ARTIGOS

Drivers of *Fusarium* dispersion in Madeira Archipelago (Portugal)

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Data de chegada: 01/03/2021. Aceito para publicação em: 09/12/2021

10.1590/0100-5405/249307

ABSTRACT

Camacho, I.; Leça, R.; Sardinha, D.; Fernandez, M.; Camacho, R. Drivers of *Fusarium* dispersion in Madeira Archipelago (Portugal). ***Summa Phytopathologica***, v.48, n.1, p.9-16, 2022.

The present study aimed to analyze the possible routes of *Fusarium* spp. introduction in Madeira between 1990 and 2018 and to elucidate the factors that favored the introduction and settling of this fungus in the Island. Phytosanitary surveys were carried out in several crops and plants imported to Madeira. The isolates of *Fusarium* spp. were obtained from underground and aerial organs of the plants and cultured on differential media for species identification. Fungal colony and spore morphology were observed under a microscope and identified based on bibliography and dichotomous keys. The phytosanitary analysis for the incidence of *Fusarium* spp. in plants or crops indicated an increasing trend in the number of fungi, especially between 1990 and 2001. The greatest fungal contamination occurred in the municipalities located in the southern coast of the Island. Most of the contaminated samples were from Portugal (96.9%), while 0.1% to 1.6% samples derived from foreign countries, especially the Netherlands and France. Of 3,246 samples infected with *Fusarium* spp., 1,212 were from horticultural (37.3%), ornamental (36.9%), tropical and subtropical (16.9%), and temperate plants (9.9%). Fusarium wilt (Panama Disease) caused by *F. oxysporum* f. sp. *cubense* occurred in several products imported to Madeira. Other species like *Fusarium oxysporum* were also detected in several plants and agricultural products, along with *Fusarium* sp. and *Fusarium equiseti*. The geoclimatic conditions of Madeira can be suitable for the development and dispersion of these fungi. The trade of cultivars and plants from Portugal and from foreign countries has been an important route of *Fusarium* introduction in Madeira.

Keywords: *Fusarium*; phytopathogen; phytosanitary control; invasion; Madeira.

RESUMO

Camacho, I.; Leça, R.; Sardinha, D.; Fernandez, M.; Camacho, R. Promotores da dispersão de *Fusarium* no Arquipélago da Madeira (Portugal). ***Summa Phytopathologica***, v.48, n.1, p.9-16, 2022.

O trabalho teve como objetivo analisar as possíveis vias de introdução de *Fusarium* spp. na Madeira entre 1990 e 2018, para elucidar os fatores que favoreceram a sua introdução e fixação na ilha. Realizaram-se análises fitossanitárias em culturas e plantas importadas para a Madeira. Os isolados de *Fusarium* spp. foram obtidos de órgãos subterrâneos e aéreos das plantas e cultivados em meios diferenciais para identificação das espécies. A colônia de fungos e a morfologia dos esporos foram observadas ao microscópio e identificados com o auxílio de bibliografia e chaves dicotómicas. A análise fitossanitária revelou que a incidência de *Fusarium* spp. em plantas ou culturas apresentou uma tendência crescente no número de fungos, principalmente entre 1990 e 2001. A contaminação fúngica mais elevada ocorreu nos municípios localizados no litoral sul da ilha. A maioria das amostras contaminadas proveio de Portugal (96,9%) e 0,1% a 1,6% provieram do exterior, sobretudo da Holanda e França. De 3.246 amostras infectadas com *Fusarium* spp., 1212 eram hortícolas (37,3%), ornamentais (36,9%), tropicais e subtropicais (16,9%) e temperadas (9,9%). Fusarium Wilt (doença do Panamá) causada por *F. oxysporum* f. sp. *cubense* ocorreu em vários produtos importados para a Madeira. Outros como *Fusarium oxysporum* spp. foram detectados em várias plantas e produtos agrícolas, juntamente com *Fusarium* sp. e *Fusarium equiseti*. As condições geoclimáticas da Madeira podem ser adequadas para o desenvolvimento e dispersão destes fungos. O comércio de cultivares e plantas de Portugal e do estrangeiro tem sido uma importante via de introdução do *Fusarium* na Madeira.

Palavras-chave: *Fusarium*; fitopatogénio; controle fitossanitário; invasões; Madeira.

Fusarium species are among the most important soil-borne phytopathogenic fungi worldwide (18). They are common in fertile cultivated and rangeland soils, either as parasites, in association with plant roots, or as saprophytes, showing cosmopolitan distribution (17). Several species constitute important plant pathogens, causing vascular wilts, collar rot, stalk and head rots, while other species are endophytic, leading to symptomless plant tissue infection (12, 14). *Fusarium* also represents a common cause of food spoilage and, together with *Penicillium* and *Aspergillus*, can lead to important stored-grain losses. Some species can produce mycotoxins and are often involved in mycotoxicoses in animals and occasionally in men (12).

Plant infections, caused by *Fusarium* or not, can occur at all developmental stages, from germinating seeds to mature vegetative tissues, depending on the host plant and the species involved (15). Fungal growth and toxin production can be affected by factors such as crop variety, type of species and environmental conditions (21). Representatives of these fungi can be found in most bioclimatic regions of the world, including the tropical and temperate grasslands

(12). Their distribution is influenced by environmental factors, such as rainfall, soil and vegetation type (26), revealing a particular ability to survive at distinct temperature ranges, especially in drought periods (26). In addition, *Fusarium* species show an efficient dispersion mechanism, dispersing spores under wet and hot weather or even under rainy conditions (17).

The genus *Fusarium* currently comprises nearly 300 recognized species occurring worldwide in a diversity of habitats (8, 17); its species identification and classification is commonly based on morphological and cultural characters, fungus-specific region and gene sequencing (9). Macroscopic and microscopic features are key features for *Fusarium* species differentiation (15), which remains a rapid and less expensive technique to validate a primary alarm of foodstuff contamination.

Occurrence of this fungus, causing an array of diseases, has been described for several plant species that have economic importance, namely sweet potato (27), passionfruit (19), cereals (11) and other hosts, like ornamental plants.

In Madeira Island, occurrence of *Fusarium* spores in the atmosphere is common (25), especially before the hottest period of the year (before June), and dispersion is usually favored by humid warm weather and rainfall. Nearly two-thirds of Madeira Archipelago territory are a national park with unique endemic flora and fauna. Its mild subtropical climate enables the coexistence of a noticeable variety of tropical and subtropical plants, representing a suitable substrate for fungal growth and reproduction (1). Notwithstanding, descriptions of *Fusarium* in the Island are scarce. In 1973, an outbreak of fusariosis provoked by *Fusarium oxysporum* sp. *cubense* (Banana *Fusarium* wilt, also known as Panama disease) affected a plantation in Funchal Municipality. The infection affected the banana crop commonly named "Pequena Anã", known until that moment as resistant to the disease. Since then, several infections were observed along the southern coast of the Island (in Câmara de Lobos and Ponta do Sol Municipalities), which varied according to the farming practices and the time of the year (22). In the study published by Moura & Rodrigues (16), infections by *Fusarium* sp., *Fusarium solani* and *Fusarium equiseti* were described in a protea cultivation in Madeira Island, an outbreak that attacked the roots and crown and produced root rot.

Despite the growing body of published research on *Fusarium* invasions worldwide and their impacts on local ecosystems, there are no studies addressing *Fusarium* introductions in Portugal, namely in Madeira region. Therefore, the present study aimed to analyze the possible routes of *Fusarium* spp. introduction in Madeira in the three last decades and to elucidate the factors that favored the introduction and settling of this fungus in the Island.

MATERIALS AND METHODS

Site description

The study took place in Madeira (Portugal), between January 1990 and January 2018, at Agricultural Quality Laboratory (LQA) – "Direção Regional de Agricultura da Madeira" (DRA). Madeira is an archipelago composed of two inhabited islands (Madeira and Porto Santo) and two uninhabited islands that belong to the Natural Park of Madeira ("Desertas" and "Selvagens"). Madeira is a volcanic island, located 900 km south-west from Portugal and 600 km west from the western African coast. Its surface area is 739 km^2 and 58 km by 23 km range. Madeira Island is within the Macaronesian biogeographical region (23) and shows mild temperatures year-round (18.7°C on average), relative humidity varying between 55% and 75%, and rainfall ranging from 500 mm to 1000 mm.

Laboratory analysis

During the study period (1990-2018), phytosanitary surveys were carried out to evaluate the incidence of the phytopathogenic fungus *Fusarium* spp. in different crops and plants, in particular: temperate fruits, tropical and subtropical fruits, and horticultural and ornamental plants.

The analyzed samples consisted of symptomatic and asymptomatic plants from producers in mainland Portugal, autonomous region of the Azores, autonomous region of Madeira, and plants imported from France, Italy, the United Kingdom, Spain, the Netherlands, South Africa, Brazil, Australia and Thailand. Most of the analyzed samples were collected by different DRA Services from farms and cargo terminals at the airport and port.

The standard analysis for *Fusarium* spp. isolates currently performed at LQA-DRA laboratory is described below. *Fusarium* spp. isolates were obtained from tissue fragments of underground and aerial organs of the plants under analysis. After disinfection (10.0% sodium hypochlorite), they were washed in sterile distilled water, dried on filter paper, and placed in Petri dishes with different culture media: Corn Meal Agar (CMA), Corn Meal Agar + Antibiotics (CMA + A), Potato Carrot Agar (PCA), Potato Carrot Agar + Antibiotics (PCA + A) and Potato Dextrose Agar (PDA), followed by incubation at 21.5 ± 3.5°C. In each analysis, a blank test was also performed. Plates were periodically observed for growth. Fungal structures were stained with lactophenol cotton blue for further microscopic examination of spore structures under a binocular magnifying glass (Nikon SMZ-U) and an optical microscope (Nikon Model Eclipse E-600) at 10x, 20x, 40x and 100x magnifications. Species identification involved the use of morphological and cultural characteristics, a procedure broadly adopted in different studies and/or classification schemes of fungi (29). Fungal elements were identified up to genus/species level. Pathogenicity test in the respective host was not carried out with the obtained *Fusarium* isolate.

Statistical analysis

Data were obtained from the samples submitted to LQA for fungal screening; thus, statistical inference may be hindered. The current study describes the evolution of detected *Fusarium* cases, their origin and the affected plant types.

To verify temporal evolution, moving-base indexes were calculated since they reflect the percentage variation in relation to the previous year. The frequency tables show the spatial and temporal evolution of *Fusarium*, as well as its incidence according to the types of colonized plants.

RESULTS AND DISCUSSION

The phytosanitary analysis carried out in Madeira considering the incidence of *Fusarium* spp. in plants or crops showed an increasing trend in the number of fungi between 1990 and 2001 (Figure 1A) and a downward trend thereafter. During the study period, the agricultural area was reduced, and the highest value was found in 1999 (Figure 1B).

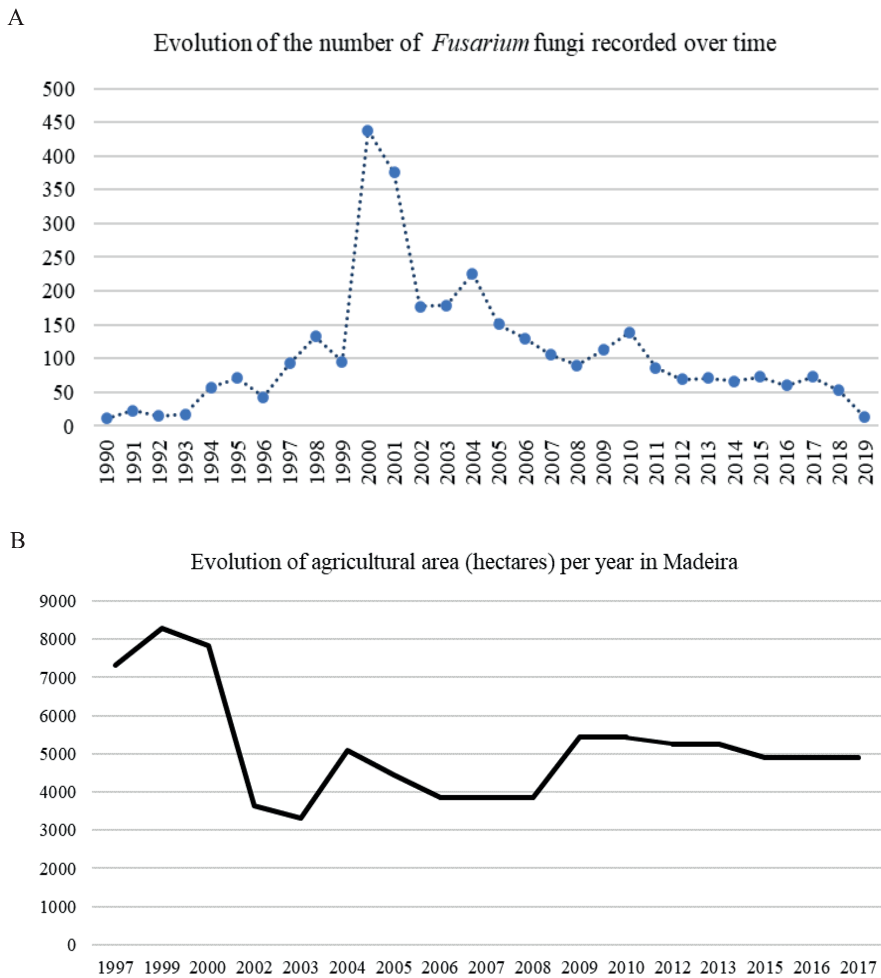

Figure 1. Annual concentration of *Fusarium* **s**pp. infections detected during the study period overall (A) and in Madeira Muncipality (B) (22, 30).

Contaminated samples were mostly from Portugal (96.9%), while 0.1% to 1.6% derived from foreign countries, especially the Netherlands, France and Spain. Among the Portuguese regions, Madeira revealed the highest rate of contaminated samples (91.4%), followed by Porto Santo (4.9%) and Ponta Delgada – Azores (0.3%) (Figure 2). Locally, the largest number of contaminated samples derived from the southern coast of Madeira (Funchal, Santa Cruz, Ponta do Sol and Câmara de Lobos) and from Santana (northern coast), municipalities that have an important agricultural area percentage.

The plants or crops infected by *Fusarium* spp. were obtained from all municipalities in Madeira (Table 1). Most of the observed fungi were detected in samples from Funchal (20.8%) and Ponta do Sol (17.3%), followed by Santa Cruz (14.5%), Santana (13.3%) and Câmara de Lobos (11.2%). Of 3,246 samples infected with *Fusarium* spp., 1,212 were from horticultural plants (37.3%), followed by ornamental plants (38.8%), tropical and subtropical fruit trees (16.9%) and temperate fruit trees (9.9%). Considering the plants imported from the Netherlands, 70.6% infections caused by *Fusarium* spp. occurred in potatoes, and the remaining infections were observed in ornamental plants (Table 2). As regards the contaminated samples derived from France, the fungus was present in temperate fruit trees, showing the highest incidence in vine (17.9%) and apple trees (14.3%).

Analyzing the incidence of fungi among each plant group in Madeira, the municipalities showing higher rates of *Fusarium* spp. contamination were Funchal, Santa Cruz and Ponta do Sol. In vegetables, the infection rate was more pronounced in Santana (66.0%) and Câmara de Lobos (65.6%), whereas in ornamental plants contamination was mostly found in samples from Ponta do Sol (60.4%) and Funchal (41.1%). Infected samples from temperate fruit trees derived particularly from Santana (14.2%) and Funchal (8.9%), while those from tropical and subtropical fruit trees were primarily from Funchal (35.7%) and Ponta do Sol (15.3%). Overall, the vegetables and temperate plants most infected by *Fusarium* spp. were from municipalities in both coasts of Madeira (Table 3), whilst the ornamental plants from Porto Santo Island were particularly affected by the fungus.

Mycological analysis allowed the identification of several fungi of the genus *Fusarium*. The horticultural products and the municipalities presenting the largest number of *Fusarium* infections were Câmara de Lobos and Santana, revealing *Fusarium* sp., *Fusarium equiseti*, *Fusarium moniliforme*, *Fusarium oxysporum*, *Fusarium oxysporum* f. sp. *lycopersici, Fusarium oxysporum* f. sp. *phaseoli* and *Fusarium solani*.

Considering ornamental plants, the most representative municipalities were Funchal and Ponta do Sol, and the most common fungi were: *Fusarium* sp., *Fusarium equiseti, Fusarium moniliforme, Fusarium oxysporum*, *Fusarium oxysporum* f. sp. *dianthi, Fusarium poae, Fusarium roseum, Fusarium roseum* var. *graminearum* and *Fusarium solani.*

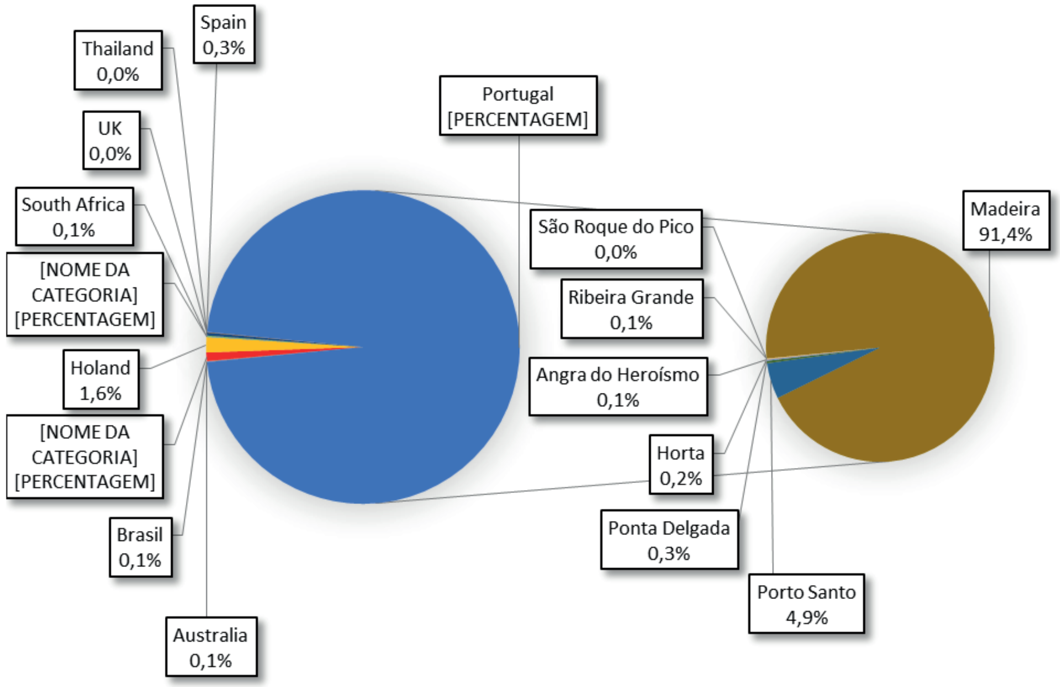

Figure 2. Geographic origin of contaminated samples.

Table 1. Distribution of samples contaminated by ***Fusarium*** spp. among Madeira Municipalities and the corresponding agricultural area (30).

Municipality in Madeira	n (%)	Agricultural area used as ha (%)*
Calheta	221 (7.1%)	516.7 (9.5%)
Câmara de Lobos	349 (11.2%)	710.39 (13.1%)
Funchal	649 (20.8%)	375.61 (6.9%)
Machico	78 (2.5%)	548.46 (10.1%)
Ponta do Sol	541 (17.3%)	423.83 (7.8%)
Porto Moniz	119 (3.8%)	274.95 (5.1%)
Porto Santo	159 (5.1%)	309.34 (5.7%)
Ribeira Brava	87 (2.8%)	466.2 (8.6%)
Santa Cruz	453 (14.5%)	452.7 (8.3%)
Santana	415 (13.3%)	911.4 (16.8%)
São Vicente	54 (1.7%)	438.83 (8.1%)
Total	3125 (100%)	5428.41 (100%)

For temperate fruits in Funchal and Santana, the most frequently identified fungi were: *Fusarium* sp., *Fusarium equiseti*, *Fusarium solani* and *Fusarium avenaceaum.*

As represented in Table 2, the group of tropical and subtropical fruits had Funchal and Ponta do Sol as the most prominent municipalities, and the most frequently identified fungi were: *Fusarium* sp., *Fusarium equiseti, Fusarium moniliforme, Fusarium moniliforme* var. *subglutinans, Fusarium oxysporum*, *Fusarium oxysporum* f. sp. *cubense, Fusarium oxysporum* f. sp. *passiflorae* and *Fusarium solani.*

Fusarium is considered one of the most remarkable genera of fungi, occurring in most bioclimatic regions of the world (28). Madeira Island presents a temperate hyperoceanic submediterranean bioclimate and a mediterranean pluviseasonal oceanic bioclimate on the southern coast (23). The temperate climate of Madeira region, showing mild temperatures and relative humidity levels, can promote the development and spread of common outdoor fungal spores, including these anamorphic fungi (25).

The climatic conditions of Madeira, together with its mountainous relief, allow greatly diverse cultivation. As observed in the present survey, the product varieties are directly related to location and altitude: in lower areas, Mediterranean products are found (figs, vines and cereals). European fruit trees abound in the valleys, producing cherries, apples and plums. Near the seacoast, especially in the southern coast, tropical species prevail (bananas, sugar cane, custard apple and passion fruit). Such geoclimatic conditions are prone to soil-borne phytopathogens, such as *Fusarium*, known for posing serious constraints to plant growth and productivity. Therefore, *Fusarium* species are important pathogens of agricultural plants and livestock (19).

The analyzed samples infected by *Fusarium* consisted of symptomatic and asymptomatic plants and/or horticultural plants from

Table 2. Distribution of contaminated samples according to plant group and country of origin and Madeira Municipalities.

	Horticulture	**Ornamental plants**	**Temperate fruit trees**	**Tropical and subtropical fruit trees**	**Total**
Country of origin	n (%)	n (%)	n (%)	n (%)	n (%)
Australia	0 (0%)	1 (0.1%)	0 (0%)	1 (0.2%)	2 (0.1%)
Brazil	0 (0%)	2 (0.2%)	0 (0%)	0 (0%)	2 (0.1%)
France	0 (0%)	0 (0%)	28 (8.8%)	0 (0%)	28 (0.9%)
Netherlands	36 (3%)	15 (1.3%)	0 (0%)	0 (0%)	51 (1.6%)
Italy	0 (0%)	0 (0%)	2 (0.6%)	0 (0%)	2 (0.1%)
South Africa	0 (0%)	3 (0.3%)	0 (0%)	0 (0%)	3 (0.1%)
Spain	4 (0.3%)	6 (0.5%)	0 (0%)	0 (0%)	10 (0.3%)
Thailand	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)	1 (0%)
UK	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)	1 (0%)
Portugal	1172 (96.7%)	1136 (97.5%)	290 (90.6%)	548 (99.8%)	3146 (96.9%)
Total	1212 (100%)	1165 (100%)	320 (100%)	549 (100%)	3246 (100%)
Municipality in Madeira	Horticulture	Ornamental plants	Temperate fruit trees	Tropical and subtropical fruit trees	Total
	n (%)	n (%)	n (%)	n (%)	n
Calheta	78 (35.3%)	96 (43.4%)	26 (11.8%)	21 (9.5%)	221
Câmara de Lobos	229 (65.6%)	37 (10.6%)	21 (6.0%)	62 (17.8%)	349
Funchal	92 (14.2%)	267 (41.1%)	58 (8.9%)	232 (35.7%)	649
Machico	19 (24.4%)	20 (25.6%)	20 (25.6%)	19 (24.4%)	78
Ponta do Sol	129 (23.8%)	327 (60.4%)	2 (0.4%)	83 (15.3%)	541
Porto Moniz	64 (53.8%)	39 (32.8%)	14 (11.8%)	2 (1.7%)	119
Porto Santo	20 (12.6%)	105 (66.0%)	30 (18.9%)	4 (2.5%)	159
Ribeira Brava	43 (49.4%)	16 (18.4%)	6 (6.9%)	22 (25.3%)	87
Santa Cruz	191 (42.2%)	160 (35.3%)	43 (9.5%)	59 (13.0%)	453
Santana	274 (66.0%)	44 (10.6%)	59 (14.2%)	38 (9.2%)	415
São Vicente	22 (40.7%)	15 (27.8%)	11 (20.4%)	6 (11.1%)	54
Total	1161	1126	290	548	3125

Portugal and several foreign countries. Diverse studies have reported that the trade of live plants is an important route of introduction and spread within countries and continents and that the human-assisted distribution of fungi around the world is the most important pathway of introduction (30). According to Burgess et al. (2), there are hidden microorganisms in seeds, plants themselves, or soil in which the plants were grown, which are largely ignored in the global transportation of plants. The above-mentioned authors stressed that those so-called hitchhikers may be beneficial or detrimental to their hosts, may become naturalized without causing harm, or may negatively affect native plants (6).

For our study period, an increase in agricultural products imported to Madeira was reported. On the other hand, the agricultural area was gradually reduced, especially in 2000-2002 (5). During that period, *Fusarium* infections reached the highest peak in Madeira. In addition, lower production of banana crops was reported in 1999 due to the adverse weather conditions that affected the Island, which can explain the higher importation rates of agricultural products in 2000-2002 (7). According to Lockwood et al. (13), higher levels of imports are therefore likely to increase the probability of introduction of fungi and the propagule pressure, which is an important determinant of invasion success.

Our results are in line with previous studies showing that globalization, especially international trade, is a major driver of biological invasions across taxa and regions (4). Increasing trade volume is probably an important factor contributing to increase the number of alien fungi in the studied region. *Fusarium* introductions in Madeira region, similarly to other fungal introductions worldwide, are considered an unintended consequence of human-mediated movement and trade (6).

Globally, crop losses due to plant diseases caused by such phytopathogens represent a major threat to food security worldwide (10). As a result of several years of introducing crops and plants, it is likely that large numbers of fungi have been introduced in Madeira.

The widespread distribution of *Fusarium* species has been attributed to their ability to grow on a wide range of substrates and to their efficient mechanisms for spore dispersal (19). Likewise, passive spore dispersal cannot be excluded across continents for fungi dispersed by airborne spores. Such dispersal is favored by some fungal features, including their inconspicuousness and production of numerous small propagules (6). Propagule characteristics are related to successful long-distance dispersal since it allows the rapid spread of fungi once they are introduced (20). Similarly to other regions across Europe, the influence of geographical, environmental (climate) and economic factors in

Table 3. Plants or crops more frequently infected by *Fusarium* spp.

	Porto Moniz	São Vicente	Santana	Porto Santo Island
Madeira Municipalities located in the northern coast	Horticulture **(53.8%)**	Horticulture **(40.7%)**	Horticulture **(60.5%)**	Horticulture **(12.6%)**
	Cabbage **(4.2%)**	Cabbage **(4.6%)**	Bean **(7.5%)**	Watermelon **(3.8%)**
	Potato **(38.7%)**	Cucumber **(3.4%)**	Broccoli **(3.1%)**	Ornamental plants **(66%)**
	Ornamental plants **(32.8%)**	Potato **(8%)**	Cabbage **(4.3%)**	Palm of Canary Island **(57.2%)**
	Carnation **(5%)**	Strawberry **(3.4%)**	Cucumber **(5.3%)**	Date Palm **(6.9%)**
	Protea **(25.2%)**	Tomato **(3.4%)**	Potato **(16.4%)**	Temperate fruit trees **(18.9%)**
	Temperate fruit trees **(11.8%)**	Ornamental plants **(27.8%)**	Strawberry **(11.6%)**	Fig **(15.1%)**
	Vine **(10.9%)**	*Protea* **(16.1%)**	Sweet potato **(4.8%)**	Tropical and subtropical fruit trees **(2.5%)**
	Tropical and subtropical fruit trees **(1.7%)**	Temperate fruit trees **(20.4%)**	Tomato **(3.4%)**	Lemon (3.9%)
		Vine **(10.3%)**	Ornamental plants **(9.7%)**	
		Tropical and subtropical fruit trees **(11.1%)**	Temperate fruit trees **(13%)**	
			Apple trees **(1.9%)**	
			Chestnut **(1.7%)**	
			Tropical and subtropical fruit trees **(8.4%)**	

	Calheta	Ponta do Sol	Ribeira Brava	Câmara de Lobos	Funchal	Santa Cruz	Machico
	Horticulture **(35.3%)**	Horticulture **(23.8%)**	Horticulture **(49.4%)**	Horticulture **(65.6%)**	Horticulture **(14.2%)**	Horticulture **(42.2%)**	Horticulture **(24.4%)**
Madeira Municipalities located in the southern coast	Potato **(13.1%)**	Cucumber **(5.2%)**	Cucumber **(17.2%)**	Bean **(7.4%)**	Lettuce **(1.1%)**	Lettuce **(9.7%)**	Potato **(9%)**
	Tomato **(10.9%)**	Tomato **(10.5%)**		Lettuce **(7.4%)**	Tomato **(5.1%)**	Onion **(3.5%)**	Ornamental plants **(25.6%)**
	Ornamental plants **(43.4%)**	Ornamental plants **(60.4%)**	Strawberry **(4.6%)**	Potato **(4.6%)**	Ornamental plants **(41.1%)**	Strawberry **(3.8%)**	*Protea* (9%)
	Carnation **(25.3%)**	Carnation **(20.5%)**	Tomato **(14.9%)**	Strawberry **(4.9%)**	Camellia **(1.8%)**	Tomato **(8.8%)**	Temperate fruit trees (25.6%)
	Protea **(10%)**	Cattleya **(7.8%)**	Ornamental plants **(18.4%)**	Tomato **(27.2%)**	Flamingo flower **(5.1%)**	Ornamental plants **(35.3%)**	Apple trees (5.1%)
	Temperate fruit trees **(11.8%)**	Flamingo flower **(8.7%)**	Carnation **(3.4%)**	Ornamental plants **(10.6%)**	Temperate fruit trees **(8.9%)**	Carnation **(7.5%)**	Vine (14.1%)
	Apple tree **(6.3%)**	Temperate fruit trees **(0.4%)**	*Gerbera* **(4.6%)**	Temperate fruit trees **(6%)**	Tropical and subtropical fruit trees **(35.7%)**	*Cymbidium* **(5.7%)**	Tropical and subtropical fruit trees **(24.4%)**
	Tropical and subtropical fruit trees **(9.5%)**	Tropical and subtropical fruit trees **(15.3%)**	Temperate fruit trees **(6.9%)**	Tropical and subtropical fruit trees **(17.8%)**	Banana plant **(16.5%)**	Protea **(7.7%)**	Avocado (7.7%)
	Banana plant **(6.3%)**	Banana plant **(8.9%)**	Tropical and subtropical fruit trees **(25.3%)**	Banana plant **(13.8%)**	Orange tree **(5.2%)**	Temperate fruit trees **(9.5%)**	Custard Apple (10.3%)
		Papaya **(3.9%)**	Banana plant **(3.4%)**			Chestnut **(3.8%)**	
			Mango **(5.7%)**			Tropical and subtropical fruit trees **(13%)**	
			Orange tree **(8%)**				

Madeira region might be explanatory factors of the distribution and spread of such fungi (13).

The mycological analysis performed in the present study revealed several common *Fusarium* species described in the literature. Banana fusarium wilt (also known as Panama disease) caused by *F. oxysporum* f. sp. *cubense* occurred in several products imported to Madeira. This is the most important fungal species that attacks banana plants in Madeira Island, constituting more than 50% of the fungi identified in this crop (28). Madeira has the major production area at national level considering banana plantations, and monitoring such fungal introductions in the region is very important.

Fusarium oxysporum is a ubiquitous species complex of fungi that includes soil-borne plant pathogenic lineages that are the causal agents of vascular wilt disease in a broad range of plant species, including cotton, tomatoes and vegetables (3).

Fusarium equiseti represented another frequent species in the present survey. It is a cosmopolitan soil inhabitant, common in drier areas and a frequent colonizer of senescent or damaged plant tissue. Although it is not an important plant pathogen, *Fusarium equiseti* has been implicated in a few diseases such as rots of cucurbit fruits in contact with the soil (26). Infected soil and asymptomatic plants are the most probable pathways, easily escaping phytosanitary inspections (13). Notwithstanding, the phytosanitary monitoring carried out by local authorities has been crucial to detect and trace unintentional introduction processes of several phytopathogenic fungi, including *Fusarium* spp. in Madeira.

Finally, the adoption of a rotation system might reduce *Fusarium* wilt incidence and bring economic benefits to local farmers. Moreover, the early detection of outbreaks in small regions like Madeira can succeed with the eradication of host plants, limiting, if possible, the host range.

ACKNOWLEDGMENTS

The authors are grateful to the Agricultural Quality Laboratory – “Direção Regional de Agricultura da Madeira” for all laboratory support.

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