
<i>Trichoderma lixii</i>	<i>Cornus</i> spp.	leaf	USA, Japan	[95]
<i>Tubakia</i> sp.	<i>Cornus</i> spp.	leaf	USA, Japan	[95]
<i>Verticillium dahliae</i>	<i>Cornus</i> spp.	leaf	USA	[95]
<i>Xylaria</i> sp.	<i>Cornus</i> spp.	leaf	USA	[95]

2.8. Hamamelis

Hamamelis (Hamamelidaceae), commonly known as witch hazel, comprises six species of ornamental shrubs. This genus is distributed across North America and eastern Asia. Bark extracts contain proanthocyanidins and polyphenolic fractions, with medicinal properties [107,108].

Fungal endophytes belonging to genera *Colletotrichum*, *Nigrospora*, *Pezicula*, and *Phyllosticta* have been isolated from *Hamamelis* plant tissues in the USA, China, Netherlands, Canada, and Japan (Table 9).

Table 9. Endophytic fungi isolated from *Hamamelis* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Colletotrichum acutatum</i>	<i>H. virginiana</i>	leaf	Dutchess Co., USA	[109]
	<i>Hamamelis</i> sp.	leaf	Litchfield, USA	[109]
<i>Nigrospora oryzae</i>	<i>H. mollis</i>	leaf	China	[110]
<i>Pezicula sporulosa</i>	<i>H. mollis</i>	-	Netherlands	[111]
	<i>H. virginiana</i>	-	Canada	[112]
<i>Phyllosticta hamamelidis</i>	<i>H. japonica</i>	leaf	Japan	[113,114]

2.9. Jasminum

The genus *Jasminum* (Oleaceae) includes more than 200 species distributed in China, Africa, Asia, Australia, South Pacific Islands, and Europe. Jasmines are widely cultivated for ornamental, medical, and cosmeceutical uses. The species *J. sambac*, commonly known as Arabian Jasmine, is cultivated throughout India and tropical regions. This genus has been reported for several uses due to the following pharmaceutical activities: antimicrobial [115], antioxidant [116], antidiabetic [117], antiviral [118], and antitumor [119]. Seven species of endophytic fungi of the genus *Colletotrichum* have been reported from *J. sambac* in India and Vietnam (Table 10).

Table 10. Endophytic fungi isolated from *Jasminum* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Colletotrichum dematium</i>	<i>J. sambac</i>	leaf	India	[120]
<i>Colletotrichum truncatum</i>	<i>J. sambac</i>	leaf	Vietnam	[121]
<i>Colletotrichum jasminicola</i>	<i>J. sambac</i>	leaf, shoot	India	[120]
<i>Colletotrichum jasminigenum</i>	<i>J. sambac</i>	leaf	Vietnam	[121]
<i>Colletotrichum jasmini-sambac</i>	<i>J. sambac</i>	leaf	Vietnam	[121]
<i>Colletotrichum siamense</i>	<i>J. sambac</i>	leaf	Vietnam	[121]
<i>Colletotrichum</i> sp.	<i>J. sambac</i>	leaf	Vietnam	[121]

2.10. *Ligustrum*

Ligustrum (Family *Oleaceae*) is a genus of about 50 species of shrubs and trees from warm areas of Europe to Asia [122]. Several species of the genus have been cultivated in many areas of the world as urban ornamental hedge and street trees. In particular, the most widespread species *L. lucidum* compete with and inhibit the regeneration of native flora, becoming invasive in many areas with a subtropical and temperate climate, such as North America, South America, Europe, Asia, Africa, and Oceania [123]. Due to its active constituents such as glycosides, flavonoids, phenylpropanoids, phenylethanoid, and terpenoids, *Ligustrum* spp. have been widely used as a health remedy in European, Chinese, and Japanese communities [124,125].

Collected data showed that 29 species of endophytes belonging to 20 genera have been found in plant tissues of *L. lucidum*, *L. compactum*, *L. quihoui*, *L. obsusifolium*, and *L. vulgare* (Table 11): *Guignardia* (3 isolates), *Alternaria* (2 isolates), *Colletotrichum* (3 isolates), *Fusarium* (2 isolates), *Xylaria* (2 isolates), *Pestalotiopsis* (1 isolate), *Trichoderma* (2 isolates), *Lasiodiplodia* (2 isolates), *Phomopsis* (3 isolates), and one isolate of *Diplodia*, *Geotrichum*, *Libertella*, *Neocosmospora*, *Cladosporium*, *Peroneutypa*, *Penicillium*, *Phyllosticta*, *Pycnidiaella*, and *Rhizopus*, respectively.

Table 11. Endophytic fungi isolated from *Ligustrum* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Alternaria alternata</i>	<i>L. lucidum</i>	leaf, petiole	Buenos Aires, Argentina	[126]
<i>Alternaria cheiranthi</i>	<i>L. lucidum</i>	leaf	Buenos Aires, Argentina	[126]
<i>Cladosporium oxysporum</i>	<i>L. lucidum</i>	leaf	Buenos Aires, Argentina	[126]
<i>Colletotrichum crassipes</i>	<i>L. lucidum</i>	leaf	Buenos Aires, Argentina	[126]
<i>Colletotrichum</i> sp.	<i>L. roxburghii</i>	leaf	Bhavani, India	[34]
<i>Colletotrichum gloeosporioides</i>	<i>L. lucidum</i>	leaf	Buenos Aires, Argentina	[126]
<i>Diplodia mutila</i>	<i>L. lucidum</i>	stem	Buenos Aires, Argentina	[127]
<i>Fusarium oxysporum</i>	<i>L. lucidum</i>	-	Jiangsu, China	[128]
<i>Fusarium lateritium</i>	<i>L. lucidum</i>	stem	Buenos Aires, Argentina	[127]
<i>Geotrichum candidum</i>	<i>L. lucidum</i>	leaf	Buenos Aires, Argentina	[126]
<i>Guignardia mangiferae</i>	<i>L. compactum</i> var. <i>tschonski</i>	leaf	Kyoto, Japan	[129]
	<i>L. quihoui</i>	leaf	Kyoto, Japan	[129]
	<i>L. obsusifolium</i>	leaf	Kyoto, Japan	[129]
<i>Lasiodiplodia theobromae</i>	<i>L. lucidum</i>	stem	Buenos Aires, Argentina	[127]
<i>Lasiodiplodia</i> sp.	<i>L. roxburghii</i>	leaf	Bhavani, India	[34]
<i>Libertella</i> sp.	<i>L. lucidum</i>	branches	Argentina	[130]
<i>Neocosmospora solani</i>	<i>L. lucidum</i>	-	Jiangsu, China	[128]
<i>Peroneutypa scoparia</i>	<i>L. lucidum</i>	branches	Argentina	[130]
<i>Penicillium</i> sp.	<i>L. lucidum</i>	leaf	China	[131]
<i>Pestalotiopsis</i> sp.	<i>L. roxburghii</i>	leaf	India	[132]
			Bhavani, India	[34]
<i>Phomopsis ligustri-vulgaris</i>	<i>L. lucidum</i>	leaf	Buenos Aires, Argentina	[126]
	<i>L. vulgare</i>	leaf	Braunschweig, Germany	[133]
<i>Phomopsis</i> sp.	<i>L. roxburghii</i>	leaf	Bhavani, India	[34]
<i>Phyllosticta</i> sp.	<i>L. roxburghii</i>	leaf	Bhavani, India	[34]

Table 11. Cont.

Species	Host Plant	Plant Part	Country	Reference
<i>Pycnidiaella resiniae</i>	<i>L. lucidum</i>	leaf	Buenos Aires, Argentina	[126]
<i>Rhizopus microsporus</i>	<i>L. lucidum</i>	stem	Buenos Aires, Argentina	[127]
<i>Trichoderma harzianum</i>	<i>L. lucidum</i>	leaf	Buenos Aires, Argentina	[126]
<i>Trichoderma koningii</i>	<i>L. lucidum</i>	stem	Buenos Aires, Argentina	[127]
<i>Xylaria</i> sp.	<i>L. roxburghii</i>	leaf	Bhavani, India	[34]
	<i>L. lucidum</i>	leaf	Buenos Aires, Argentina	[126]

2.11. *Lonicera*

Lonicera (Caprifoliaceae) is a genus that comprises more than 150 species of shrubs and twining climbers, occurring in North America, South Europe, North Africa, Philippines, and Malaysia [134]. *L. japonica* and *L. morrowii*, which are native to Asia, are ornamental species distributed in many areas of the world. In the USA, they are considered invasive plants [135]. Only 3 fungal species have been found to grow as endophytes in *Lonicera* plant tissues (Table 12): *Fusarium* sp., *Phyllosticta* sp., and *Guignardia mangiferae*.

Table 12. Endophytic fungi isolated from *Lonicera* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Fusarium</i> sp.	<i>L. japonica</i>	leaf	Henan, China	[136]
<i>Guignardia mangiferae</i>	<i>L. morrowii</i>	leaf	Kyoto, Japan	[129]
<i>Phyllosticta</i> sp.	<i>L. morrowii</i>	leaf	Kyoto, Japan	[129]

2.12. *Nerium*

N. oleander, commonly called oleander, is the only species currently classified in the genus *Nerium* (Family Apocynaceae). This evergreen shrub is native or naturalized to a wide area, from the Mediterranean region to the Arabian Peninsula and Asia [137]. Several biologically active compounds have been reported in the bark (cardenolides, triterpenoidal saponins, oleanderol, rutin, dambonitol in leaves, odorosides), roots (triterpene, steroidal cardenolide, volatile oil, stearic acid, oleic acid), and flowers (gitoxigenin, uzarigenin, strosposide, odoroside H) [137–140].

Collected data showed that 38 fungi were isolated from leaves, stems, flowers, and roots of plants collected in India and China (Table 13). These isolates belong to the genera, *Fusarium* (4 isolates), *Penicillium* (4 isolates), *Cladosporium* (3 isolates), *Chaetomium* (3 isolates), *Colletotrichum* (3 isolates), *Aspergillus* (3 isolates), *Curvularia* (2 isolates), *Alternaria* (2 isolates), *Cylindrocephalum* (1 isolate), *Lasiodiplodia* (1 isolate), *Torula* (1 isolate), *Phyllosticta* (1 isolate), *Phoma* (1), *Rhizopus* (1 isolate), *Geomyces* (1 isolate), *Pseudothielavia* (1 isolate), *Trichoderma* (1 isolate), *Xylaria* (1 isolate), *Bipolaris* (1 isolate), *Cochliobolus* (1 isolate), and *Drechslera* (1 isolate).

Table 13. Endophytic fungi isolated from *Nerium* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Alternaria brassicicola</i>	<i>N. oleander</i>	stem, flower	India	[141]
<i>Alternaria</i> sp.	<i>N. oleander</i>	leaf	Southern India	[142]
<i>Aspergillus flavus</i>	<i>N. oleander</i>	flower	Chennai, India	[143]
<i>Aspergillus niger</i>	<i>N. oleander</i>	flower	Chennai, India	[143]
<i>Aspergillus</i> sp.	<i>N. oleander</i>	stem, root	China	[144]
<i>Bipolaris</i> sp.	<i>N. oleander</i>	stem, flower	India	[141]
	<i>N. oleander</i>	stem, flower	India	[141]
<i>Chaetomium</i> sp.	<i>N. oleander</i>	stem	Hong Kong, China	[145]
	<i>N. oleander</i>	leaf	Southern India	[142]
	<i>N. oleander</i>	stem	Hong Kong, China	[145]
<i>Cladosporium</i> sp.	<i>N. oleander</i>	stem	India	[141]
	<i>N. oleander</i>	leaf	Southern India	[142]

Table 13. Cont.

Species	Host Plant	Plant Part	Country	Reference
<i>Cochliobolus</i> sp.	<i>N. oleander</i>	stem, flower	India	[141]
	<i>N. oleander</i>	stem	Hong Kong, China	[145]
<i>Colletotrichum</i> sp.	<i>N. oleander</i>	flower	Chennai, India	[143]
	<i>N. oleander</i>	leaf	Southern India	[142]
<i>Curvularia brachyspora</i>	<i>N. oleander</i>	stem, flower	India	[141]
<i>Curvularia</i> sp.	<i>N. oleander</i>	stem, flower	India	[141]
<i>Cylindrocephalum</i> sp.	<i>N. oleander</i>	stem, flower	India	[141]
<i>Drechslera</i> sp.	<i>N. oleander</i>	stem	India	[141]
<i>Fusarium oxysporum</i>	<i>N. oleander</i>	flower	Chennai, India	[143]
<i>Fusarium semitectum</i>	<i>N. oleander</i>	stem, flower	India	[141]
	<i>N. oleander</i>	stem, flower	India	[141]
<i>Fusarium</i> sp.	<i>N. oleander</i>	leaf	Southern India	[142]
<i>Geomyces</i> sp.	<i>N. oleander</i>	stem	China	[144]
<i>Lasioidiplodia theobromae</i>	<i>N. oleander</i>	flower	Chennai, India	[143]
<i>Nigrospora</i> sp.	<i>N. oleander</i>	root	China	[144]
	<i>N. oleander</i>	stem	China	[144]
	<i>N. oleander</i>	stem, flower	India	[141]
<i>Penicillium</i> sp.	<i>N. oleander</i>	root	China	[146]
	<i>N. oleander</i>	leaf	Southern India	[142]
<i>Phoma</i> sp.	<i>N. oleander</i>	stem	Hong Kong, China	[145]
<i>Phyllosticta</i> sp.	<i>N. oleander</i>	leaf	Southern India	[142]
<i>Rhizopus stolonifera</i>	<i>N. oleander</i>	flower	Chennai, India	[143]
<i>Pseudothielavia terricola</i>	<i>N. oleander</i>	stem	India	[141]
<i>Torula</i> sp.	<i>N. oleander</i>	stem	Hong Kong, China	[145]
<i>Trichoderma</i> sp.	<i>N. oleander</i>	stem, root	China	[144]
<i>Xylaria</i> sp.	<i>N. oleander</i>	leaf	Southern India	[142]

2.13. Robinia

Robinia is a genus of flowering plants of the family Fabaceae. *R. pseudoacacia*, called black locust, grows naturally on a wide range of sites. It is considered to be one of the 40 most invasive woody species all over the world [147] and it is included in the invasive alien species list of the EU [148,149]. It is used for many purposes, such as ornamental plant, for shelterbelts, land reclamation, fuelwood, and pulp production [147]. Six species of endophytic fungi were isolated from *R. pseudoacacia* in Germany, Slovakia, Hungary, and China (Table 14).

Table 14. Endophytic fungi isolated from *Robinia* species.

Species	Host Plant	Plant Part	Country	Reference
<i>Beauveria bassiana</i>	<i>R. pseudoacacia</i>	-	Mlyňany, Slovakia	[150]
<i>Diaporthe oncostoma</i>	<i>R. pseudoacacia</i>	stem	Hungary	[151]
<i>Monodictys fluctuata</i>	<i>R. pseudoacacia</i>	-	Germany	[152]
<i>Fusarium</i> sp.	<i>R. pseudoacacia</i>	-	Huaxi district, China	[153]
<i>Gloniopsis</i> sp.	<i>R. pseudoacacia</i>	-	Huaxi district, China	[153]
<i>Clonostachys</i> sp.	<i>R. pseudoacacia</i>	-	Huaxi district, China	[153]

3. An Overview of Fungal Diversity and Frequency

Investigations on the mycobiota of plants frequently reported new taxa or new species distribution, and several fungi are still undiscovered or undetected. Numerous higher plants have developed a variety of resistance mechanisms to prevent fungal infections. However, the presence of weakly pathogenic fungi in healthy plant tissues highlights the evolutionary continuum between latent pathogens and symptomless endophytes [15]. Generally, all plants have symbiotic interactions with fungal endophytes which can influence host performance in terms of disease resistance [154–156], stress tolerance [157], and biomass accumulation [158]. Fungal endophytes may also change according

to plant tissues colonized [159], phenological growth stages, host genotypes [160], and geographical distribution areas [161].

In this review, a total of 428 endophytic species belonging to 122 fungal genera have been found in association with 13 plant genera (Table 1). The greatest level of fungal diversity was reported in association with *Bauhinia* with 43 fungal genera and 94 fungal species, and *Cornus* with 44 fungal genera and 78 fungal species. The degree of fungal recovery from *Acacia* (29 genera, 51 species), *Albizia* (14 genera, 27 species), *Berberis* (17 genera, 29 species), *Caesalpinia* (19 genera, 42 species), *Cassia* (15 genera, 19 species), *Ligustrum* (20 genera, 29 species), and *Nerium* (21 genera, 37 species) was nearly half in comparison to the abundance noted in the genera *Bauhinia* and *Cornus*. Nonetheless, the lowest diversity showed for *Hamamelis* (4 species/genera), *Jasminus* (7 species, 1 genera), *Lonicera* (3 species/genera), and *Robinia* (6 species/genera) was also due to the lack of published research about fungal endophytes in these plant genera.

The literature evidenced that several fungal endophytes live in association with the investigated plants. The most representative genera in terms of abundance of isolated species were *Aspergillus* (40 spp.), *Penicillium* (30), *Fusarium* (29), *Colletotrichum* (27), *Alternaria* (14), and *Cladosporium* (14). These genera include ubiquitous and generalist fungi as well as several plant pathogens and saprobes [162–164].

It is worth noting the relative homogeneity in distribution of fungi such as *Colletotrichum*, *Fusarium*, and *Alternaria* among these plant genera. In fact, *Colletotrichum* was undetected only in *Lonicera* and *Robinia*, *Fusarium* in *Caesalpinia*, and *Hamamelis*, *Jasminus*, and *Alternaria* in *Cassia* and *Lonicera*. Although scarcely abundant, the fungal genus *Phyllosticta* was almost reported for all selected plants except for *Albizia*, *Jasminus*, *Robinia*, and *Hamamelis*. Other endophytic fungi were detected more occasionally. Future surveys may reveal the presence of additional fungal species also from less investigated plants, such as *Robinia*, *Jasminum*, and *Lonicera*.

The presence of pathogenic or saprotrophic fungi has already been discussed by several authors [165,166]. Table 1 shows that several of the listed fungi were apparently restricted to a single plant genus or at least exhibit some preference for a particular one. Some common and ubiquitous pathogens have been recovered in more than one plant host. This is the case of *F. oxysporum* (8 host plant species belonging to 7 different genera), *A. alternata*, *A. niger*, *C. gloeosporioides* (7 host plant species), *N. oryzae* (4 host plant species), *B. dothidea*, *C. globosum*, *C. acutatum* (3 host plant species), *A. ochraceus*, *A. pullulans*, and *C. truncatum* (3 host plant species).

4. The Most Common Plant Pathogens

The most frequent endophytes detected from the investigated plants are cosmopolitan and ubiquitous pathogens that may cause severe yield losses. In detail, *F. oxysporum* is responsible for the wilt of vascular tissues on numerous crops that may result in plant death, even if several strains have proved to be non-pathogenic [167]. It has been isolated from 8 different plant species belonging to 7 genera, namely *A. hindsii*, *A. julibrissin*, *B. malabarica*, *B. phoenicea*, *B. aristata*, *C. officinalis*, *L. lucidum*, and *N. oleander*. The fungus *A. alternata* may infect over 380 host plant species causing leaf spots, rots, and blights. It includes opportunistic forms in developing field crops as well as saprophytic strains that may cause harvest and post-harvest spoilage of harvested products. One of the major concerns represented by its infection is related to the production of mycotoxins that may be introduced in the food chain [168]. In this review, *A. alternata* has been found in association with 3 genera, in 7 plant species (*B. malabarica*, *B. racemosa*, *B. poiretii*, *B. aristata*, *Cornus* sp., *L. lucidum*, and *C. pulcherrima*). The saprophytic pathogen *A. niger* is responsible for the spoilage of a wide range of fruit, vegetable, and food products. It is also the causal agent of the black rot of onion bulbs, the kernel rot of maize, and the black mold rot of cherry [169,170]. It has been found within plant tissues of *A. arabica*, *A. lebeck*, *B. fortificata*, *B. malabarica*, *B. racemosa*, *C. pulcherrima*, and *N. oleander* (7 plant species or 4 genera). Furthermore, three different species of *Colletotrichum* have been isolated from reviewed plants. *C. gloeosporioides* has been isolated from 7 plant species (3 genera), namely *A. hindsii*, *B. racemosa*,

B. aristata, *C. echinata*, *C. officinalis*, *C. stolonifera*, and *L. lucidum*, whereas *C. acutatum* has been found in *Cornus* spp., *Hamamelis* sp., and *H. virginiana* (3 species; 2 genera). Both *Colletotrichum* species may cause severe fruit rot mainly occurring in pre- and post-harvest [171]. Moreover, *C. truncatum*, the causal agent of anthracnose disease affecting several leguminous crops [171], has been collected from 2 plant genera, namely *A. hindsii* and *J. sambac*. Furthermore, *C. lunata*, was isolated from the tissues of 4 plant species (2 genera), including *B. malabarica*, *B. racemosa*, *B. phoenicea*, and *C. sappan*, is the causal agent of seed and seedling blight in several crops, such as rice, millet, sugarcane, and rice, and of maize leaf spot [172]. Besides, *B. dothidea* reported in association with *A. karroo*, *Cornus* sp., and *C. officinalis* may cause cankers, dieback, fruit rot, and blue stain in woody plants, including *Acacia*, *Eucalyptus*, *Vitis*, and *Pistachio* [12]. Concerning the species *F. lateritium*, it has been extensively investigated as the causal agent of chlorotic leaf distortion on sweet potato (*Ipomoea batatas*) in the USA [173]. This fungus has been isolated from three different plant species and genera (*B. aristata*, *C. controversa*, and *L. lucidum*). Moreover, the common soil-borne fungus *G. candidum*, found in association with *B. vahlii*, *C. sappan*, and *L. lucidum*, is the causal agent of sour-rot of tomatoes and citrus fruits, and it is also one of the most economically important post-harvest diseases of citrus [174]. Also, *C. cladosporioides*, detected in *B. racemosa*, *C. echinata*, and *C. stolonifera*, is the causal agent of blossom blight in strawberries [175]. Other pathogenic fungi associated with these selected plants are less widespread and some of them are subjected to containment measures in some countries. This is the case of *N. parvum*, *N. oryzae*, *L. theobromae*, and *D. destructiva*. In particular, *N. parvum*, isolated as an endophyte in three *Acacia* species (*A. heterophylla*, *A. karroo*, and *A. koa*), is one of the most aggressive causal agent of Botryosphaeria dieback on the grapevine and it is known as an aggressive polyphagous pathogen attacking more than 100 plant hosts [176]. Also, *N. oryzae*, reported from *H. mollis*, *B. phoenicea*, *B. racemosa*, and *B. fortificata*, may reduce plant growth and seed quality of rice plants as well as *Brassica* spp., maize, and cotton [177]. Moreover, *L. theobromae*, found in association with six different plant species (*A. karroo*, *A. koa*, *B. racemosa*, *C. echinata*, *L. lucidum*, and *N. oleander*), is the causal agent of dieback, root rot, and blights for a wide range of plant hosts, mainly located in tropical and subtropical regions [178]. Finally, *D. destructiva*, recovered from three different species of *Cornus*, is the causal agent of the dogwood anthracnose, a devastating disease that was firstly documented in the USA and then introduced into Europe [179].

Generally, closely related organisms, including pathogenic fungi as well as those non-pathogenic, may share similar ecological niches and may potentially interact among themselves. Their co-occurrence could be due to phylogenetic evolution or some unclear biological benefits gained [180,181]. The effects of this interaction may lead to a definition of spaces for development and survival. Nevertheless, it is widely known that non-indigenous species represent one of the greatest threats to native biodiversity [11,23–25]. In fact, a fungal invasion into a new ecosystem may change the native endophytic community structure, leading to the extinction of host-specialized fungi [182]. This antagonistic phenomenon is regulated by the production of antifungal compounds, mycoparasitism, or competition for space and resources [180], as well as a synergy of these interactions [181]. Biological invasions may set in motion a long-lasting cascade of effects on the plant host and associated species in unpredictable ways. Generally, the ecological importance of native species prior to the invasion may not be quantified because of the lack of information on fungal communities, especially for non-pathogenic fungal species. As a consequence of global trade and climatic or environmental changes, studies about the impact of new organisms on the ecosystem represent innovative challenges worldwide. In view of these considerations, even if fungal pathogens found in association with investigated plants are widely distributed in the EU [182–190], the risk posed by the introduction of potentially noxious species may be very high. Thus, our results suggest the importance of monitoring imported material to avoid the introduction of such alien species.

5. Emerging and Potential Threats Due to Commercial Trade

Several species reported in this review are Quarantine Pests (QP) or Regulated as Non-Quarantine Pests (RNQP), as defined by containment measures within the importing country [191]. Among the fungal pathogens found in *Cornus* species, *Elsinoe fawcettii* is listed as a QP in the EU, Tunisia, and Israel. This fungus is the causal agent of Citrus scab and it is one of the most important pathogens in many areas of citrus production [192]. *E. fawcettii* is common in South America and its presence has been detected in other areas such as Central and South Africa, India and South-Eastern Asia, and Australia [192].

Furthermore, the following pathogens are RNQP in the EU: *F. verticilloides* (isolated from *B. malabarica* and *A. lebbek*), *C. acutatum* (isolated from *Cornus* spp., *H. virginiana*, and *Hamamelis* sp.), *S. sclerotiorum* (isolated from *C. stolonifera*), and *V. dahliae* (isolated from *Cornus* sp.). Outside the EU, the following species are listed as QP: *L. theobromae* and *P. palmivora* (in Morocco), *A. nidulans*, *A. macrospora*, *C. kahawae*, *C. citrullina*, *C. herbarum*, *C. pallescens*, *A. brassicicola*, *F. semitectum*, *F. verticillioides*, *N. oryzae*, and *P. longissima* (in Mexico), *P. graminis* (Canada and USA), *Diaporthe tersa* (in Israel), *C. acutatum* (in Tunisia and Israel), and *C. gloeosporioides* and *P. capitalensis* (in Egypt) [192].

Organisms that move across continents may or may not become dangerous depending on several factors, and unexpected consequences may occur [193,194]. The current knowledge about the fungal community associated with ornamental plants and their interaction with the environment is fragmentary. Fungi species generally well known as pathogens, are not necessarily pathogenic when isolated as endophytes [6–8]. Genetic mutation can occur in virulent pathogens, transforming the original pathogen into a nonpathogenic strain [9]. Likewise, even though some endophytes are mutualistic, this does not imply that they will not have negative impacts if introduced in a new ecosystem [6,9]. Alien pathogens can often encounter more susceptible host plants and different microbial and abiotic environments without their own ‘natural enemies’. The so-called ‘risk pathway’ defined by international protocols tend to assume that the pathogen will attack a plant host taxonomically similar to that of the susceptible plant species in its native countries. However, an invasive pathogen may spread to new target hosts, when introduced in a new ecosystem, and novel pathogen combinations can occur [11]. The disease outcomes of these combinations may be extremely complex and the invasive pathogen populations can reach explosive distribution levels that are usually difficult to eradicate once established [23–25]. Beyond the damage which may occur on the host plant species and local microbial communities, biological invasions may affect entire ecosystems and the connected ecosystem processes and services, such as soil fertility, fire control, hydrology, and recreation and tourism amenities [23–25]. In response to expanding global trade, several EU regulations [27–29] and international protocols [195,196] are aimed at regulating over-dissemination and accidental introduction of plant diseases. However, despite existing laws and efforts to prevent the introduction of potential pathogens at ports of entry, many of them will evade detection and establish alien populations [197,198]. Many pathogenic fungi may be undetected, transported in the form of inocula as endophytes, propagules, mycelium, or spores of vegetative material. In addition, large import volumes often permit the inspection of only a small proportion of the introduced plants. According to the precautionary principle, all imported plant species should be considered as a potential threat (vectors of fungi), therefore the presence and establishment may not depend on the number of arrivals. As a consequence, even a reduced amount of infected plants, which can easily escape phytosanitary inspections, may cause the introduction and the spread of diseases with devastating outcomes [199]. The development of tools, such as new molecular diagnostics [200] and volatile compounds detection devices [201], that allow the rapid and on-site identification of potentially invasive species and the screening of large volumes of plants, clearly appears to be essential [202]. Despite increasing trade, targeted investment in biosecurity may be effective to reduce pathogen introduction and limit the establishment of alien microorganisms. Thus, we highlight the importance of surveillance due to the potential risk of accidental introductions in the absence of effective biosecurity measures.

6. Conclusions

Globalization has led to intensified movement of people, plants, and plant products, and an increase in the unintentional introduction of non-native fungal species into new ecosystems. Many plant pathogens are biological opportunistic invaders causing several billion dollars in losses to crops, pastures, and forests annually, worldwide. Consideration needs to be given to building resilience in the new environments, from the perspective of pathogen introductions. In particular, the monitoring of plants and plant products, plus early identification-detection of pathogen risks are key steps towards ensuring successful regulation to exclude potential disorders caused by pathogens. This review demonstrated the broad fungal diversity recovered from a small group of ornamental plants that have been relatively unexplored as fungal hosts. Even if the reviewed plant genera are not recognized as sources of significant forest diseases, that have had an ecosystemic impact on a continental scale in the past, we highlight the risk represented by plants as inoculum sources of potentially harmful organisms. Overall, many other species not listed by the EU have represented or may cause important impact in many ecosystemic, environmental, and ecological issues. Our literature search revealed that fungal species may also be introduced through a few hundred plants and invade new ecosystems. In this context, it is important to underline that the amount of imported plant material may not be related to a specific risk, but needs to be considered and evaluated to estimate the negative impacts on agriculture, forestry, and public health, associated with non-indigenous species in European ecosystems. For example, little is known about the effects of invasive species on ecosystem services, although some historic pest invasions (e.g., chestnut blight from North America to Europe) have destroyed host tree species in their locations. The true challenge lies in preventing further damage to natural and managed ecosystems. For this reason, preventative policies need to take into account the means through which pathogens gain access to the EU. The accidental introduction of potentially harmful pathogens also links to other issues of major policy concern (i.e., biotechnology, human health, climate change, etc.) that should be addressed through improved international cooperation and a holistic approach. We should expect that some strategies should be continued or further established to prevent or monitor future introductions, especially at airports, seaports, and other ports of entry, to reduce risks to an acceptable level and preserve natural and agricultural ecosystems.

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