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An Early Bioinvasion in the Azores. Global Circulation and Local Dynamics (1840s–1860s) in Response to the Brown Soft-Scale *Coccus hesperidum*

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Abstract: Bioinvasions occurred in the past as they do in the present, raising a set of ecological, economic, cultural and scientific changes. This paper focuses on how people dealt with and overcame the introduction and spread of the brown soft scale (*Coccus hesperidum*) in the Azorean orange groves in the 1840s–1860s. It describes the difficulties in the detection and the identification of the causal agent, the underestimation of the impacts in the early moments, the slow response and the limitations on methods of control. This is the earliest historical case of a plant pest documented in the Azores archipelago and the first that led to regulations concerning preventive measures and control. Research results are discussed in the framework of the global transfer of living organisms, rethinking Crosby's original model of "Europeanizing" the colonial and overseas territories in the context of the nineteenth century empires. They highlight the relevance of understanding local dynamics, which reconsider the relationship between the center and the periphery.

Keywords: invasion species; Azores islands; 19th century; *Coccus hesperidum*

1. Introduction

Fighting against live organisms that cause great economic and environmental harm to an area outside their natural range, those called invasive species, is a current scientific and management challenge all over the world. The number of introduced species is increasing steadily (Keller et al. 2011), and climate change creates new natural opportunities and worsens problems for society in this dimension as well (Hellmann et al. 2008; Ziska et al. 2011). Attempts to control awful animals and plants are often inadequate and unsuccessful: carelessness and political restraints are the basis of control failures when and where they occur; lack of knowledge and doubtfulness are seen as severe constraints (Caceres-Escobar et al. 2019). The literature about the historical and social perspectives on introductions and invasions has multiplied in the last few decades, demanding interdisciplinarity (Vaz et al. 2017). Not reducing narratives to a good-versus-bad battle, environmental history approaches them by capturing the cultural and natural complexities of the phenomena and revealing how these bioinvasions have unfolded (Lidström et al. 2016; Pooley and Queiroz 2018).

Although the transfer of live organisms through human agency has been happening for a long time, the technological changes of the first decades of the nineteenth century increased the trade of food and agricultural products and the movement of people across borders. Therefore, studies of the consequences of past introductions are part of late modern and contemporary history, mainly from the mid-1800s to the present, with *Oidium tuckeri* (1850s and onward) and the grape phylloxera (1860s and onward) as typical examples.

In the aftermath of the Industrial Revolution, steamships crossing the Atlantic "erase some of the constraints of nature (. . .) annihilate distance, and made economic to produce in higher scales",

carrying goods to faraway territories, which were sold to wealthy buyers (McNeill and McNeill 2003). Due to this rapid form of transportation, the produce arrived there faster and, therefore, remained fairly fresh. The risk of accidental introduction of weeds, pests and diseases rose as a consequence of this traffic, particularly frequent in the Atlantic Ocean.

Located in the middle of the Northern Hemisphere of the Atlantic Ocean, the remote Azores islands were active agents in the maritime circulation in the late modern period. Due to geographical and socioeconomic reasons, the archipelago was a relevant stopover in the trade routes that linked the United Kingdom, some ports of Northern Europe (such as Hamburg), the Iberian Peninsula, the United States of America, Brazil and Spanish America. Ships used these islands to rest and get supplies. This traffic helped the Azoreans in two main ways: it brought manufactured and basic goods, and it helped drain excess agricultural commodities (mainly oranges during this period), leaving fresh currency for other transactions needed by the island's economy.

The archipelago has three groups of islands: the eastern group, Santa Maria (97 km^2) and S. Miguel (747 km^2); the middle group, Terceira (397 km^2), Graciosa (61 km^2), S. Jorge (238 km^2), Pico (447 km^2) and Faial (173 km^2); and the western group, Flores (143 km^2) and Corvo (17 km^2) (Figure 1). During the nineteenth century, the jurisdiction over these Portuguese islands fell to three civil governors (with responsibilities in agriculture) appointed by the Lisbon-based government: (1) one in Ponta Delgada (the main town of S. Miguel), (2) one in Angra do Heroísmo (the main town of Terceira) and (3) one in Horta (the main town of Faial). One port in each group was a relevant stopover for travel and trade.

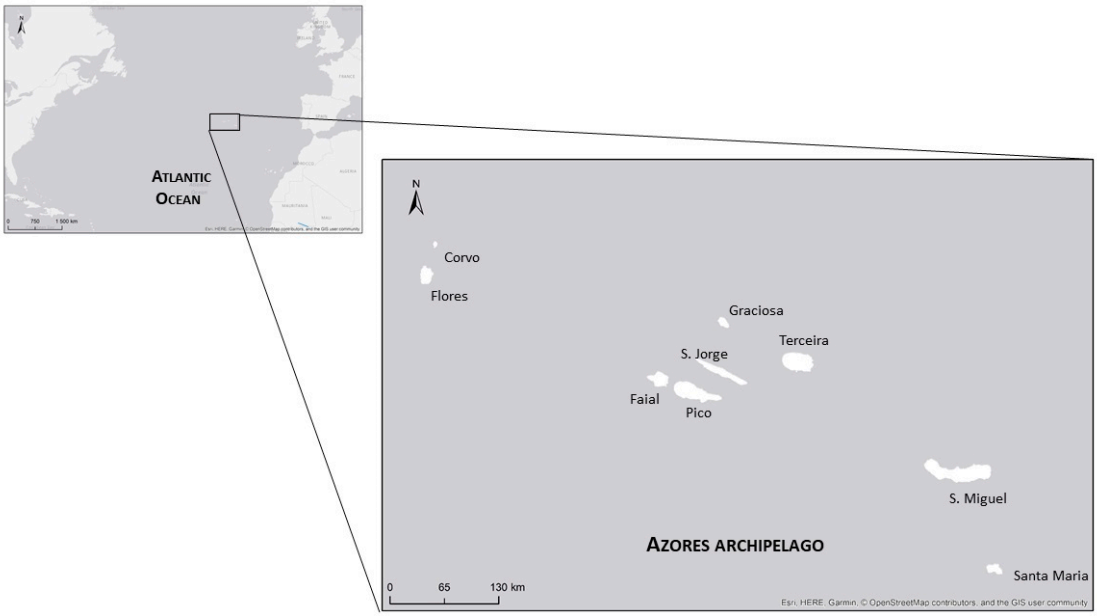

Figure 1. Location and map of the Azores archipelago.

This paper is about the earliest well-documented historical case of bioinvasions of the Azores archipelago: the brown soft scale *Coccus hesperidum* (family Coccidae, order Hemiptera), which invaded orange groves, causing damage from the 1840s to the 1860s. Recently, research was published on the origin, spread and impact of the pest in the archipelago, how the insular and central powers intervened at an early stage of policy development to protect populations against pests and diseases in the context of Portuguese liberalism and how it led to the establishment of a Portuguese national regulation for controlling plant pests (Queiroz and Alves 2019). The severity of the economic losses described by the farmers and the authorities has been discussed in another new publication. It shows disparities between inflated rhetoric and figures of total exports before and after the brown soft scale, explained by changes in land use and commercial opportunities that also occurred during this period (Queiroz and Amorim 2020).

Herein is a different approach focused on how the authorities and farmers dealt with the scientific uncertainties of their time, how the invasion was perceived and what the knowledge on the pest and methods of treatment was. This paper also adds a contribution to the history of bioinvasions in the Atlantic islands and expands on what Alfred W. Crosby wrote about the environmental history of this Macaronesian archipelago. In a founding text of the field of environmental history—*The Columbian Exchange: Biological and Cultural Consequences of 1492* (1972)—he presented how the movement of organisms changed the history of the planet, humans included. In the following decade, he enlarged his analysis of the important role of biology in European expansion from 900 to 1900, introducing the concept of "ecological imperialism". It is still one of the more prolific topics discussed in the study of the interrelationship between humans and nature over time. In Crosby's words, the Azores were first among the biogeographic regions in "ascending order of their degrees of influence on the course of European imperialism" (p. 73, 2nd ed.)[1].

The brown soft- scale is parthenogenetic, and the numerous legions of females are constituted by brown, elliptical and flattened bodies 3.0–5.0 mm long, covered by a shield (Figure 2). It has a long record of damaging citrus trees and, as a result of human dissemination throughout the centuries, it now has a worldwide distribution. It attacks the surface of the plant, with a preference for the top part of the leaves along the midrib. The insect also settles in branches and fruits, using its mouth parts to penetrate the surface layers and to reach the sap vessels, from which it feeds. Not only does it harm the conductive structures and remove part of the fluid, but it also creates areas of frailty that facilitate the attack by other pathogens. The honeydew substance that it secretes is a suitable culture medium conducive to fungi and viruses, and it also attracts ants. The ants, on the other hand, feed off the secretions of the brown soft scales and help them by removing or eliminating their natural enemies. A tree infested with these insects becomes diminished in its ability to produce flowers and fruits.

Figure 2. Female and juvenile brown soft scales (*Coccus hesperidum*) on the underside of a leaf.

The paper is organized into four sections. This introduction is followed by the description of the Azorean land use and the aesthetic and economic relevance of citrus cultivation in the past.

[1] The others are Madeira and the Canary Islands.

The subsequent section approaches (1) the taxonomic doubts about the insect and the naming attempts, (2) the discussions about the origin and character of the pest in light of the ideas of the time and (3) the consequences of these theories on the various preventive and control measures that took place. The last section discusses the research results, recalling some previous historiography about the need to rethink the global model of a "Columbian Exchange" and enlarge the ecological imperialism paradigm with a deeper understanding of its diversified patterns and processes.

2. Materials and Methods

There is extensive documentation on how people handled this unknown insect on the different Azorean islands. This paper explores unpublished documentation deposited in the Portuguese National Archives (ANTT, Lisbon), particularly the correspondence between the civil governors of the Azorean districts and other local institutions and that of the national authorities. Articles published in Azorean newspapers are also important sources since they help us understand the impact of the pest and the theories that civil society disseminated about it at the time. Using the proceedings of sessions where the subject was discussed and in which legislation was adopted, this article also examines the political discourse and opinions about the pests conveyed by the representatives of the mainland and the islands in the national parliament (*Diário da Câmara dos Deputados*, 1845).

3. Results

3.1. Setting the Scene: The Azorean Garden of the Hesperides

The sweet orange, *Citrus sinensis*, arrived in the Azores in the early seventeenth century and gradually replaced the bitter orange, *Citrus aurantium*, which had, for some time, been produced in the archipelago[2]. Both species originated from Asia and, as with others of the same family, spread to the entire world where they could be acclimatized. The historical exploitation of citrus species developed in many different geographies, contributing to the economies of European countries (e.g., Portugal, Spain) as it did to the North American states of Florida and California, Brazil and even India, where the citron (*Citrus medica* L.) was sanctified and consecrated to the elephant-headed Ganesh, god of knowledge and wisdom (Scora 1975). Nowadays, the list of the world's leading citrus fruit producers no longer includes Portugal but China, Brazil, the USA, India, Mexico and Spain (Liu et al. 2012; UNCTAD 2004).

Hesperides, by Giovanni Battista Ferrari (1646), influenced citrus cultivation in Portugal, providing the notion that orange trees belonged not only in groves because of their fruit productivity but also in gardens due to their ornamental character, standing beauty, color and fragrance (Rodrigues 2016). The two-volume standard work on the culture of citrus fruits by Johann Christoph Volkamer (*Nürnbergische Hesperides* (Volkamer 1708); *Continuation* (Volkamer 1714)) had a great impact on the elites of the Western world (Lauterbach 2016), although there is no evidence of its specific influence in the Azores archipelago. Contrarily to the "orangeries" represented in this work—protected environments amenable to the growth of oranges, lemons and other citrus trees built in climatically harsh places like Northern Europe—the Hesperides proved to be well-adapted to the climate of the islands, and their presence there was old. In S. Miguel, an orchard that had already been mentioned by Gaspar Frutuoso in *Saudades da Terra* (1586–1590) and that supplied the town with "China oranges" (a common name that evokes their origin) was still growing during the nineteenth century; in Nabiças (Terceira) ca. 1834, there was an orchard of sweet orange trees that had reportedly been there for over 200 years (Anon 1872; Canto e Castro 1834).

For several decades in the nineteenth century, distinguished visitors passed through the islands, invited by wealthy residents, some of whom were foreign farmers and traders. They recorded their observations regarding the productivity of these trees and the quality of their fruits. John W. Webster

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[2] *Citrus sinensis* and *Citrus aurantium*, the Latin names for the sweet orange and the bitter orange, respectively.

celebrated the beauty and taste of the oranges and lemons and described the splendid estates in S. Miguel, named "*quintas*", with orange plantations surrounded by thick stone walls. He was, however, critical of the ways in which the locals cultivated the trees: "There can be no doubt that, if proper care and attention were paid to them, crops far more abundant than the present might be obtained. No precautions, except occasionally the application of a thin coat of tar, are ever taken to prevent the destructive attacks of insects, and injuries from other causes (Webster 1821)." Fowler described the town and bay of Horta (Faial) as "the most perfect and splendid amphitheatre. The town is built close to the shore, from which it rises to a considerable elevation, interspersed throughout with gardens, orangeries, and other plantations" (Fowler 1831). Further on, the author mentioned the citrus fruits that could be seen in the gardens of farmers and merchants, namely in the Bagatelle mansion, owned by the Dabney family: "[t]he garden, which is most tastefully laid out, displays a rich variety of tropical and European trees and plants;—the orange, lemon, banana, fig, vine, apple, pear, myrtle, geranium, rose, etc. growing luxuriantly together, with flowers of every scent and hue" (Fowler 1831).[3] The Bullar brothers also commented on the "churches, convents, college, villas, and houses [which stood] with conspicuous compactness in ranges one above another, their brilliant whiteness made more striking by the intermixture of the deep green foliage of the orange-gardens, whilst lofty cultivated hills and green mountains [rose] at the back of all" (Bullar and Bullar 1841).

The Azorean orange gardens and groves became a source of livelihood and pride for the delighted sight and taste of the wealthy islanders and a major support for the Azorean economy. In the first decades of the nineteenth century, traders in S. Miguel were mainly foreigners (76% in 1930), but a change occurred thereafter, and the commercial inventory from 1860 shows that a large majority of exporters were then nationals (Dias 1999). The business had grown significantly, triggering the power of a bourgeois elite, with visible long-term consequences in the place (Dias 1995).

Both Europeans and Americans considered the orange a prized product and a delicacy; consequently, its export expanded during the 1840s and 1850s. More than any other fruit, the orange was resistant to transport and long-term storage. With the increase in maritime links in the North Atlantic, more foreign ships made stopovers in the Azores, taking the opportunity to load citrus fruits, which were then resold in other ports. At the same time, in the largest market for oranges (England), the population's purchasing power increased due to the Industrial Revolution. During the golden age of orange exports in S. Miguel, which began in the 1840s (de Miranda 1989), the brown soft scale attacked the orange orchards on the Azores archipelago. Three decades of *Coccus* dissemination began with the first records of the insect on the islands, which date back to 1837 (Faial), 1842 (S. Miguel), 1846 (S. Jorge) and 1850 (Terceira) (Dabney 1843; Anon 1984, 1850).

3.2. What Is and What to Do with the Brown Soft Scale

Recognizing the inability to control the pest, the Royal Academy of Sciences of Lisbon (*Real Academia das Ciências de Lisboa*) decided to award a cash prize to anyone who would write a monograph that established "the description of the disease which destroyed the orange groves of Faial and Pico Islands and which [was] already spreading throughout the mainland, [and to study] its causes, nature and appropriate treatment, indicating preventive measures" (Anon 1848). However, it was difficult to address the unknown *Coccus*, and the few Portuguese naturalists in the academy never answered the call. Conversely, the authorities and local farmers from the islands shared the knowledge they had gathered. The elements of this demand illuminate the following explanatory narrative about their scientific responses to the invasion process.

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[3] The writer refers to the mansion of the American Consuls in Faial: John B. Dabney (1767–1826), Charles W. Dabney (1794–1871) and Samuel Wyllys Dabney (1826–1893).

3.2.1. Pest Identification and Naming

When the pest had already caused much damage in Faial, Nicolau Caetano de Bettencourt, a doctor and public health delegate of Angra do Heroísmo, recognized the pest as an unprecedented insect in the orange groves of the Azores. His first scientific identification resulted from the inspection, with a rudimentary microscope, of an orange tree leaf from Faial, "contaminated and full of this insect's eggs". Although extremely cautious in his diagnosis, the public health delegate made a correct identification of the insect, even using its Latin name: "on an exotic bush, introduced on the Faial island, an insect was developed that I have not yet seen described by zoologists, which [is] quite similar to Linnaeus's *Coccus hesperidum* and belongs to this genus". Bettencourt was unable to immediately solve the insect's specific status, but he was quite categorical as to its genus[4]. However, as a member of the Royal Academy of Sciences (*Real Academia das Ciências de Lisboa*) remarked in a very critical manner, "resemblance is not reality"[5].

The name *Coccus* was, nevertheless, adopted, and it appeared in a variety of documents. When the pest reached S. Miguel (1843), a local doctor placed the pest's classification in the genus *Coccus*, as his colleague had previously done, despite his doubts about "whether or not it [was] the same species or family as the ones from Faial" (Amaral 1843).

Prior to its inclusion in the *Systema Naturae*, the French Academy of Sciences was already displaying the first drawings of the orange tree brown soft scale. This species lived "attached to any foreign plants and mainly to orange trees" (De la Hire and Sedileau [1666] 1869). The insect caused damage to fruticulture: "orange trees, lemon trees and the other trees of this family are equally attacked by these insects whose extensive numbers make the trees sometimes languish and considerably harms their production" (Olivier 1789). In 1818, the British Royal Orchard caretaker reported the damage witnessed: "[a]bout twelve years ago the orange trees in the greenhouse in Kensington gardens were so much infested with a species of *Coccus*, that I was obliged to head them all down, and clean the insects as above directed" (Forsyth 1818). Echoes from other identical situations arrived from Florida (USA) and the island of Cuba (a Spanish colony at the time)[6].

Due to its morphology and behavior, the locals called this organism bark lice (*piolho da casca*), bug (*bicho*), scale insect (*lapa*), cochineal insect (*cochonilha*) and orange tree devourer (*devorista das laranjeiras*). Aphids, brown soft scales and cochineal insects all belong to the same group within the Hemiptera order. However, there are great morphological differences between the first two groups, which are discernible to the naked eye. Curiously enough, when the liberal leaders who won the Portuguese Civil War took key positions in the state (1834–1836), the unhappy sections of the population, who believed their leaders to be abusing their positions to their own advantage, began calling them *devoristas* (Oliveira-Martins 1981). It was from this term that the name "orange tree devourer" emerged.

The American consul in Faial reported the efforts made to fight the pest on this island and explained how, a few years after the first record of the pest's occurrence, the trees began to show a better physical condition (Dabney 1851). While praising the lemon trees, which were full of fruits and entirely free from the bug, C. W. Dabney noted that these were the first victims of the *Aphis*. The Azorean farmers were not very accurate in the denomination of this species, and the authorities reproduced this imprecise information often. Aphids, unlike brown soft scales, clearly display a head, thorax and abdomen, in addition to three very distinctive pairs of legs. The Royal Academy of Sciences

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[4] Nicolau Caetano de Bettencourt, 18 May 1843, Letter from the Health Delegate to the Administrator of the Council of Angra do Heroísmo, ANTT, Ministry of Agriculture, 1st incorporation [hereafter MA 1st], Lisbon.

[5] Francisco Ignacio dos Santos Cruz, 22 January 1844, Opinion of the Royal Academy of Science of Lisbon about the infestation of orange-tree orchards in the Azores, ANTT MA 1st, Lisbon.

[6] José Silvestre Ribeiro, 1 July 1843, Letter from the Civil Governor of Angra do Heroísmo addressed to the Ministry of Finance, ANTT MA 1st, Lisbon.

of Lisbon commented that it was not "(. . .) clear which out of seventy-five species [was] *Aphis* as presented by Linnaeus, as he [did] not mention any that inhabit[ed] the orange trees"[7].

Bark lice (*piolho da casca*) was the vernacular name of an aphid. The term might have been induced from reading foreign bibliographies, namely the report to the legislature "on insects that are harmful to vegetation", where the term was broadly used to refer to Hemiptera (and therefore also to brown soft scales): "[e]arly in the spring the bark lice are found apparently torpid, situated longitudinally in regard to the branch, the head upwards, and sticking by their flattened inferior surface closely to the bark. (. . .) the common species, *Coccus hesperidum*, infesting the myrtle" (Harris 1841). Considering C. W. Dabney's American origin and interest in horticulture, it is likely that he had read this report. It is also possible that he read Harris's answer to Mr. Joseph Breck, published in the *Journal of the Massachusetts Horticultural Society*, of which Dabney was an honorary member in 1836: "[t]here are many kinds of scale-insects and bark-lice, which are injurious to plants. They fasten upon the bark and leaves, and suck out the sup, by means of their short beaks, which are concealed under the fore part of their bodies. The scientific name for such insects is *Coccus*" (Harris 1843).

Official correspondence between the central government and the regional Azorean authorities quoted other technical publications, amongst which were two leaflets from the *Farmer's Encyclopedia* by C. W. Johnson: the leaflet about the "*Coccus*" made reference to the leaflet about the "bark lice" in all aspects concerning the means and methods of control[8].

The identification of the pest was still a relevant subject in 1844, when the pest was proliferating in S. Miguel. In an attempt to identify it as the same organism that had devastated the orange groves in Faial years before, the Society for the Promotion of Agriculture in S. Miguel (*Sociedade para a Promoção da Agricultura Micaelense*)[9] used the name "orange-tree cochineal insect" attached to the Latin term *Coccus hesperidum*: "[w]hat do you demonstrate its identity with?—With the decision of men of science. With the unanimous testimony of all those that just came from that island, with the opinion of all those who had time to observe the insect, an annoying inhabitant of both islands" (Canto 1844). Right before adopting legislation for the control of this pest, the House of Representatives discussed the doubts surrounding the denomination of this species. In fact, those who believed the insect should not be fought were using this uncertainty regarding its name as an argument. Others found this question irrelevant: "whether it is *coccus hesperidum* or *orange-tree devourer*, a matter concerning the name. I ask this: because we do not know what the actual name of the bug is, should we not tackle its destruction? I believe so. (*yea*)[10]." Finally, a legal text was approved and published on 13 February 1845.

By 1850, this issue was still very much alive. Although the brown soft scale had no similarity with "the *coccus* by Linnaeus, *vide* Dictionary of the technical terms of Natural History, extracted from the works of this wise naturalist", many believed that tackling the pest was more important than naming it, which was in itself a difficult task considering its characteristics: "amazing propagation, extremely small size, and its univalve crustacean casing peripherally attached to the vegetable" (Torres 1850).

From that time on, entomologists renamed this species *Eulecanium hesperidum* and *Lecanium hesperidum*, terms that are nowadays synonyms of the currently used *Coccus hesperidum* (e.g., in the Centre for Agriculture and Bioscience International (CABI) Plantwise Knowledge Bank and European and Mediterranean Plant Protection Organization (EPPO) Global Database).

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[7] Francisco Ignacio dos Santos Cruz, 22 January 1844.

[8] J.J. Castro, 4 July 1844, Letter from the secretary of the Ministry of the Kingdom to the Civil Governor of Ponta Delgada, ANTT MA 1st, Lisbon; these leaflets were later compiled into a single book: (Johnson 1858).

[9] It was created in 1843 to combat the backwardness of agriculture on the island. Its newspaper, named *O Agricultor Michaelense*, was one of the most influential vehicles for disseminating knowledge during the period of the invasion of *Coccus hesperidum*.

[10] *Diário da Câmara dos Deputados*, 29 January 1845, p. 6.

3.2.2. Origin of the Pest

During the spread period, an introduction from the outside was doubtful. Many locals supported the hypothesis of a spontaneous origin, which would later on be the cause of subsequent cases of plant pests from other unknown organisms (e.g., the cottony cushion scale *Icerya purchasi* in California (Sackman 2005)). Nevertheless, when the pest was detected in S. Miguel (1842), the islanders considered both its spontaneous generation and its introduction from the outside. A few lemon trees brought to the island five years before from Faial seemed to have been the source of one of the outbreaks. However, the neighboring farm, which contained lemon trees from the same source, showed no signs of infestation. Furthermore, the organism was present in other places that had not received any trees from outside sources. Written records stated, "[i]n some English papers we read that before 1820 the *Coccus hesperidum* was unknown in England. Twenty years later we have seen it in the Azores. Has it been imported with infested commodities or was it spontaneous? Even nowadays this is unknown" (Amaral 1843). Meanwhile, an eminent Portuguese naturalist advised the Azoreans not to "waste their time investigating whether the insect came from America or not" and instead to care for their trees[11].

From the mid-eighteenth century to the mid-nineteenth century, the most prestigious European naturalists stood out with theories about the spontaneous generation of living organisms (Strick 2000). Following the theory of "archebiosis", living things could supposedly appear from inorganic starting materials. Many scientists from the Christian cultures of Western Europe opposed these ideas since they opened up the possibility of a universe without a Creator God. French naturalists Buffon (1707–1788), Lamarck (1744–1829) and Geoffroy de Saint-Hilaire considered that "heterogeneity" offered a better explanation for the appearance of new species: parts of preexisting species, in particular conditions, could combine in order to create a different organism that would still be somehow similar to that which had been at its origin. The theory of evolution by natural selection, which opposed this, arose at the end of the 1850s, but it only arrived in the Azores three decades after the *Coccus* outbreak (Arruda 2005).

In addition, those who defended the spontaneous generation theory had a social advantage since the theory did not blame anyone for the disaster of the orange groves. A sector of the Azorean society seemed to fear linking any of the leading traders of the islands to the introduction of the insect, namely the American consul in Faial. Nevertheless, Bettencourt and, later on, Torres (1850) identified Charles W. Dabney as the importer of the introduction vectors[12]. All the transactions of goods and products from abroad were made through his business. In fact, the passion he felt for gardening and horticulture makes it plausible for him to have promoted the importation of live specimens of various plants to diversify his collection and those of his neighbors, plants which probably carried some specimens of this devastating insect. Contrary to what the Latin name suggests (*hesperidum* evokes the citrus tree), this *Coccus* species has an impact on trees, shrubs and herbs from different botanical families. For that reason, besides the lemon trees previously mentioned, other plant species might have also been the vector. The letters exchanged between Dabney's relatives and from them to foreign correspondents mentioned the circulation of plants (live parts and seeds) to and from the Azores. For example, in a letter from 1832, Frances A. Dabney mentioned the cargo assigned to a servant who accompanied her on her transatlantic voyage: "*Grilo* has charged of (sic) some pineapple plants in a box for you, part of which came from Trinidad" (Dabney n.d.).

José Silvestre Ribeiro, the civil governor of Angra do Heroísmo, referred to those who did not believe in the introduction of this species with a touch of irony: "[s]ome people believe in the insect's spontaneous origin, as a result of much vigour, warming up and manure"[13]. He centered his argument

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[11] Viscount of Vilarinho de São Romão, 3 January 1844, Opinion of the Royal Academy of Science of Lisbon about the infestation of orange-tree orchards in the Azores, ANTT MA 1st, Lisbon.
[12] Nicolau Caetano de Bettencourt, 18 May 1843.
[13] José Silvestre Ribeiro, 12 October 1843, Letter from the Civil Governor of Angra de Heroísmo addressed to the Ministry of the Kingdom, ANTT MA 1st, Lisbon.

on the pest's dispersal potential through transatlantic trade, fearing damage on Terceira Island similar to or worse than that occurring on Faial.

In subsequent years, other possibilities of geographic origin based on different trading partners but with identical vectors emerged. In addition to the United States, some records favored a Brazilian origin. In 1852, a report from an "intelligent man" sent from Angra do Heroísmo to the Ministry of Agriculture read, "[the insect] seems to have first been imported into Faial via some plants from America, and then from that island to São Miguel. But on Terceira Island, one constantly hears that [the insect] came from Brazil on some orange trees that were brought from there" (Bettencourt 1854).

3.2.3. Cause or Effect?

Part of the scientific community still considered that an unknown cause had been attracting the insect and that a previous general weakness of the orange trees had potentiated its spread. Naturalists attributed this feebleness to "atmospheric changes" since "the part of the affected trees is always the most exposed to the influence of the atmosphere", hence "the impossibility of knowing completely the nature of the diseases, as well as the curative and preservative therapeutics" (Viana 1855). These ideas were rooted in the classical miasmatic theory, first formulated by Hippocrates (ca. 460–377 B.C.E.), who believed that bad air was pestilence, and later expanded upon by Galen (ca. 130–201 C.E.), who traced individual susceptibility to the balance of humors in the body. During the Middle Ages, it focused on explaining contagion and why some contracted the plague while others did not, and in the mid-nineteenth century, it was used to explain numerous human diseases, including tuberculosis, malaria and cholera (Sterner 2007). Corresponding to the Zallingerian period of the history of phytopathology, when the most striking phytopathologic publication was *De morbis plantarum* (1773) by Johann Baptista Zallinger, "the cause of the diseases in plants was generally attributed to occult influences or to the effects of the elements, especially unfavorable soil, winds, low temperatures, and the like" (Whetzel 1918). In the 1840s and 1850s in the Azores, local educated farmers were still considering this physiological thesis about the origin of the plant pest (i.e., its result from insufficient climate, soil and fertilization)[14]. Most of the people who inhabited the islands were resistant to the idea that "[the] accidents caused by *Coccus* [were] primarily a kind of subsidence of the tree where the insect exist[ed], and then a real apathy which almost always [led] to the death of the plant"[15].

Each of these hypotheses, the insect being directly responsible for the disease or the disease being a consequence of a particular weakness of the orange trees that had then attracted the insect, required a different delineation of the problem's mitigation strategies. Those who thought the infestation was a result of a previous morbidity prioritized the recovery of the normal vitality of the trees and believed that the elimination of adult specimens and laid eggs was secondary. Thus, the control measures were not aimed at the insect. On the other hand, if the biological agent was responsible, people had to eliminate it by any means possible. This perspective also justified the need to take preventive measures to contain the spread, such as those implemented by the civil governor in 1843 and further imposed by the authorities of Angra do Heroísmo to "prohibit the introduction of plants, shrubs, firewood, and fruits coming from Faial (. . .) to prevent the introduction of such an insect"[16].

In 1844, the Royal Academy of Sciences stated that the orange trees on the islands were weak and sick because they resulted from successive generations of vegetative propagation and grafting[17]. The trees that were to be used in new orange groves should come from plants germinated from seeds instead of cuttings from affected orange trees. The great influence this institution exercised in the circles of power reinforced the doubts about the plant pest and weakened the control and containment policies, namely the ban on imports from contaminated regions in the ports of the

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[14] These ideas were only surpassed by the germ theory developed by Louis Pasteur in the 1860s and Robert Koch in the 1870s.
[15] Nicolau Anastácio de Bettencourt, *Boletim do MOPCI* 4 (April 1854): Appendix.
[16] José Silvestre Ribeiro, 1 July 1843.
[17] Viscount of Vilarinho de São Romão, 3 January 1844.

mainland, which had been requested by landowners and orange farmers from the region of Lisbon[18]. The Azorean "gentlefarmers" recommended pruning and cutting, in accordance with the procedures suggested by Mr. Forsyth, the orchard caretaker of the British king George IV: "pedicle insects flee cleanliness and light" (Amaral 1851).

Throughout the 1840s and 1850s, the insect became the enemy, and the Azorean farmers devoted their efforts to the testing of new recovery attempts. On the island of S. Miguel, after the pruning of the affected branches and leaves, a local newspaper published Forsyth's method to treat the infected trees, which advised the farmers to rub the areas that had been cut with a "mixture of equal parts of urine and soapy water" and to seal them with "patches of Saint Fiacre" (mud and dung) or with the "Forsyth ointment" (dung, lime or gypsum, ash and fine sand); "[the] ointment (. . .) would only begin to loosen with the rains of the following winter, with the trunk then looking green and healthy" (Forsyth 1843 and Anon 1849). Organized services, created to treat the affected orange trees from 1844 to 1849 in Ponta Delgada, carried out these treatments, which did not destroy the insects but instead reinvigorated the trees; however, the results were widely unsuccessful (Correia 1849). Progressively, the population recognized the insect as the true cause of crop losses. As such, a series of disputes among the Azorean society over the best and most effective formulas and treatments to wipe out the *Coccus* began. Farmers continued to test other recipes based on the combination of oil and other products. Some of the local farmers had already suggested recipes named "oily-alkali-vegetable fluid", which were incidentally not new (Torres 1850; Dabney 1844). They were made by mixing oil and alkaline substances and seemed effective, as the oil decreased the insects' adhesion to the plant structures, and the alkaline substances were toxic to the insect. Islanders used whale oil extracted from their killings in the surrounding sea or from whales occasionally found dead on the beaches. Coincidentally, the Japanese were also using whale oil on rice crops as an insecticide during the same period (Arch 2015), as were American farmers: "A solution of whale oil soap, in the proportion of two pounds of soap to fifteen gallons of water, is recommended as the best known means of destroying plant-lice, and other insects injurious to plants, flowers and fruits. It was first made known by Mr. Haggerston of Boston, who designed it originally for the destruction of the rose slug and received a premium of $125 from the Massachusetts Horticultural Society for his discovery" (UBJFE 1858).

These co-occurrences might have been a result of the extended network of scientific knowledge of the time. The Azorean *gentlefarmers*, part of whom were English speakers by birth or scholarship, belonged to it. Yet, each recipe was presented as a completely new discovery. The availability of whale oil in these places contributed to its specific use. However, on Terceira Island in 1852, due to the evident inefficiency of the treatments, many believed that the application of a linseed-oil-based varnish could achieve better results[19].

The oily substances made the brown soft scales lose their adhesion to the shell and their grip on trunks, branches and leaves. Fifty years later, after testing other methods such as gassing and spraying different nongreasy washes (e.g., distillate, resin wash and kerosene emulsion), the US *Farmers' Bulletin* stated, "The oily washes are by far the best for use on citrus trees against scale insects" (Marlatt 1903).

4. Discussion

The infestation of the Azorean orange groves occurred four centuries after the Portuguese colonized this unpopulated Atlantic archipelago. A long history of environmental changes has already been made, namely to the Macaronesian native forest of endemic laurels, to create a widespread agrarian landscape where it happened (Triantis et al. 2010). Although the episode resulted from the commerce and agricultural transformations conducted by Portuguese administrations in their

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[18] Count of Farrobo and others, n/d (presumably 1843) Letter addressed to Queen Maria II, archived at the Civil Government of Lisbon, ANTT MA 1st, Lisbon.

[19] Nicolau Anastácio de Bettencourt, *Boletim do MOPCI* 4 (April 1854): Appendix.

overseas territories, it cannot be simply described or explained as a phenomenon of "Europeanization", implying movements in one sole direction from the Old World to the New World (Crosby 2004). First, the orange trees had an Asian origin, and the Portuguese, among others, had extensively traded their fruits through the maritime routes. Second, the nonnative pest impacted nonnative agricultural production and garden plants in worldwide circulation. To Crosby's Green Imperialism paradigm, it updates and diversifies the list of episodes of successes and failures in ecological mastery of nature, giving relevance to small-scale dynamics in reframing the original model and its narratives about the center and periphery.

The Azores being politically dependent on a power settled far away in mainland Europe, the biogeographic and cultural isolation and the remoteness of the Azoreans is called into question by this research. Actually, the same insect species invaded the orchards and gardens elsewhere at that time, and the agronomic knowledge and the methods of treatment referred to in the Azorean historical sources were used in several parts of the world. The "fashionable landscapes" of the orange groves, cared for or injured during the mid-nineteenth century in the archipelago, show "the tensions of order, mobility and hybridity" that characterize modernity in different geographies (Pawson 2008).

As others have highlighted before, local variations of a general movement of plant and animal transfers should be integrated into the original "Columbian Exchange" model due to knowledge and natural limitations affecting the pattern, scale and success of transfers, among other factors (Coates 1997; Beinart and Middleton 2004). This particular invasion and others that came after are better described by the globalization process, which increased international commodity trade and travel in several directions (O'Rourke and Willianson 1999), fostering the economy but also cultural encounters and biological interchanges among different territories on the planet. The expansion of the brown soft scale is a human agency better classified as part of the "human web", as McNeill and McNeill (2003) referred to it, which promoted the contact of living beings geographically and ecologically separate.

Controlling that plant pest was an almost unworkable task at that time. It invaded the Azorean islands before the existence of industrial treatments and insecticides, such as the commercial brand of lead arsenate Paris green, for instance. The responses of the Azorean authorities and educated farmers, some of whom were foreign residents, showed at once a global knowledge of scientific theories and a local observation and practical understanding. Their attempts at formulating recipes to eliminate insects, albeit grounded on the existing biology and chemistry, relied on experimentation.

Engaging themselves in agricultural development, they revealed their progressive thinking, if not on how to control an invasive species, at least on the risks behind transferring organisms. The rationality of protection, both "insurance" and "precaution", can now be traced to the 1840s in the Azorean district of Angra do Heroísmo. Local authorities established the first standards and regulations and were pioneers in this form of thinking. In fact, the measures taken in this district might have delayed the arrival of the pest to Terceira Island, as the insect only reached it 13 years after being detected on the neighboring island of Faial and 8 years after S. Miguel, where prevention had not been set up. Furthermore, by the local experience, the farmers were likely to be more aware of the possibilities of pest control.

Some may say that an emergent understanding or entomological knowledge did not arise from this particular crisis—neither in the Azores nor in the entire world. Historical bioinvasions occurred thereafter in orange groves worldwide due to other insect agents, such as the cottony cushion scale, *Icerya purchasi*, which devastated the citrus industry in California until a natural enemy from Australia was introduced in 1888, or the red scale, *Aonidiella aurantii*, the most injurious insect attacking citrus in parts of California, Australia and South Africa between 1879 and 1948 (DeBach and Rosen 1991; Compere 1961). However, each of the cases forced communities to confront each other with their uncertainty and to improve their expertise in identifying the agents involved and in protecting people and their economic activities.

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References

Amaral, J. J. 1843. *O Agricultor Micaelense* S2: 27–28, November.

Amaral, J. J. 1851. Coccus hesperidum. *Revista dos Açores*. February 12. Available online: http://purl.pt/19257 (accessed on 10 May 2020).

Anon. 1984. Quando vires as barbas do teu vizinho a arder, bota as tuas de molho. *O Angrense*. December 31. Available online: https://www.fcsh.unl.pt/pragasnosperiodicos/items/show/56 (accessed on 30 April 2020).

Anon. 1848. Laranjaes. *O Agricultor Micaelense (2ª série)* 3: 62, March.

Anon. 1849. *O Agricultor Micaelense*. (2ª série) 18; June. pp. 312–14. Available online: http://www.fcsh.unl.pt/pragasnosperiodicos/items/show/115 (accessed on 30 April 2020).

Anon. 1850. *O Angrense*. January 17. Available online: http://www.fcsh.unl.pt/pragasnosperiodicos/items/show/60 (accessed on 30 April 2020).

Anon. 1872. Nota Histórica sobre a cultura da laranjeira doce em Portugal e nos Açores. *O Jorgense* 78: 1.

Arch, Jakobina. 2015. Whale oil pesticide: Natural history, animal resources, and agriculture in early Modern Japan. In *New Perspectives on the History of Life Sciences and Agriculture*. Cham: Springer, pp. 93–111.

Arruda, Luís M. 2005. Evolucionismo e biogeografia na obra científica de Francisco Arruda Furtado e seu contributo para o conhecimento científico das ilhas dos Açores. In *As Ilhas Atlânticas e a Ciência. História da Ciência e Das Técnicas*. Funchal: Centro de Estudos de História do Atlântico, pp. 265–75.

Beinart, William, and Karen Middleton. 2004. Plant transfers in historical perspective: A review article. *Environment and History* 10: 3–29. [CrossRef]

Bettencourt, Nicolau Anastácio de. 1854. Ofício do Governador Civil de Angra do Heroísmo e Relatório da Comissão respectiva, acerca da moléstia das laranjeiras. *Boletim do MOPCI*. April 4, Appendix.

Bullar, John, and Henry Bullar. 1841. *A Winter in the Azores; and Summer at the Baths of the Furnas*. London: Samuel Bentley, pp. 137–38.

Caceres-Escobar, Hernan, Salit Kark, Scott C. Atkinson, Hugh P. Possingham, and Katrina J. Davis. 2019. Integrating local knowledge to prioritise invasive species management. *People and Nature*. [CrossRef]

Canto, José do. 1844. Coccus hesperidum (Cochonilha das laranjeiras). *O Agricultor Michaelense* 5: 68–69, February. Available online: http://www.fcsh.unl.pt/pragasnosperiodicos/items/show/112 (accessed on 4 April 2020).

Canto e Castro, Luís Meirelles. 1834. Letter to M. Huzard. In *Memória Sobre as Ilhas Dos Açores e Principalmente Sobre a Terceira: Considerando a Educação da Mocidade, a Agricultura, o Comércio, a Administração da Fazenda Pública, e o Governo Municipal*. Paris: Imprensa de Mme Huzard, pp. 51–63.

Coates, Peter. 1997. Improving on 'A paradise of Game': Ecological impacts, game management, and alaska's buffalo transplant. *The Western Historical Quarterly* 28: 133–59. [CrossRef]

Compere, H. 1961. The red scale and its insect enemies. *Hilgardia* 31: 173–278. [CrossRef]

Correia, José Jácome. 1849. Parecer da Sociedade Promotora da Agricultura Micaelense sobre a consulta do Exº Governador Civil deste Distrito em data de 25 de Abril, relativa ao modo de obstar ou atenuar os efeitos do inseto destruidor das laranjeiras. *O Agricultor Micaelense (2ªsérie)* 17: 299–302.

Crosby, Alfred W. 2004. *Ecological Imperialism. The Biological Expansion of Europe*, 2nd ed. New York: Cambridge UP.

Dabney, Charles W. 1843. Carta ao Sr. Redactor do Angrense. *O Angrense*, 1, July 29.

Dabney, Charles W. 1844. *O Agricultor Micaelense*, 54–55, January 4.

Dabney, Charles W. 1851. *O Agricultor Micaelense (2ªsérie)* 38: 638–39, February.

Dabney, Roxana Lewis. n.d. *Annals of the Dabney Family in Fayal*. Boston: Mudge, vol. I, p. 278.

De la Hire and Sedileau. 1869. Description d'un insecte qui s'attache à quelques plantes étrangères et principalement aux orangers. *Mémoires de l'Académie Royale des Sciences* 10: 10–14. First published 1666.

de Miranda, Sacuntala. 1989. *O Ciclo Da Laranja e Os «Gentlemen Farmers» Da Ilha Da S. Miguel*. Ponta Delgada: Instituto Cultural de Ponta Delgada.

DeBach, Paul, and David Rosen. 1991. *Biological Control by Natural Enemies*, 2nd ed. Cambridge: Cambridge University Press.

Dias, Fátima Sequeira. 1995. A Importância Da Economia Da Laranja No Arquipélago Dos Açores Durante o Século XIX. *Arquipélago—História. 2ª série* 1: 189–240.

Dias, Fátima S. 1999. *A Importância Da Economia da Laranja. in Uma Estratégia De Sucesso Numa Economia Periférica. A Casa Bensaúde e os Açores 1800–1870*. Ponta Delgada: Ribeiro & Caravana Editores, pp. 160–69.

Ferrari, Giovanni Battista. 1646. *Hesperides sive de Malorum Aureorum cultura et usu. Libri Quatuor*. Rome: Sumptibus Hermanni Scheus.

Forsyth, William. 1818. *A Treatise on the Culture and Management of Fruit-Trees; in Which a New Method of Pruning and Training Is Fully Described. To Which Is Added, a New and Improved Edition of «Observations on the Diseases, Defects, and Injuries, in All Kinds of Fruit and Forest Trees»: With an Account of a Particular Method of Cure*. London: Longman, Hurst, Rees [etc.], p. 439.

Forsyth, William. 1843. [Excerpt of a treatise on the culture and management of fruit trees]. *O Agricultor Micaelense*, 42–43, December 3.

Fowler, John. 1831. *Journal of a Tour in the State of New York, in the Year 1830, with Remarks on Agriculture in Those Parts most Eligible for Settlers and Return to England by the Western Islands, in Consequence of Shipwreck in the Robert Fulton*. London: Whittaker, Treacher and Arnot, p. 279.

Harris, Thaddeus William. 1841. *A Report on the Insects of Massachusetts, Injurious to Vegetation*. Cambridge: Folson, Wells and Thurston, p. 199.

Harris, Thaddeus William. 1843. On the coccus. *New England Farmer* XXIII: 4.

Hellmann, Jessica J., James E. Byers, Britta G. Bierwagen, and Jeffrey S. Dukes. 2008. Five potential consequences of climate change for invasive species. *Conservation Biology* 22: 534–43. [CrossRef]

Johnson, Cuthbert William. 1858. *The American Farmer's Encyclopedia; Embracing All The Recent Discoveries in Agricultural Chemistry*. New York: A. O. Moore.

Keller, Reuben P., Juergen Geist, Jonathan M. Jeschke, and Ingolf Kühn. 2011. Invasive species in Europe: Ecology, status, and policy. *Environmental Sciences Europe* 23: 1–17. [CrossRef]

Lauterbach, Iris. 2016. Commerce and erudition: Civic self-representation through botany and horticulture in germany, sixteenth to eighteenth centuries. In *Gardens, Knowledge and the Sciences in the Early Modern Period*. Edited by Hubertus Fischer, Volker R. Remmert and Joachim Wolschke-Bulmahn. Cham: Birkhäuser, pp. 319–41.

Lidström, Susanna, Simon West, Tania Katzschner, M. Isabel Pérez-Ramos, and Hedley Twidle. 2016. Invasive narratives and the inverse of slow violence: Alien species in science and society. *Environmental Humanities* 7: 1–40. [CrossRef]

Liu, YuQiu, Emily Heying, and Sherry A. Tanumihardjo. 2012. History, global distribution, and nutritional importance of citrus fruits. *Comprehensive Reviews in Food Science and Food Safety* 11: 530–45. [CrossRef]

Marlatt, Charles Lester. 1903. Scale insects and mites on citrus trees. *Farmers' Bulletin* 172: 17.

McNeill, John Robert, and William Hardy McNeill. 2003. *The Human Web: A Bird's Eye View of World History*. New York and London: W.W. Norton & Company, p. 219.

O'Rourke, Kevin, and Jeoffrey Willianson. 1999. *Globalization and History*. Cambridge: MIT Press.

Oliveira-Martins, Joaquim Pedro de. 1981. *Portugal Contemporâneo*. Porto: Lello & Irmão.

Olivier, Guillaume-Antoine. 1789. *Histoire Naturelle. Insectes. Tome 6*. Paris: Agasse H., p. 93.

Pawson, Eric. 2008. Plants, mobilities and landscapes: Environmental histories of botanical exchange. *Geography Compass* 2: 1464–77. [CrossRef]

Pooley, Simon, and Ana Isabel Queiroz. 2018. Introduction. Historical perspectives on bioinvasions in the Mediterranean region. In *Histories of Bioinvasions in the Mediterranean*. Cham: Springer, pp. 1–19.

Queiroz, Ana Isabel, and Daniel Alves. 2019. Praga e Poder: História do devorista das laranjeiras (Açores, Portugal, 1840–1860) [Pest and Power: The history of the "orange tree devourer" (Azores, Portugal, 1840–1860)". *Análise Social* 231: 226–54.

Queiroz, Ana Isabel Inês Gomes, and Inês Amorim. 2020. The spectre of historical crop losses: Challenging questions and methodological issues. *Historia Agraria* 82. [CrossRef]

Rodrigues, Ana Duarte. 2016. Gardening knowledge through the circulation of agricultural treatises in Portugal from the sixteenth to eighteenth centuries. In *Gardens, Knowledge and the Sciences in the Early Modern Period*. Cham: Birkhäuser, pp. 305–17.

Sackman, Douglas Cazaux. 2005. *Orange Empire. California and the Fruits of Eden*. Berkeley: University of California Press.

Scora, Rainer W. 1975. On the history and origin of citrus. *Bulletin of the Torrey Botanical Club* 102: 369. [CrossRef]

Sterner, Carl S. 2007. A Brief History of Miasmic Theory. Available online: http://www.carlsterner.com/research/files/History_of_Miasmic_Theory_2007.pdf (accessed on 2 June 2020).

Strick, James E. 2000. *Sparks of Life. Darwinism and the Victorian Debates over Spontaneous Generation*. Cambridge and London: Harvard University Press.

Torres, Domingos Monteiro. 1850. *Considerações Acerca Do Coccus Das Laranjeiras, e Do Fluido-Oleoso-Alkali-Vegetal; Que Reduz e Aniquila o Mesmo Insecto*. Ponta Delgada: Typ. de João Jacinto Botelho.

Triantis, Kostas A., Paulo A. V. Borges, Richard J. Ladle, Joaquín Hortal, Pedro Cardoso, Clara Gaspar, and Francisco Dinis. 2010. Extinction debt on oceanic islands. *Ecography* 33: 285–94. [CrossRef]

UBJFE (Upon the Basis of Johnson's Farmer's Encyclopaedia). 1858. *The American Farmer's Encyclopaedia: Embracing All the Recent Discoveries in Agricultural Chemistry, and the Use of Mineral, Vegetable and Animal Manures, with Descriptions and Figures of American Insects, Injurious to Vegetation. Being a Complete Guide for the Cultivation of Every Variety of Garden and Field Crops. Illustrated by Numerous Engravings of Grasses, Grains, Animals, Implements, Insects, etc.*. New York: Moore, A. O, Agricultural book Publisher, p. 105.

UNCTAD (United Nations Conference on Trade and Development). 2004. Market Information in the Commodities Area: Information on Citrus Fruit. Available online: http://r0.unctad.org/infocomm/anglais/orange/sitemap.htm (accessed on 2 June 2020).

Vaz, Ana S., Christoph Kueffer, Christian A. Kull, David M. Richardson, Stefan Schindler, A. Jesús Muñoz-Pajares, and Joana R. Vicente. 2017. The progress of interdisciplinarity in invasion science. *Ambio* 46: 428–42. [CrossRef]

Viana, A. M. Pinto. 1855. Ofício do Secretário do Governador Civil de Évora em resposta à circular de 12 de Novembro de 1853 sobre as moléstias das árvores. *Boletim do MOPCI* 10: 177.

Volkamer, Johann Christoph. 1708. *Nürnbergische Hesperides*. Nürnberg: Endter.

Volkamer, Johann Christoph. 1714. *Continuation der Nürnbergischen Hesperidum*. Nürnberg: Sohn & Erben.

Webster, John W. 1821. *A Description of the Island of the St. Michael, Comprising an Account of Its Geological Structure: With Remarks on the Other Azores or Western Island*. Boston: R.P. and C. Williams, p. 97.

Whetzel, Herbert Hice. 1918. *An Outline of the History of Phytopathology*. Philadelphia: W. B. Saunders, p. 32.

Ziska, Lewis H., Dana M. Blumenthal, G. Brett Runion, E. Raymond Hunt, and Hilda Diaz-Soltero. 2011. Invasive species and climate change: An agronomic perspective. *Climatic Change* 105: 13–42. [CrossRef]