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The presence of the Agave weevil *Scyphophorus acupunctatus* Gyllenhal, 1838 (Coleoptera: Dryophthoridae) in Madeira Archipelago. A new biological control opportunity or a new invasive species?

by

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With **7** figures and **1** appendix

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Abstract. The occurrence of *Scyphophorus acupunctatus* Gyllenhal, 1838 in the Archipelago of Madeira is here confirmed, being the first record of the Agave weevil in Macaronesia. Larvae and imagos collected in Porto Santo Island, on *Agave americana* L. and *Furcraea foetida* (L.) Haw., confirm the reproduction of this species, which is apparently in a process of becoming established. Measures to control this insect so as not to pose a threat to the native species *Dracaena draco* (L.) L. are also presented. The number of Dryophthoridae taxa known to the Madeira Archipelago rises to seven recorded species.

Keywords. Coleoptera, Curculionoidea, Dryophthoridae, *Scyphophorus acupunctatus*, new record, invasive species, *Agave*, pest, Madeira Archipelago, Porto Santo, Macaronesia.

Introduction

The Agave weevil *Scyphophorus acupunctatus* Gyllenhal, 1838 is a Dryophthoridae species native to the Nearctic region, and introduced in nearby areas (United States of America, Mexico, Belize, Cayman Islands, Costa Rica, Cuba, Curaçao, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Puerto Rico, US Virgin Islands, Argentina, Brazil, Colombia, Venezuela) (Halffter 1956, Vaurie 1971, Ramirez-Choza 1978, Van Rossem et al. 1981, O'Brien & Wibmer 1982, Servin et al. 2006, Setliff & Anderson 2011, Molina 2013, Aquino-Balaños (2006); EPPO 2014). It has also been introduced and naturalized in the African continent (Kenya, South Africa, Tanzania) (Servin et al. 2006, Smith et al. 2012, Molina 2013, EPPO 2014), Asia (Indonesia, Israel, Kalimantan, Sumatra, Saudi Arabia) (Vaurie 1971, Kalshoven 1981, Servin et al. 2006, Molina 2013, EPPO 2014) and Oceania (Australia, Fiji, New Zealand) (Vaurie 1971, Van Rossem et al. 1981, Servin et al. 2006, Riba i Flinch & Alonso-Zarazaga 2007, Molina 2013, EPPO 2014). In Europe, it has been recorded firstly in the Netherlands in 1980 on imported ornamental *Yucca* plants (Van Rossem et al. 1981), as well as several times between 1984-2006 on imported ornamental plants of the genus *Beaucarnea*, *Dasylirion* and *Yucca* (PQR 2007, Potting et al. 2009). In addition, it has been recorded in Lombardia, Italy, in 2000 on *Beaucarnea recurvata* Lem., as a glass-house incursion (Colombo 2000) and as well as on *Agave americana* L. in Sicily in a public park in 2006 (EPPO 2008a). Finally, infested *A. americana* L. plants were found in Saint-Tropez, France, in a public park in 2007 (EPPO 2008b); Spain (Riba i Flinch & Alonso-Zarazaga 2007, Martín-Taboada et al. 2019) and in Greece (Kontodimas & Kallinikou 2010) on *A. americana* L. and *Agave* spp. In Cyprus it was recorded for the first time in 2013, being accidentally captured in both pitfall and funnel traps placed across the country for the monitoring of red palm weevil, *Rhynchophorus ferrugineus* (Olivier, 1790) (Vassilis & Pavlos 2015). The first records from Continental Portugal came from the south region of Algarve in 2019 and Setúbal in 2018, being found on a plant nursery, private gardens and feral populations of *Agave* sp. (Naves & Boavida 2021).

The list of Curculionoidea of the Archipelago of Madeira is increasing year by year, with several new records of exotic species being added (Stüben 2017, Bella & Aguiar 2020, Andrade & Stüben 2020, Stüben 2022). The rising number of records of introduced alien species in the past decades, eg. *Rhynchophorus ferrugineus* (Olivier, 1790), *Diaprepes abbreviatus* Linnaeus, 1758 and now *S. acupunctatus* Gyllenhal, 1838, is explained by the exponential growth in the

number of people, cargo and plant material that move daily between different destinations worldwide (Hulme 2009). Introduced species, many times, pose a threat to the native diversity of the colonized regions, causing ecological disturbances to many native taxa. Island ecosystems, such as the ones found on Madeira Archipelago, are even more susceptible to the introduction of imported species and to the disturbances to already very fragile and endangered habitats (Davis 2003).

Material and methods

The discovery of the first insects, and the collection of later specimens was always carried out when observing plants that showed signs of the presence of this species.

Abbreviations used in the text for the collections where the specimens are deposited: ICLAM – Insect collection Laboratório de Qualidade Agrícola; AAPC – António Aguiar private collection; ISPC – Isamberto Silva private collection; MAPC – Miguel Andrade private collection; ETPC – Elisa Teixeira private collection. (There are also numerous specimens (10 Ex.) in the PST - P. E. Stüben collection).

The species was first barcoded by Peter E. Stüben. The CO1 sequence can be found on the DVD of his book "Weevils of Macaronesia" as well as in GenBank (Porto Santo: Vila Baleira, Collector's No. 3481-PST, MW520550). All photographs of specimens, host plants and habitats were taken on the island of Porto Santo. Pinned specimens were observed and photographed with a Leica® M125 stereomicroscope equipped with a Leica® IC80 HD camera and Leica® Application Suite LAS 3.8 with Multifocus Module for image stacking, with post-processing made in Adobe Photoshop CC.

Fig. 1. *Scyphophorus acupunctatus* distribution map: red marks – collected specimens; white marks – observed specimens on populations of infested plants.

Results

On November 2019, Adriano Andrade collected the first specimens of *S. acupunctatus* from the gardens of the “Hotel Vila Baleira”, Cabeço da Ponta, in plants of *Agave americana* L. that presented clear signs of rotting, with darkening of the stem and wilting leaves. Upon closer inspection, several weevils were detected both at the base of the leaves and inside the rotten stem. Some specimens were sent to the Laboratório de Qualidade Agrícola da Madeira, in Camacha, were António F. Aguiar identified these specimens as belonging to the species *Scyphophorus acupunctatus* Gyllenhal, 1838. A little later, Peter E. Stüben carried out the CO1 barcoding and thus also the molecular confirmation of the morphological determination (Stüben 2022).

In April 2021, more specimens were found in the “Parque Florestal dos Salões” area by Isamberto Silva, when an adult individual was collected in flight. In the vicinity of this site two species of Agavoideae, *Agave americana* L. and *Furcraea foetida* (L.) Haw., were present, with some plants showing symptoms of being used as host plants by this weevil. The removal of dead leaves and the opening of the rotten stem of *F. foetida* plants revealed an infestation with this pest (see figure 2). All stages of its life cycle were observed, with special attention to the aggregation of adults and the number of mature larvae that pierced the stem and leaf petioles, creating galleries. Later in the same year, during a visit to Porto Santo Island, Elisa Teixeira confirmed to the author that the presence of this species is somewhat common, well established on the island, with several locations where it can be found, always associated with populations of *Agave americana* or related species (see figures 4 and 5). Two years after it was first recorded (November of 2019), the population of this weevil on the island of Porto Santo seems to be increasing both in number as in distribution area. The host plants observed so far were *Agave americana* and *Furcraea foetida*, both naturalized American Asparagaceae (subfamily Agavoideae) that occur on the island, also planted in the gardens of hotels and parks (Carvalho et al. 2013, Vieira 2002).

Collected material

8 exs: ex *Agave americana*, Jardim do Hotel Vila Baleira, Cabeço da Ponta, Porto Santo Il, 33°2’14.021”N, 16°21’43.063”W, 17 m, 28.11.2019, F. Aguiar det., Adriano Andrade leg. (6 specimens deposited on ICLAM with the sample number 08966; 2 specimens deposited on AAPC with the sample number 1859). **20 exs:** ex *Fourcraea foetida*, Posto Florestal dos Salões, Porto Santo Il, 33°3'58.649"N, 16°20'6.071"W, 30 m, 16.04.2021, M. Andrade det., Isamberto Silva leg. (10 specimens deposited on ISPC; 10 specimens deposited on MAPC). **6 exs:** ex *Agave americana*, Miradouro das Flores, Porto Santo Il, 33°2’2.403’’N, 16°22’48.417’’W, 125 m, Elisa Teixeira det., Elisa Teixeira leg. ETPC. **3 exs:** ex *Agave americana*, Pico do Castelo, Porto Santo Il, 33°4’35.292’’N, 16°20’1.792’’W, 200 m, 04.10.2021, Elisa Teixeira det., Elisa Teixeira leg. ETPC.

Fig. 2. A. Imagos and mature larva of *S. acupunctatus*; B. Host plant *Furcraea foetida* (L.) Haw.; C. Rotted stem with galleries. (Photos: Isamberto Silva).

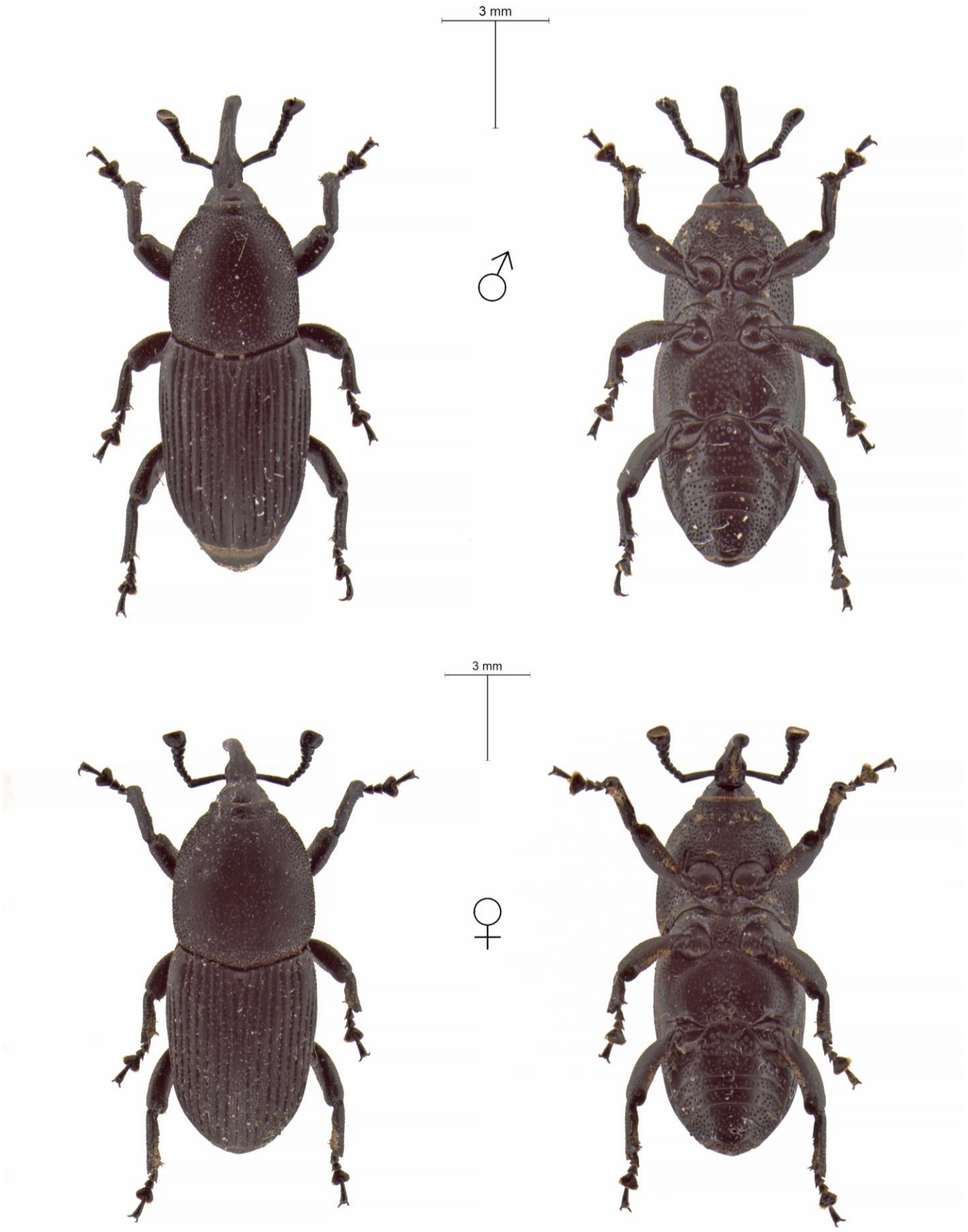

Fig. 3. Male and female specimens of *Scyphophorus acupunctatus* collected in Porto Santo. MAPC. (Photos: António Aguiar).

Fig. 4. A. *Agave americana* L. planted on a roadside; B. Young infested plant; C. Mature plant with signs of *S. acupunctatus*; D. Aggregation of *S. acupunctatus* adults. (Photos: Elisa Teixeira).

Discussion

Six species of Dryophthoridae have been previously recorded from Madeira Archipelago, being included in this list: *Cosmopolites sordidus* (Germar, 1824), *Rhynchophorus ferrugineus* (Olivier, 1790), *Sitophilus granarius* (Linnaeus, 1758), *Sitophilus oryzae* (Linnaeus, 1763), *Sitophilus zeamais* Motschulsky, 1855, and *Sphenophorus venatus* (Say, 1831) ssp. *vestitus* Chittenden, 1904 (Stüben, 2017). All of the above are introduced species that depend exclusively on human conditions such as the storage of dried grains and the presence of introduced plants to complete their development. It is important to note that this is the first island of Macaronesia where *Scyphophorus* is present, or at least, has been recorded. Due to its flight capacity and the frequent movements of people, plants and goods, together with the proximity of the islands we can expect it will reach Madeira Island soon, and then the other archipelagos.

According to Bolaños et al. (2014), *S. acupunctatus* feeds on both domesticated and wild *Agave* species in its native region, Mexico. In Porto Santo various species of Agavoideae, including *Agave americana* L., *A. attenuata* Salm-Dyck, and others are cultivated as ornamental plants in gardens (Vieira 2002). The century plant (*Agave americana* L.) is considered to be an invasive species in many habitats across the world, including the Mediterranean basin and the Macaronesian islands, causing diversity impoverishment by competing with the native flora (Osorio et al. 2008). It can be found on the islands of Madeira and Porto Santo, where it inhabits mainly coastal dunes, rocky shores, cliffs, anthropogenous habitats and degraded natural habitats of native vegetation (Osorio et al. 2008, Jardim & Menezes

de Sequeira 2008, Vieira 2002). In Spain, studies show that this Crassulacean Acid Metabolism-possessing plant species has higher rhizome and bulbil production, and higher establishment rates in sandy soils than in clay soils, thus suggesting that sandy soils are an opportunity for a higher clonal reproduction rate of *Agave* (Badano & Pugnaire 2004). In Porto Santo *A. americana* populations can be found in several sandy dunes across the island, which, by theory, favor the colonization and expansion of this plant over the dune and coastal ecosystems.

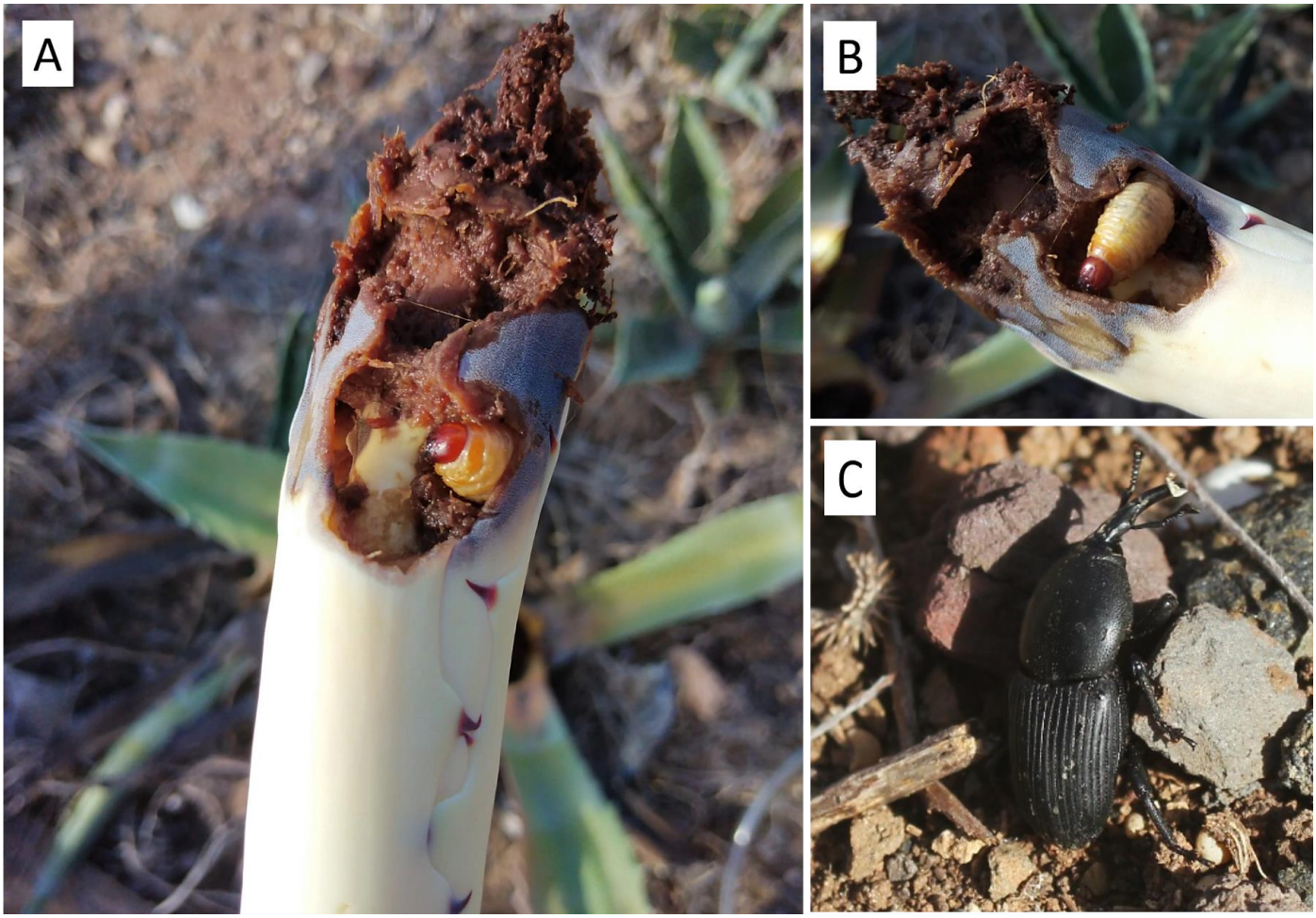

Fig. 5. - A, B. Larva inside gallery on leaf petiole of the terminal shoot. C. Adult of *Scyphophorus acupunctatus*. (Photos: Elisa Teixeira).

Hereupon, one could think the introduction of *Scyphophorus acupunctarus* plays the best way to naturally control *Agave* plants throughout the island. However there are a few factors to consider. When the agave weevil colonizes a new plant, it makes it possible for pathogens to enter into the plant (Rodríguez 1999); bacteria, algae, and fungi have been detected in the reddened tissues near the galleries caused by the agave weevil larvae (Waring & Smith 1986). Several species of bacteria associated with agave bud rot have been reported. Vélez et al. (1996) isolated *Erwinia* sp. of the *Carotovora* group from *A. tequilana* A. Weber. Later, Martínez-Ramírez (2011) confirmed that *E. carotovora* is the causal agent of soft rot in *A. tequilana*. Additionally, other microorganisms have been associated with the rot in *A. tequilana*, such as *E. cacticida*, *P. agglomerans*, *Pseudomonas* sp., *Bacillus pumilus* (Bacillaceae), *Arthrobacter* sp. (Micrococcaceae), *Streptomyces* sp. (Streptomycetaceae), and the fungus *Fusarium oxysporum* Schltdl. (Nectriaceae) (Rodríguez 1999; Espinosa-Paz et al. 2005; Jiménez-Hidalgo et al. 2004; Rincón-Enríquez et al. 2014). In most cases, if left untreated, plants infected with these pathogens will eventually wither to death. Besides all costs associated with the treatment and removal of the infected plants, this could possibly pose a new threat for the flora of Porto Santo. As is known, this species has already been cited by several authors for having as its main host plants those belonging to the genus *Agave* (Halffter 1956; Cuervo-Parra et al. 2019), however other genera of the Asparagaceae family have also been detected with attacks of *Scyphophorus acupunctatus*, such as species of the genus *Beaucarnea*, *Dasylirion*, *Furcraea*, *Polianthes*, *Sansevieria*, *Yucca* and *Dracaena* (Ruiz-Montiel et al. 2008, Maya et al. 2011).

The Canary Islands dragon tree (*Dracaena draco* (L.) L.) is a species of evergreen tree native to Macaronesia (Cape Verde, Canary Islands, Madeira and western Morocco). *Dracaena draco* subsp. *draco* is very rare in nature, and extinct in the wild on Porto Santo (Carvalho et al. 2013). Due to its xerophilous characteristics, it is widely used in gar-

dens, and more recently in reforestation projects at Pico do Castelo, in Porto Santo (Filipe 2007). *Dracaena draco* is listed as host plant species (suitable) for the life cycle of *S. acupunctatus*, firstly by the California Agricultural Department in 1959 (Vaurie 1971), and more recently in Spain (Guerrero et al. 2021).

Fig. 6. Reforestation projects with the plantation of dragon trees (*Dracaena draco*), on the slopes of Pico do Castelo, in Porto Santo. (Photos: R. Dias).

An interesting aspect about this weevil is the ability of both sexes to start a colonization event on an agave plant. It is explained as the aggregation pheromones released by males, acting together with the volatile compounds released by the host plant (after a cut, for example), have the ability to attract more individuals of both sexes, possibly indicating that there are resources to colonize. The female weevil (mainly the gravid specimens) attracted by the chemical signs, seek and select an agave plant to oviposit, feed, shelter and to reproduce (Figueroa-Castro et al. 2015). However, there was no sexual dimorphism in the antennal responses when exposed to four synthetic compounds, indicating that both sexes have equal relevance in colonization processes, and both should be targeted during capture. The compound 2-methyl-4-octanone was the most abundant component released by males, suggesting that is the major aggregation pheromone of *S. acupunctatus* (Ruiz-Montiel et al. 2008). A previous study showed that traps baited with *S. acupunctatus* males plus agave leaves captured significantly more weevils than traps baited only with agave, although the relation between the influence of agave kairomones and the quantity of aggregation pheromones, produced by the males, is not totally clear; the use of synthetic kairomones instead of agave plant material would reduce time and labour costs associated with trap maintenance (Ruiz-Montiel et al. 2008).

Conclusion

It is then suggested that the competent authorities try to carry out a project to eradicate this weevil species from Porto Santo, in order to avoid the threat it poses to the dragon trees, found in many gardens, parks and reforested areas, and to prevent its expansion to the main island of Madeira. Biological control techniques, manual collecting, application of systemic insecticides, should be used in order to try to eliminate the populations of the agave weevil. However,

its control with insecticides applied directly to the plants can be difficult because the larvae are located in tunnels inside the plant (Valdés-Rodríguez et al. 2004). The main damage is caused by the feeding of the larvae, and the microorganisms associated with it. In addition to mechanical damage by feeding, this insect facilitates infection with phytopathogens, thus causing putrescence. It is recommended to use these in alternation or rotation with different insecticide classes, different mechanisms of activity, or in conjunction with other alternatives, such as food attractants, entomopathogenic fungi, and aggregation pheromones, to obtain better control of *S. acupunctatus* under field conditions (Terán-Vargas et al. 2012). Presently, neither biological nor chemical control methods have shown significant efficacy for control of this pest (Cuervo-Parra et al. 2019). However, it is necessary to develop and improve the already existing methods to prevent the occurrence of this weevil on the Madeira Archipelago, where it can become yet another risk to the already threatened dragon tree (*Dracaena draco* ssp. *draco*), thus avoiding the disappearance of this plant symbol that is the main element of Porto Santo's coat of arms.

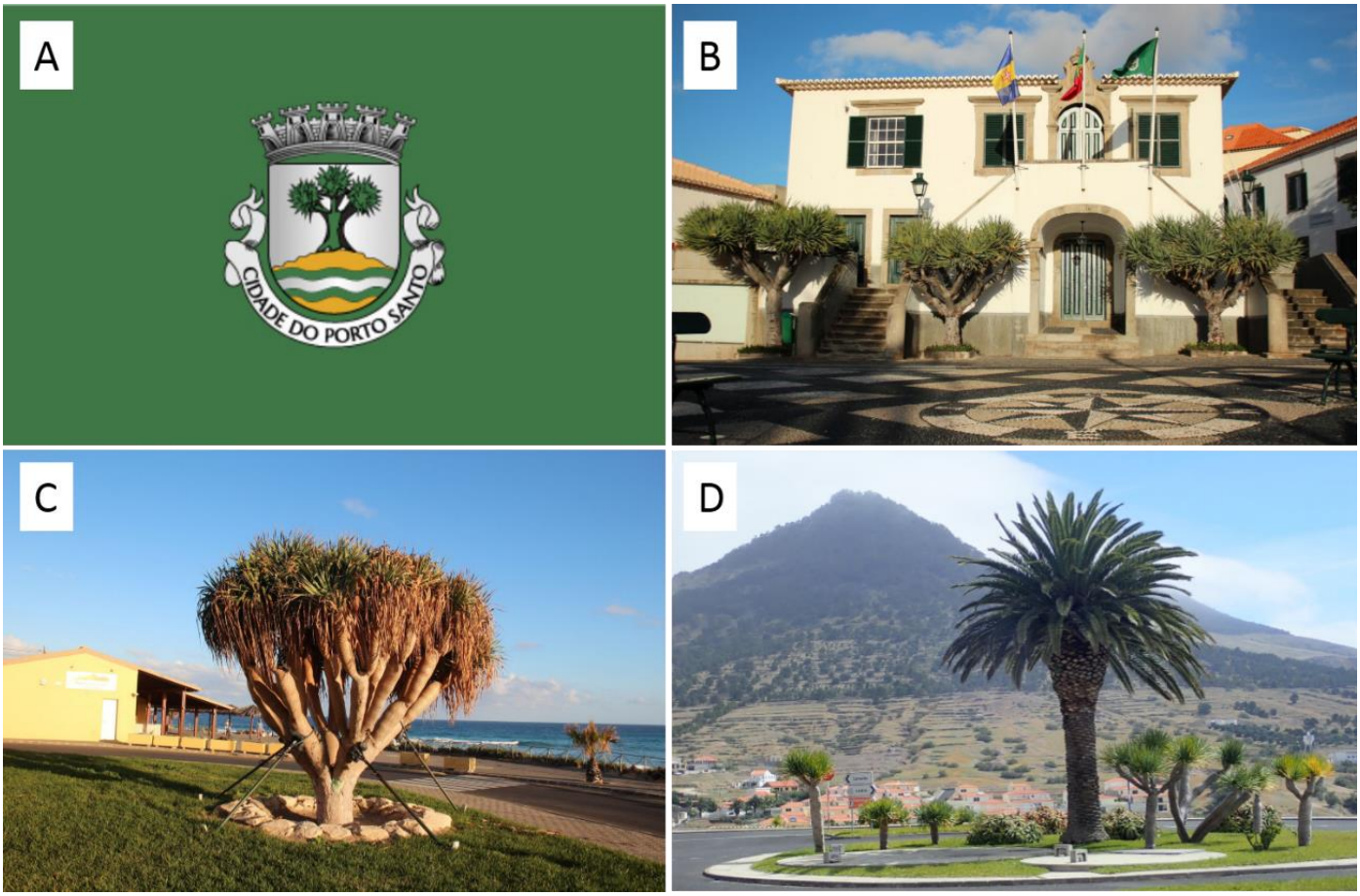

Fig. 7. A. Coat of Arms of Porto Santo; B. Former town hall with planted dragon trees; C, D. Dragon trees used as ornamental plants in gardens and parks around the island. (Photos: J. Campinho and P. Stüben).

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Appendix

CO1 Barcode

Portugal, Porto Santo, Hotel Vila Baleira, sítio do Cabeco da Ponta, 33°2’14”N 16°21’43”, 17 m, 4.12.2019, ex *Agave americana*, leg. Adriano Andrade, coll. Aguiar, Stüben, DNA (CO1): 3481-PST (SDEI)

>Scyphophorus acupunctatus Porto Santo: Vila Baleira GenBank: MW520550

CACTTTATACTTTATTTTTGGAGCATGATCAGGAATATTAGGAACCTCTTTAAGAATACTAATTCGAGCAGAATTAG
GCAACCCTGGATCCTTAATTGGTGATGATCAGATTTATAATGTAATTGTTACTGCCCATGCATTTATTATAATTTTC
TTTATAGTTATACCAATTTTAATTGGAGGATTTGGAAATTGATTAGTCCCTCTAATACTAGGAGCCCCTGATATAGC
TTTTCCACGTCTTAATAATATAAGATTTTGACTACTGCCTCCCTCACTAACACTACTTTTAATGAGAAGTATCGTTG
AAAAAGGGGCTGGAACCGGTTGAACAGTTTACCCTCCATTGTCTGCCAATGTAGCACATAATGGGGCATCAGTA
GATTTAGCAATTTTTAGATTACATATATCAGGAGTTTCTTCTATTTTGGGAGCTATTAATTTTATTTCTACAGCTATT
AATATACGCCCTATAGGAATAATTTCAGAACGTCTACCATTATTCGTCTGAGCTGTAAGAATTACTGCATTACTATT
ATTACTATCTTTACCAGTTTTAGCCGGAGCTATTACTATATTATTAACTGATCGTAATATTAATACATCTTTTTTTGA
CCCTGCAGGAGGAGGAGACCCTATTCTTTACCAACATTTATTC