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Discovery of *Hishimonus diffractus* Dai, Fletcher & Zhang, 2013 (Hemiptera: Auchenorrhyncha: Cicadellidae) in Europe, with remarks on previously recorded species of the genus

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Abstract

During recent surveys on leafhoppers in urban and agroecosystem areas in Europe the Oriental *Hishimonus diffractus* Dai, Fletcher & Zhang, 2013 (Hemiptera, Cicadellidae) has been found. This species, described from China and Thailand, is recorded here for the first time from Europe in the following countries: France, Portugal (Madeira), Spain, Gibraltar, United Kingdom, and Italy (Sicily). *H. diffractus* has been found associated with *Jasminum* and *Olea* (Oleaceae), *Citrus* (Rutaceae), *Pittosporum* (Pittosporaceae), *Rubus* (Rosaceae), *Nerium* (Apocynaceae) and *Vitis* (Vitaceae). Presence of the adults, morphological features, and some biological notes are provided to *H. diffractus*. Furthermore, *Hishimonus hamatus* Kuoh, 1976 is here reported for the first time in Spain and France. All *Hishimonus* species introduced in Europe are considered, and their economic importance discussed. Details on the first record and country in Europe, origin area, current distribution and host plants are given for each species.

Key words: Cicadellidae, *Hishimonus*, *Citrus* and *Olea* orchards, vineyards, alien species, Europe

Introduction

In Europe, insects represent one of the most numerous groups of introduced organisms, comprising nearly 94% of alien terrestrial invertebrates (Roques *et al.* 2009; Bella 2014). Accidental introductions of alien invasive arthropods, a worldwide phenomenon, may cause significant economic losses and are particularly insidious in countries with intensive international movements of goods and people.

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In Europe, the number of allochthonous Auchenorrhyncha (Fulgoromorpha and Cicadomorpha) accidentally introduced in recent times has significantly increased (Mifsud *et al.* 2010), and the non-native species to Europe were recently summarized by D'Urso *et al.* (2019), with a total of 30 species: Delphacidae (1 species), Issidae (1 sp.), Acanaloniidae (1 sp.), Flatidae (1 sp.), Ricaniidae (3 spp.), Membracidae (1 sp.), and Cicadellidae (22 spp.). Most of them originated from Asia (14 species), but also from North America (12 spp.), Africa (4 spp.), and Oceania (1 sp.). The first European occurrences of half of these alien species, were reported within the past 20 years (D'Urso & Bella 2021); this trend continues in fact, with seven additional species having reached Europe in recent years: *Siphanta acuta* (Walker, 1851) from Azores (Portugal) (Borges *et al.* 2013), *Anzygina honiloa* (Kirkaldy, 1906) from Greece (Thanou *et al.* 2018), *Pochazia shantungensis* (Chou & Lu, 1977) from European Turkey (Hizal *et al.* 2019), *Empoasca fabalis* De Long, 1930 from Madeira Island (Portugal) (Aguín-Pombo & Freitas 2020), *Eutettix variabilis* Hepner, 1942 from continental Portugal (Sousa *et al.* 2021), *Gyponana mali* DeLong, 1942 from Switzerland and Italy (Trivellone *et al.* 2021), and *Draeculacephala robinsoni* Hamilton, 1967 from France and Spain (Rösch *et al*. 2022).

The genus *Hishimonus* Ishihara, 1953 (Deltocephalinae, Opsiini) up to now has about seventy species widely distributed in Asia, Africa, and Australia (Dai *et al.* 2013; Fletcher & Dai 2013; Viraktamath & Murthy 2014; Du & Dai, 2019), with its greatest diversity in the Oriental region with minor extensions into the Ethiopian, Australian, and Palaearctic regions (Knight 2010). A great number of species have recently been described (Kamitani *et al.* 2011; Fletcher & Dai 2013; Dai *et al.* 2013; Viraktamath & Murthy 2014; Meshram & Chaubey 2016; Du & Dai 2019), and several species were recently first recorded from Russia (Gnezdilov 2008), Slovenia (Seljak 2013), Thailand (Dai *et al.* 2013), and Pakistan (Hassan *et al.* 2018). Currently, *Hishimonus* is reported for Afghanistan, Armenia, Australia, Borneo, China, Ethiopia, Fiji, Georgia, India, Indonesia, Iran, Japan, Korea, Malaysia, Oman, Pakistan, Papua New Guinea, the Philippines, Singapore, Sri Lanka, Tanzania, Thailand, and Saudi Arabia (Dai *et al.* 2013; El-Sonbati *et al.* 2018; Du & Dai 2019). In Europe only two species of this genus are reported: *H. hamatus* recorded in Switzerland, Slovenia, Germany, Corsica, and Austria, and *H. sellatus* (Uhler, 1896) found in Russia (Gnezdilov 2008; Seljak 2013; Trivellone *et al.* 2015; Albre & Gibernau 2019; Holzinger *et al.* 2020; Winterhagen 2020).

The species of *Hishimonus* distributed exclusively in the temperate and subtropical regions, are usually collected on herbs and trees (Du and Dai 2019).

In this account we report the first occurrence in Europe of the Oriental leafhopper *H. diffractus* Dai, Fletcher & Zhang, 2013 (Hemiptera, Cicadellidae), recently found in France, Portugal (Madeira), Spain, Gibraltar, United Kingdom, and Italy (Sicily), and newly record *Hishimonus hamatus* Kuoh, 1976 for Spain and France. Details of dates and country of the first detection, country/area of origin, their current distribution, and the host plants are provided for *Hishimonus* species in Europe.

Materials and methods

Research was based on observations from 2007 to 2020. Specimens were found in urban environments and in cultivated areas on garden and ruderal plants, on olive trees, in citrus orchards and on yellow chromotropic sticky traps placed within vineyard canopy; some specimens were also collected manually on the host plants or by light traps. In Madeira, a systematic survey was extended to 71 localities on Madeira Island and one on Porto Santo Island until 2019. Monitoring started from May/June and continued until October/December with two types of sticky traps of 12.5 x 20 cm from Russell IPM (Russell Co., UK) and 13 x 24.5 cm from Biomip—Biological Quality (Biomip Biological Quality S.L., S.P.). The traps were replaced with new ones approximately every two weeks. On Madeira Island, 36 vineyards on the northern and 36 vineyards on the southern slopes were surveyed between the altitudes of 7 to 408 m and 57 to 737 m, respectively. *Hishimonus diffractus* was only found in vineyards on the south coast in four of the seven counties surveyed: Machico (Caniçal), Santa Cruz (Caniço), Funchal (São Martinho), and Calheta (Estreito da Calheta). In the laboratory, leafhoppers were counted in each trap. For identification, specimens were extracted from the traps with a drop of limonene and the genital structures were studied.

The specimens were identified based on the morphology of adults and confirmed by the examination of the genital structures following Dai *et al.* (2003) and Du & Dai (2019). The materials examined are stored in the author's collections and in their institutions.

New record

Family Cicadellidae

Subfamily Deltocephalinae, Tribe Opsiini

***Hishimonus* Ishihara, 1953**

Hishimonus Ishihara, 1953: 38. Type species: *Thamnotettix sellatus* Uhler, 1896: 294, by original designation.

***H. diffractus* Dai, Fletcher & Zhang, 2013**
(Plates 1–3)

Hishimonus diffractus Dai, Fletcher & Zhang, 2013: 311, Figs 2C, 2F, 8A–E

Examined material

FRANCE: Alpes-Maritimes, Cagnes-sur-Mer, 40 m a.s.l., 43.6639470, -7.1371475, 12.X.2012, 1 ♂, 1 ♀, on *Jasminum* sp. (Oleaceae), P. Gros leg., G. Kunz det..

PORTUGAL: Madeira Island, Caminho da Fonte do Livramento, Caniço, Santa Cruz, 199 m a.s.l., 32.645907, -16.843643, 04.VIII.2015, 1 ♀, on a chromotropic sticky trap placed in a vineyard, C. Brazão leg., idem., 13.X.2015, 2 ♀♀; Jardim do Lido, São Martinho, Funchal, 20 m a.s.l., 32.636268, -16.932595, 03.VIII.2017, 1 ♀, on *Nerium oleander* (Apocynaceae), C. Brazão leg.; Posto Agrário, Caniçal, Machico, 57 m a.s.l., 32.738227, -16.743737, 26.IX.2018, 1 ♀, on chromotropic sticky trap placed in a vineyard, C. Brazão leg.; Estreito da Calheta, Calheta, 286 m a.s.l., 32.732454, -17.162188, 17.IX.2019, 1 ♂, on chromotropic sticky trap placed in a vineyard, S. Freitas & L. Vieira leg. (Aguín-Pombo det., all specimens).

SPAIN: Granada, Motril, 42 m a.s.l., 36.745061, -3.516736, 28.XI.2016, 30 ♀♀, 7 ♂♂, 15 nymphs, on *Jasminum* sp., J. Marín leg., A. Miralles det.; Alicante, Pilar de Horadada, 16 m a.s.l., 37.8750813, -0.7621520, 10.V.2017, 1 ♂, on *Rubus* sp., urban garden, P. Valero leg., P. Valero & A. Miralles det.; Cádiz, Jerez de la Frontera, Zoobotánico de Jerez, 57 m a.s.l., 36.690628, -6.148324, 23.VI.2019, 15.VIII.2019, 3 ♂♂, 2 ♀♀, on *Jasminum officinale*, I. Sánchez & A. Pérez leg. and det.; Jerez de la Frontera, Club Nazaret, 92 m a.s.l., 36.678163, -6.115790, 16.VII.2019, 4 ♂♂, 3 ♀♀, 10.IX.2019, 2 ♂♂, 1 ♀, attracted by the light in an urban garden, A. Pérez leg. and det.; Jerez de la Frontera, Las Albarizas, 92 m a.s.l., 36.705135, -6.124536, 31.VIII.2019, 2 ♂♂, 4 ♀♀, on *Pittosporum tobira*, I. Sánchez leg. and det.; Mallorca, Illetas area West of Palma, 39.540011, -2.592006, 22.VI.2007, 20/30 adults, swept from a dense *Olea* bush in a local garden, S. Foster leg.; Illetas area West of Palma, 39.542013, -2.586850, 2.IX.2009, 5/10 adults, on small *Olea* in woodland on a steep slope, S. Foster leg.; Illetas area West of Palma, 39.537876, -2.589880, 16.VII.2014, 5/10 adults on *Olea* growing as a garden hedge, S. Foster leg.; Illetas area West of Palma, 39.533946, -2.589053, 01.X.2019, single adult on large mature *Olea* overhanging a car park, S. Foster leg., M.R. Wilson det..

GIBRALTAR: Botanic Garden, VI.2012, 36.131710, -5.351282, numerous males and females, light trap, M.R. Wilson leg. and det..

UNITED KINGDOM: Worcester, V/VI.2021, male and female specimens living on imported jasmine plant from garden center, G. Falmer leg., M.R. Wilson det..

ITALY: Sicily, Catania province, Acireale, 206 m a.s.l., 37.623085, -15.164439, 20.VI.2018, 1 ♂, 29.V.2020, 1 ♂, in *Citrus* orchard, S. Bella leg., V. D'Urso det..

Description

Male. Length 3.7–3.8 mm. Vertex, pronotum, and scutellum greenish yellow marked with pale brown patches. Scutellum with lateral and apical areas ivory white, marked with two brown spots near base and another before apex. Forewings silvery white with brown mottling between veins, becoming darker and denser apically; brown median diamond patch distinct, well defined by dark brown at anterior margin and posterior corner, with median section anterior to posterior patch translucent whitish (Du & Dai 2019).

Genitalia (Plate 2). Pygofer in lateral view longer than height, posterior margin rounded. Valve approximately twice as wide at base as long medially. Subgenital plates broad triangular, broadly rounded at base then rounded apically to posterior finger-like process from median corner. Paramere with apophysis long and thick, apically rounded. Connective with broad rectangular stem, about as long as lateral arms. Aedeagal shafts, in posterior view, more or

less straight, divergent of even width throughout and bearing short, sharp thorn-like process on inner margin at about one-half to two-thirds length. In lateral view, shafts evenly lightly curved from base with apical process much narrower and strongly reflexed anteriorly; gonopore subapical on posterior surface (Du and Dai 2019).

PLATE 1. *Hishimonus diffractus* Dai, Fletcher & Zhang, 2013. **A–B**) Adults; **C**) Nymphs. Spain, Granada, 28.XI.2016 (Photos J. Marin).

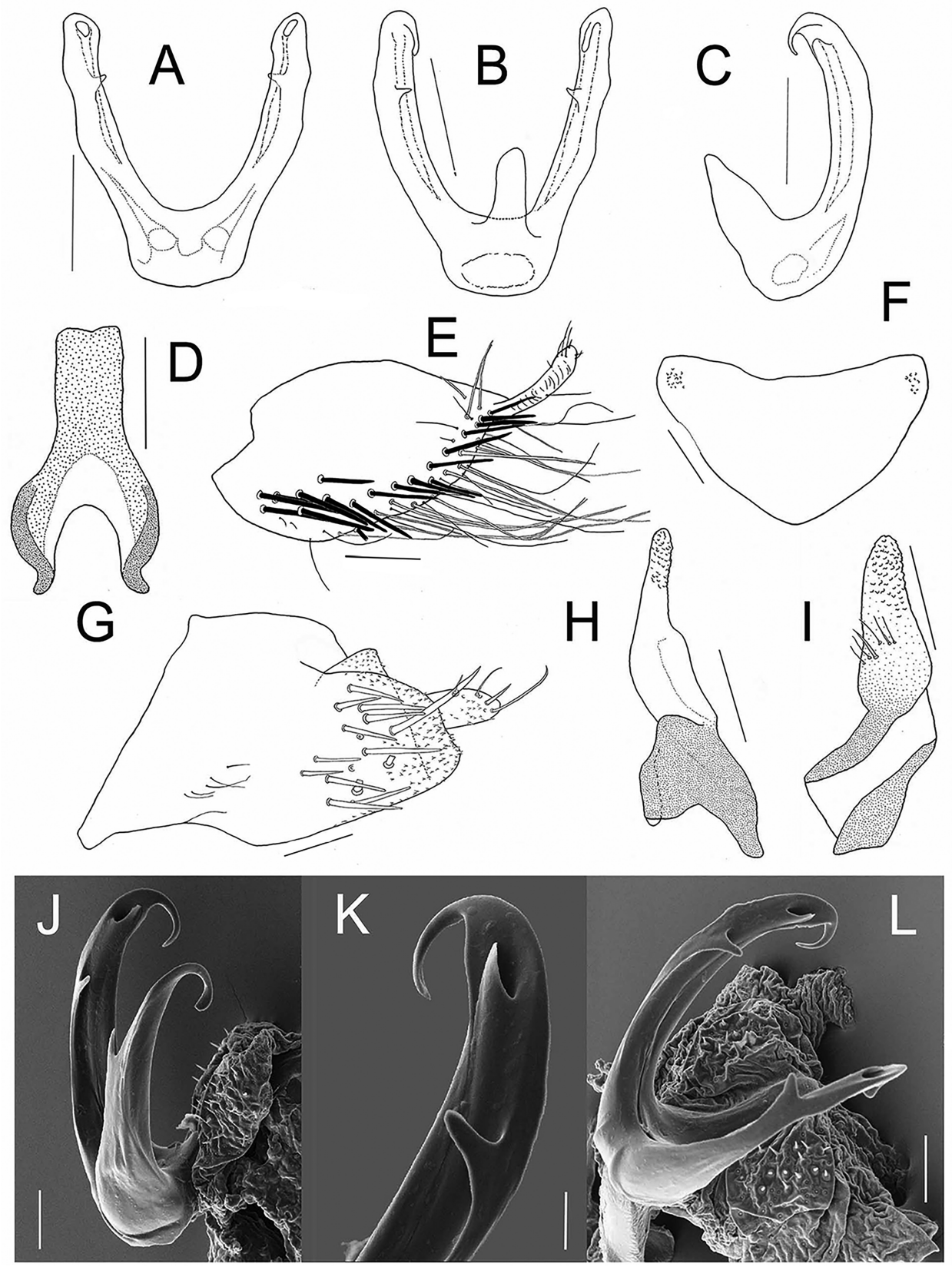

PLATE 2. *Hishimonus diffractus* Dai, Fletcher & Zhang, 2013. Male genitalia. **A–C**) Aedeagus: **A)** Anterior view, **B)** Posterior view, **C**) Lateral view; **D**) Connective, ventral view; **E**) Right subgenital plate, ventral view; **F**) Valve, ventral view; **G**) Pygopher, left lateral view; Right paramere: **H**) Ventral view, **I**) Lateral view. Aedeagus, SEM images: **J)** Dorso-lateral view, **L**) Dorsal view, **K)** Aedeagal shaft, inner side. **A–I**) Portugal, Madeira Island, Calheta, 17.IX.2019. **J–L**) Gibraltar, VI.2012 (photos M.R. Wilson). Scale: 0.1 mm for **A–I**; 50 μm for **J** and **L**, 20 μm for **K**.

Female. Length: 3.7–3.9. Aspect and colour pattern like male (Plate 3).

Genitalia. Seventh sternite 2.5 times as wide at base as long medially, its posterior margin medially concave, with posterolateral angles largely rounded; in correspondence of the median concavity an evident brown W.

Origin. Eastern Asia.

Distribution. *H. diffractus* was described from China and Thailand (Dai *et al.* 2013) and recorded in Australia (Fletcher & Dai 2013).

New records. It is here reported as new for France, Portugal (Madeira), Spain, Gibraltar, United Kingdom (as interception not in nature), and Italy (Sicily).

First record and country in Europe: 2007, Spain.

Host plant. In Europe found on *Jasminum* sp., *Nerium oleander*, *Pittosporum tobira* and *Citrus* orchards and vineyards.

Remarks. *H. diffractus* shows affinity with *H. aberrans* Knight, 1970 from China and Thailand (Dai *et al.* 2013). In *H. diffractus* the basal processes are fused with the shafts of the aedeagus on each side except for the apical portion, which remains as a short, spine-like process at about two-thirds of the length of the shaft, whereas in *H. aberrans* the basal processes are separate from the shaft for almost their entire length. Both species have the subgenital plates abruptly narrowed apically before the apical finger-like process (Dai *et al.* 2013). *H. diffractus* is easily distinguished from the two species present in Europe by the shape of the aedeagus, parameres and connective [illustrated by Du & Dai (2019), see also Seljak (2013) for *H. hamatus*] and by the female sternite VII. These characters also make it distinguishable from other species of the genus.

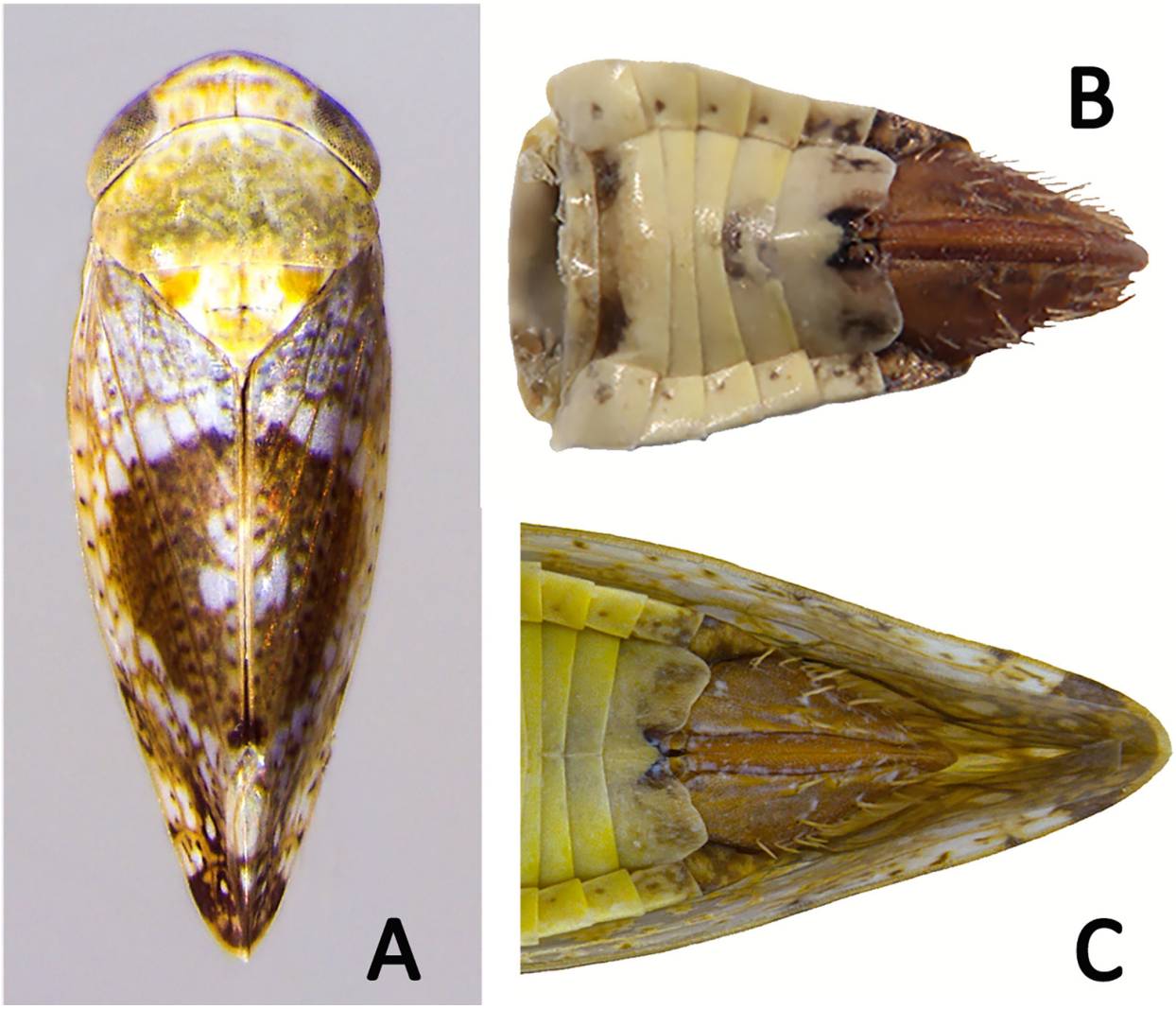

PLATE 3. *Hishimonus diffractus* Dai, Fletcher & Zhang, 2013. **A**) Female, Portugal, Madeira Island (photo A.M.F. Aguiar); **B–C**) Female abdomen, ventral view: **B**) France, Cagnes-sur-Mer, 22.VIII.2012 (photo P. Gros) and **C**) Madeira, Portugal (photo A.M.F. Aguiar).

Other species of the genus *Hishimonus* recorded from Europe

Here notes on the two *Hishimonus* species found in Europe are reported. Origin, distribution, host plants, remarks and selected references are reported for each species. In addition, country, year of discovery in Europe and relative references are given.

Hishimonus hamatus Kuoh, 1976 (= *H. araii* Okada, 1978)

(Plate 4)

Origin. Eastern Asia.

Distribution. Australia, China, Fiji, India, Indonesia, Korean peninsula, Japan, and Ethiopia (Du & Dai 2019). In Europe accidentally introduced in Slovenia (Seljak 2013), Switzerland (Trivellone *et al.* 2015), Italy (Guglielmino *et al.* 2017 as *H.* cfr. *hamatus*; Quaglino *et al.* 2019) Germany (Winterhagen 2020), Corsica (Albre & Gibernau 2019), and Austria (Holzinger *et al.* 2020).

New records. SPAIN: Girona, Beuda, 400 m a.s.l. 42.244414, -2.6919794, IX.2021, 1 ♂, R. Carbonell leg., A. Miralles det.. FRANCE: Provence-Alpes-Côte d'Azur, Vaucluse, Robion, 165 m a.s.l., 11.VI.2021, 1 ♂, light trap, B. Rasmussen leg., J.-C. Streito det. (INRA); Gordes Le Moulin des Roberts, 158 m a.s.l., 43.8859248, -5.2367057, 1 ♂, light trap, B. Rasmussen leg., J.-C. Streito det. (INRA).

First record and country in Europe. 2012, Slovenia (Seljak 2013).

Host plant. *Ilex crenata* (Aquifoliaceae), *Sambucus javanica* (Caprifoliaceae), *Euonymus japonicus* (Celastraceae), *Chamaecyparis lawsoniana*, *Cupressus sempervirens*, *Thuja occidentalis* (Cupressaceae), *Lagerstroemia indica* (Lythraceae), *Ligustrum japonicum*, *L. lucidum*, *L. ovalifolium* (Oleaceae), *Serissa japonica* (Rubiaceae) and *Vitis vinifera* (Vitaceae) (Seljak 2013; Quaglino *et al.* 2019; Winterhagen 2020).

Remarks. *H. hamatus* is very similar to *H. fuscomaculatus* Li & Wang, 2004 (China), *H. callisto* Linnavuori, 1969 (Republic of the Congo), and *H. lindbergi* Knight, 1970 (Cape Verde), but it can be distinguished by the much more slender shafts of aedeagus with convex outer margins; the Female seventh sternite has the posterior margin concave medially with an emarginate black process (Du & Dai 2019) (Plate 4).

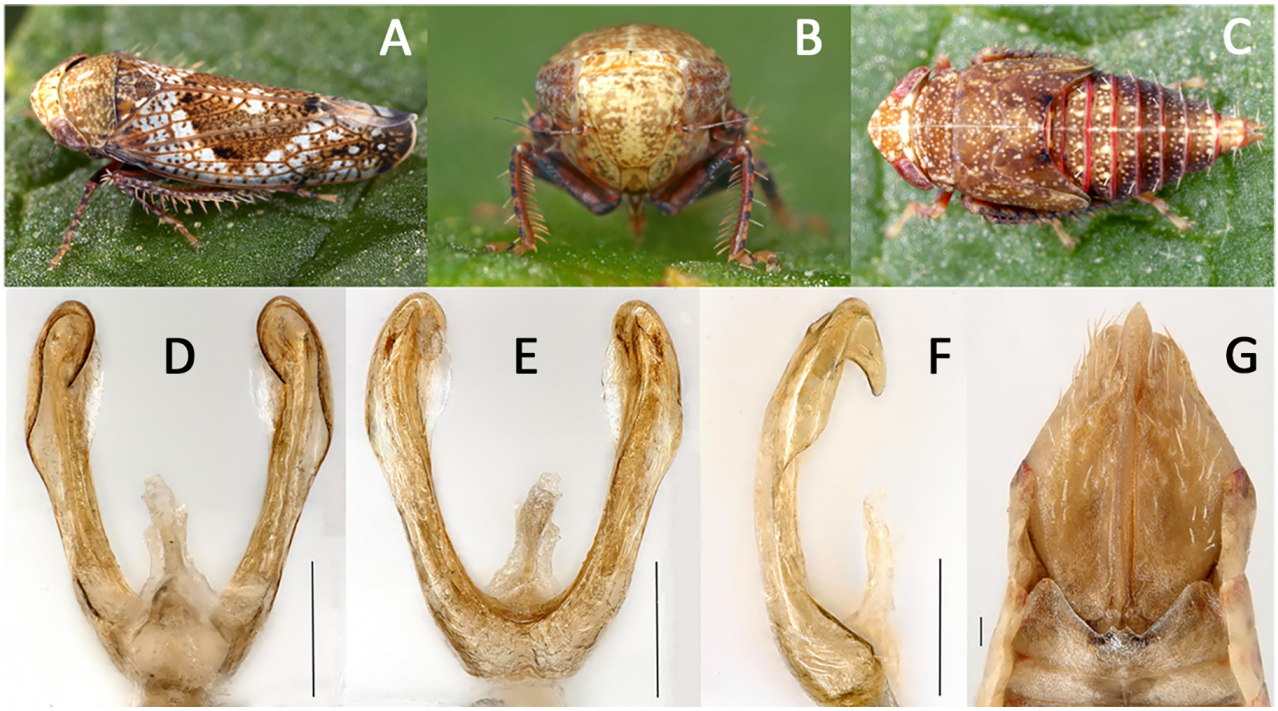

PLATE 4. *Hishimonus hamatus* Kuoh, 1976. **A–B**) Adult male; **C**) Nymph; **D–F**) Aedeagus: **D**) anterior view, **E**) posterior view, **F**) lateral view; **G**) Female abdomen, ventral view. Austria, 06.X.2021 (photos G. Kunz). Scale: 100 µm.

Hishimonus sellatus (Uhler, 1896)

Origin. Eastern Asia.

Distribution. Afghanistan, Armenia, Australia, China, Ethiopia, Georgia, India, Indonesia, Korea, Japan, Malaysia, Papua New Guinea, the Philippines, Sri Lanka, and Tanzania. In Europe accidentally introduced in Russia (Gnezdilov 2008; Dmitriev 2018).

First record and country in Europe. 2007, Russia (Krasnodar Territory) (Gnezdilov 2008).

Host plant. Polyphagous species. In China *H. sellatus* is common on *Morus alba*, *Rosa* spp., and *Ziziphus jujuba* (Hao *et al.* 2015).

Remarks. This species is similar to *Hishimonus truncatus* Kuoh, 1976 (China), but *H. sellatus* can be identified by the short, broadly lamellate, laterally concave aedeagal shafts; the female sternite VII nearly twice as wide as long, posterior margin slightly curved with two median denticles separated by a tiny notch and second valvulae with dorsal teeth small and not prominent (Du & Dai 2019). *H. sellatus* in Georgia and in southern Russia is recorded as a vector of 'Mulberry small leaf curl' a phytoplasma disease on mulberry plants (Gnezdilov 2008).

Species of *Hishimonus* at risk of introduction in Europe

Hishimonus phycitis (Distant, 1908) (= *Eutettix lugubris* Distant, 1918; *H. orientalis* Emeljanov, 1969)

Origin. Eastern Asia; described from India and Sri Lanka.

Distribution. China, India, Iran, the Kingdom of Saudi Arabia, Malaysia, Oman, Pakistan, the Philippines, Sri Lanka, Taiwan, Thailand, and in the United Arab Emirates.

Host plant. Polyphagous species, on the following plants are possible oviposition and nymphal development: *Amaranthus tricolor* (Amaranthaceae), *Lepidium sativum* (Brassicaceae), *Gossypium arboreum* (Malvaceae), *Sesamum indicum* (Pedaliaceae), *Ziziphus spina-christii* (Rhamnaceae), *Citrus aurantifolia*, *C. sinensis*, *C. paradisi*, *C. limetta*, *C. reticulata* (*e.g.* mandarin, tangerine), *C. limon*, *C. aurantium*, *C. jambhiri*, *C. volkameriana* (Rutaceae), and *Solanum melongena*, *Withania somnifera* (Solanaceae). It can also feed on: *Daucus carota* var. *sativa* (Apiaceae), *Raphanus sativus* (Brassicaceae), *Citrullus lanatus* (Cucurbitaceae), *Crotalaria juncea*, *Cyamopsis tetragonoloba*, *Medicago sativa*, *Sesbania cannabina*, *Vigna aconitifolia* (Fabaceae), *Saccharum officinarum* (Poaceae), and *Solanum lycopersicum* (Solanaceae) (Jeger *et al.* 2017).

Remarks. *H. phycitis* is very similar to *H. paraphycitis* Du & Dai, 2019 (China), but it can be identified by the circularly expanded aedeagal shaft apices (Du & Dai 2019).. Due its capacity to transmit phytoplasma diseases, *H. phycitis* is considered as a potential threat and is currently regulated by Council Directive 2000/29/EC and is regarded as 'Union quarantine pest' by the European Food Safety Authority (Jeger *et al.* 2017; EFSA 2021).

Chronology of the generic *Hishimonus* citations from Europe available on the internet

Photos of specimens of *Hishimonus* without specific attribution or with unverified determinations are reported on many citizen science platforms such as Inaturalist.org; of course, the identifications of the species should be validated by specialists after examination of the male genitalia, especially the aedeagus, because most species of the genus show a similar habitus. At least, since 2008 there are reports from mainland Spain (Granada: https://www.biodiversidadvirtual.org/insectarium/Hishimonus-sp.-img52523.html; Valencia: https://docplayer.es/83348571-Plan-de-vigilancia-fitosanitaria), and from Italy (Emilia-Romagna, Latium, Lombardy, Marche, Piedmont, Veneto, Tuscany: https://www.entomologiitaliani; https://www.naturamediterraneo.com; http://www.fitosanitario.re.it). It should be noted that the specimens reported in this paper from Granada (2016) came from exactly the same place as the specimens observed in 2008, so the species most likely is *H. diffractus*. The specimens have not been found only in crops but are already frequent in certain cities and municipalities in garden areas.

Morphological features of genera related to *Hishimonus*

Most species of *Hishimonus* also show an obvious feature in external appearance, a large semi-circular or diamond-shaped brown spot across the forewings at rest, and this characteristic is also shared with related genera such as *Hishimonoides* Ishihara, 1965, *Litura* Knight, 1970, and *Naevus* Knight, 1970, genera that are difficult to separate without examining the genital structures (Viraktamath & Murthy 2014; Du & Dai 2019). *Hishimonus* can be distinguished easily from *Naevus* and *Litura* by the atrium of the aedeagus not extended ventrad beyond the shafts, and from *Hishimonoides* by the absence of a pair of well-developed ventral paraphyses on the aedeagus (El-Sonbati *et al.* 2018). Comparative study of the *Hishimonus* male genitalia revealed that the overall structure of the genital capsule was remarkably uniform, but variation occurrs in the shape of the caudal margin of the pygofer and its length. The structure of the parameres and connective are relatively constant among species with only minor variation in relative proportions and in the shape of the paramere apophysis and preapical lobe. In the aedeagus the main variation occurrs in the relative lengths and the shape of shafts, which bear posteriorly directed processes at the base in a few species. This aspect divides the species into two groups, one with the aedeagus normally developed with the basal processes extended posteriorly and the other with the aedeagus lacking basal processes (Du & Dai 2019).

Discussion

Economic implications

Several species of alien Auchenorrhyncha are of considerable economic importance mainly due to their capacity to transmit phytopathogenic microorganisms (Weintraub & Beanland 2006; Trivellone *et al.* 2017). Some species of *Hishimonus* are known to be of economic importance because of their transmission of plant pathogens such as phytoplasmas (Trivellone *et al.* 2015).

H. sellatus is known as a vector of phylogenetically divergent phytoplasmas that damage cultivated and ornamental plants, including 'Jujube witches'-broom' (JWB), and 'Mulberry curly small-leaved' (Han & Cha 2002; Gnezdilov 2008), 'Criptotaenia japonica witches' broom', and 'Onion yellows' (Nishimura *et al.* 1998), 'Rhus yellows', and 'Hovenia witches' broom' (Kusunoki *et al.* 2002).

H. phycitis transmits 'Witches' broom disease of lime' (WBDL) (Bové & Garnier 2000), 'Sesame phyllody phytoplasma' (un Nabi *et al.* 2015), and 'Brinjal little-leaf phytoplasma' (eggplant) (Azadvar & Baranwal 2012). WBDL is associated with 'Candidatus Phytoplasma aurantifolia', considered one of the most lethal plant pathogens (EFSA 2021). In the Middle East, the WBDL phytoplasma is a very destructive disease of *Citrus* especially in Iran, India, Oman, and in the United Arab Emirates. In Iran, over 70% of adults and nymphs of *H. phycitis* collected in a lime orchard (Hormozgan province), tested positive for WBDL (Salehi *et al.* 2007), while 65% of specimens tested positive in Oman (Queiroz 2014). WBDL kills lime trees in three-five years, and in Oman from the 1970s, 90% of the cultivated area of lime (Chung *et al.* 2006; Al-Yahyai *et al.* 2015) was destroyed (Khan *et al.* 2017; El-Sonbati *et al.* 2018). In Iran and India, over 30% of Mexican lime trees were attacked (El-Sonbati *et al.* 2018). Najafiniya & Azadvar (2016) report WBDL phytoplasma also affects sweet orange and grapefruit in Iran. In India, *H. phycitis* is an important pest of *S. melongena*, due to its ability to vector 'brinjal little-leaf disease' which can cause loss in crop yield. It is also a vector of 'sesame phyllody phytoplasma', which in India can cause yield losses of up to 80% in *Sesamum indicum*. Sesame is grown to a limited degree in the EU (Cyprus, Greece, and Italy).

The introduction of alien species is considered the main cause of loss of island biodiversity, especially for small islands. Concerning Madeira, in recent years, many exotic species including leafhoppers (Freitas & Aguín-Pombo 2004; Aguín-Pombo *et al.* 2007, 2020; Aguín-Pombo & Freitas 2020) have been reported. *H. diffractus* is distributed in temperate and subtropical areas of Asia and Australia (e.g., Du & Dai 2019), so its establishment on Madeira is not surprising. The climate of the archipelago is predominantly temperate oceanic with tropical influences, high rainfall, and a mean temperature of 19 °C. The first specimens were found in 2015 in Caniço and in 2017, 2018 and 2019 they were found in three other localities from 9 km to 25 km away suggesting that it is already well established on the southern slopes of Madeira. Its apparent restriction to the southern slopes may be explained by the existence of a mountain range separating the two slopes. Madeira is very steep with 90% of its surface area above 500 m [see Aguín-Pombo & Pinheiro de Carvalho (2009) for an overview] and has a mountain range that crosses the island from east to west dividing it into two zones (north and south) with two climate types: temperate and subtropical,

respectively. This natural geographical barrier may be the cause of the differences found between the two coasts, as seems to be the case for *Scaphoideus titanus* Ball, 1932, the main vector of flavescence dorée phytoplasma in vineyards. This species, despite continuous monitoring of the vineyards over the last 20 years, it has only been found in the vineyards on the northern slopes (Aguín-Pombo *et al.* 2020). The few specimens of *H. diffractus* found in vineyards during all these years of sampling suggests that presence in the vineyards may have been occasional. However, given that species of this genus are polyphagous, careful monitoring of vineyards should be considered in the future. Another possible explanation is that populations are still very small as it expands its range. Something similar was observed in *Sophonia orientalis* (Matsumura, 1912) (Aguín-Pombo *et al.* 2007) and is common among many introduced species (Aguín-Pombo *et al.* 2010). Archipelagos of volcanic origin such as Madeira, with many endemic plant and animal species, are vulnerable to invasion by alien species (Aguín-Pombo *et al.* 2010). Their impact on native and agricultural ecosystems can be very large, therefore monitoring of *H. diffractus* on Madeira is urgently needed.

Sicily, located in the centre of the Mediterranean, shows a great wealth of habitats that depend on both the climate and geological characteristics (volcanic, chalky-sulphurous, calcareous areas, etc.); these characteristics support high biodiversity but also high fragility of the system due to its insularity (Mazzeo *et al.* 2015; Suma *et al.* 2018). Currently, there are more than 400 alien species (V. D'Urso, personal communication) some highly invasive. *Hishimonus* species, especially *H. phycitis,* could become pests for Sicilian citrus crops.

Concluding remarks

Here we report *H. diffractus* for the first time in Europe, its distribution and the first morphological details of the female of this species, unknown until now. It is interesting that the first records of the species, from Mallorca were made in 2007, some years before the species was formally described and named. Although the first capture of specimens took place in Europe, it is very likely that the species came from the Eastern Region because: *Hishimonus* has a great diversity species in the Oriental Region; the Europa has been fairly well studied and *Hishimonus* have only recently been reported; in recent years an introduction trend of alien species coming from Eastern Palaearctic Region, especially from China, has been documented. In addition, we update the distribution of *H. hamatus* with new reports in Europe.

Our data show that the genus *Hishimonus* is spreading in Europe with at least three species; many generic reports of amateurs deserve to be verified by specialists to ascertain whether other species of the genus are present in Europe. The *Hishimonus* species are much similar to each other in external morphology and coloration so they can only be with certainty distinguished through the examination of male and female genitalia.

The first record of a *Hishimonus* species in Europe (European Russia) was reported in 2007 by Gnezdilov (2008), followed by a steadily increasing number of reports from other European countries. Numerous species of *Hishimonus* could potentially acclimatize to Continental European and Mediterranean latitudes, so other species may colonize the continent in the future. *H. phycitis*, also present in Iran and the Arabian Peninsula, could easily spread to Eastern Europe and Mediterranean countries. Warming due to global climate change increases the chances for thermophilic species to reach and settle in Europe, especially in the lands around the Mediterranean Sea.

The trade of young nursery plants probably is the main factor of accidental introduction of allochthonous species of Hemiptera Auchenorrhyncha in Europe and in the Mediterranean territory (Roques *et al.* 2009; Bella & D'Urso 2012; Bella 2014; D'Urso & Bella 2021).

Many *Hishimonus* species are of considerable economic importance mainly due to the transmission of phytopathogenic microorganisms, and further research is needed to verify the capacity of the species introduced in Europe to transmit different pathogens and to evaluate their role in the cultivated and natural ecosystems (Massimino Cocuzza *et al.* 2016; El-Sonbati *et al.* 2018).

For this reason, correct identification of *Hishimonus* specimens is required, and constant monitoring is needed to track changes in the presence, diffusion and the phytosanitary status of the species, both in wild and urban areas. At present, identification of species requires study of the morphology of adult males, However, recent studies suggest that molecular tools for discriminating species based on the immature stages (Hao *et al.* 2015) could be useful for *Hishimonus* species identification and faunal surveys.

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