

SHORT COMMUNICATION

The genus *Harmonia* (Coleoptera, Coccinellidae) in the Middle East region

Amir BIRANVAND¹⁾, Oldřich NEDVĚD^{2,3)}, Wioletta TOMASZEWSKA⁴⁾, Amin N. AL ANSI⁵⁾, Lida FEKRAT⁶⁾, Zahra Mojib HAGHGHADAM⁷⁾, Mehdi Zare KHORMIZI⁸⁾, Sara NOORINAHAD⁹⁾, Derya ŞENAL¹⁰⁾, Jahanshir SHAKARAMI⁹⁾ & Danny HAELEWATERS^{2,11,12,*)}

¹⁾ Young Researchers and Elite Club, Khorramabad Branch, Islamic Azad University, Khorramabad, Iran

²⁾ Faculty of Science, University of South Bohemia, CZ-37005 České Budějovice, Czech Republic

³⁾ Biology Centre, Czech Academy of Sciences, Institute of Entomology, CZ-37005 České Budějovice, Czech Republic

⁴⁾ Museum and Institute of Zoology, Polish Academy of Sciences, PL-00-679 Warsaw, Poland

⁵⁾ King Saud University Museum of Arthropods, Department of Plant Protection, King Saud University, SA-11451 Riyadh, Saudi Arabia

⁶⁾ Department of Plant Protection, Ferdowsi University of Mashhad, Mashhad, Iran

⁷⁾ Agricultural and Natural Resources Research Center of Gilan Province, Rasht, Iran

⁸⁾ Yazd Provincial Office, Department of Environment, Iran

⁹⁾ Department of Plant Protection, Lorestan University, Iran

¹⁰⁾ Faculty of Agriculture and Natural Sciences, Bilecik Şeyh Edebali University, TR-11230 Bilecik, Turkey

¹¹⁾ Department of Organismic and Evolutionary Biology, Harvard University, Cambridge MA-02138, United States of America

¹²⁾ current affiliation: Department of Botany and Plant Pathology, Purdue University, West Lafayette IN-47907, United States of America

*) corresponding author: danny.haelewaters@gmail.com

Accepted:
12th April 2019

Published online:
17th April 2019

Abstract. The harlequin ladybird, *Harmonia axyridis* (Pallas, 1773), is native to Asia but has been introduced to many countries, both intentionally and unintentionally. In the Middle East region, *H. axyridis* was so far only known from Iran and Turkey. This study reports *H. axyridis* for the first time from a country with a hot desert climate, Saudi Arabia. The single specimen that was found is most likely the result of unintentional release. Successful spreading of *H. axyridis* in Saudi Arabia will be limited because of high temperatures during summer and scarcity of prey (aphids). New records from Iran and Turkey suggest fast spreading of *H. axyridis* in these parts of the Middle East. In addition, we also present new records from Iran and Turkey for *H. quadripunctata* (Pontoppidan, 1763), the other species in the genus that occurs in the Middle East region. A key and illustrations are provided for both species.

Key words. Coccinellidae, distribution, hot desert climate, morphology, non-native species

Zoobank: <http://zoobank.org/urn:lsid:zoobank.org:pub:605E5337-395B-4C88-AC75-E761330518FE>

© 2019 The Authors. This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivs 3.0 Licence.

Introduction

The harlequin ladybird, *Harmonia axyridis* (Pallas, 1773) (Coleoptera: Coccinellidae), is native to China, Japan, Korea, Mongolia, Eastern Russia, southern Siberia, northeastern Kazakhstan (Altai mountains), and Northern Vietnam (ROY et al. 2016). It was intentionally introduced as part of biological control programs into North America, and one western and one eastern North American population served as bridgehead populations for further invasion to South America, Europe (genetically admixed with a European biocontrol strain), and Africa (LOMBAERT et al. 2010, 2014). Nowadays, it is quickly spreading, often unintentionally, in all continents except

Antarctica and Australia (ROY et al. 2016, CAMACHO-CERVANTES et al. 2017).

Harmonia axyridis has become a concern and also a threat; it competes with native predators and parasitoids for common food resources and is efficient in intraguild predation (ROY et al. 2016). With increasing density of *H. axyridis*, the diversity of native species is reduced (KATSANIS et al. 2013, GREZ et al. 2016, HONĚK et al. 2016). KOCH et al. (2006) reported that *H. axyridis* can be a pest in food production, particularly by tainting the wine flavor as individuals get into the winemaking process. Moreover, in some regions, populations of *H. axyridis* choose conspicuous buildings for hibernation causing disturbance for humans.



Because of these negative effects, it is relevant to study natural enemies that could potentially have a role in regulating invasive populations of *H. axyridis* (CERYNGIER et al. 2018, HAELEWATERS & DE KESEL 2017, HAELEWATERS et al. 2017).

Harmonia axyridis generally lives in temperate and subtropical regions (NEDVĚD et al. 2011, GREZ et al. 2016). Physiological limits of a European invasive population of *H. axyridis* suggest that it should not survive or develop at high temperatures (KNAPP & NEDVĚD 2013). Only small numbers have been found in tropical countries, for example Kenya (NEDVĚD et al. 2011) and Tanzania (NEDVĚD & HÁVA 2016), where the establishment of viable populations in the wild is unlikely.

Here, the faunistic information about *H. axyridis* from the Middle East region is updated and new areas are added to the distribution range of this invasive alien ladybird species. Moreover, distribution data are provided for the other *Harmonia* species known from the Middle East: *H. quadripunctata* (Pontoppidan, 1763). An identification key to the *Harmonia* species in the Middle East region and illustrations of morphological characters are presented.

Material and methods

Study area. The Middle East comprises 17 countries mainly located in southwestern Asia, including countries with a coastline on the Persian Gulf, Yemen and Oman that are located south of Saudi Arabia, Asian countries located nearby the Mediterranean Sea, parts of Turkey known as Anatolia or Asia Minor, and also part of Egypt called the Sinai Desert. In other words, the Middle East includes countries located between Egypt in the west and Iran in the east, and between Turkey in the north and Yemen in the south. Middle East countries are located between 25°00' E and 63°00' E longitude and between 12°36' N and 42°00' N latitude.

Mean temperatures in Middle Eastern cities range between 0.1°C (Ankara, Turkey) and 17.9°C (Abu Dhabi, United Arab Emirates) in January, and between 22.9°C (Ankara) and 37.7°C (Kuwait City) in July (WORLD METEOROLOGICAL ORGANIZATION 1998). Mean precipitation ranges between 3.9 mm (Abu Dhabi) and 190.9 mm (Beirut, Lebanon) in January, and between 0.0 mm (8 cities, Table S1) and 37.2 mm (Saiq, Oman) in July. In Saudi Arabia, the annual mean temperature is 25.6°C, with temperatures ranging from 14.0°C in January to 35.0°C in July. Precipitation in January is 11.3 mm (max. 111.1 mm), and in July 0.4 mm (max. 8.8 mm) (WORLD METEOROLOGICAL ORGANIZATION 1998). See also the Online supplementary material: Table S1.

Collection and morphological study. Adults of ladybirds were collected using an entomological net. Specimens were dissected under a stereomicroscope. Specimens were boiled in 10% KOH for a maximum of 20 min, depending on the body color (sclerotization), in order to dissect the genitalia. Dissected parts were rinsed in water for 10 min, and then mounted in Canada balsam onto microscopic slides. Morphological examination happened under a compound microscope (Olympus CX21, Tokyo, Japan) with digital camera. Taxonomic classification is in accordance with KOVÁŘ (2007). Morphological terminology follows ŚLIPIŃSKI (2007). Studied specimens are deposited in the following collections: (1) Insect Museum of Faculty of

Agriculture, Lorestan University, Iran; (2) Plant Protection Laboratory, Faculty of Agriculture and Natural Sciences, Bilecik Şeyh Edebali University, Turkey; and (3) King Saud University Museum of Arthropods, Saudi Arabia.

Results

Two species of the genus *Harmonia* are recorded from various countries of the Middle East region in the present study: *H. axyridis* and *H. quadripunctata*. We report *H. axyridis* from Saudi Arabia for the first time. This also represents the first record of the genus for this country.

Harmonia Mulsant, 1846

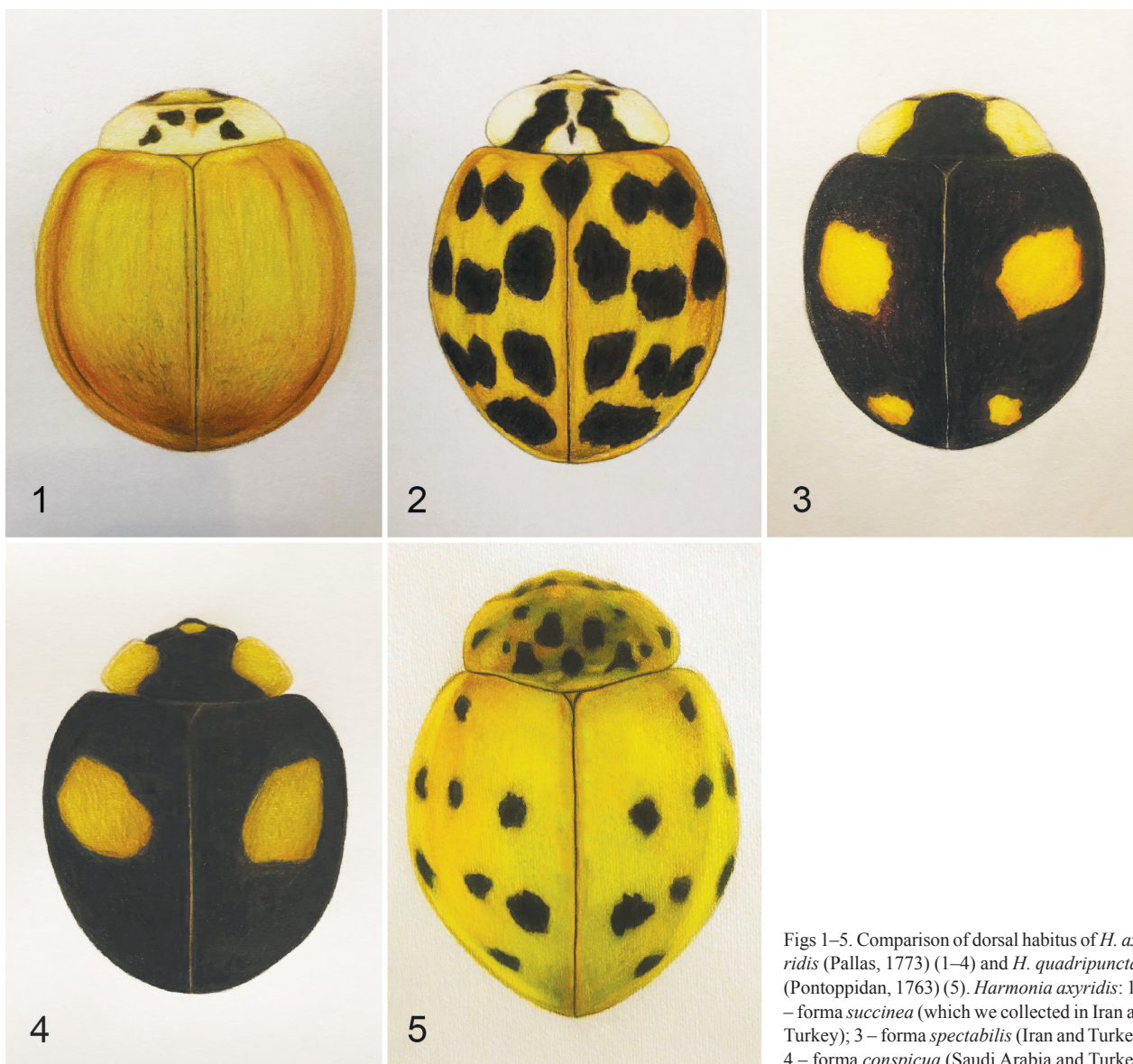
= *Leis* Mulsant, 1850; *Ballia* Mulsant, 1853; *Callineda* Crotch, 1871; *Stictoleis* Crotch, 1874; *Ptychanatis* Crotch, 1874; *Rhopalonedra* Timberlake, 1943 (*sensu* ŚLIPIŃSKI 2007).

Diagnosis. Length 4–8 mm. Elytra moderately to strongly convex, glabrous; elytral color pattern variable. Clypeus anteriorly straight between lateral projections. Antenna composed of 11 antennomeres, slightly shorter than the width of head capsule, with club moderately compact, composed of three antennomeres (Fig. 9). Terminal maxillary palpomere securiform (Fig. 11). Pronotal disc evenly convex, transverse with narrowly upturned and/or slightly thickened external borders. Prothoracic hypomeron without fovea near anterior angles; prosternal process without or with distinct lateral carinae extending anteriorly (Figs 6–7). Anterior margin of mesoventrite weakly foveate medially to straight. Elytral lateral margins narrowly raised; epipleuron not foveate. Apices of middle and hind tibiae without spurs (Fig. 8). Abdominal postcoxal lines not recurved, incomplete laterally (Fig. 12). Penis stout, consists of basal sclerite and additional apical piece. Ovipositor with coxites club-handle type; infundibulum present; spermatheca C-shaped.

Key to species of *Harmonia* in the Middle East

- 1 Body strongly convex. Pronotum white with 4 or 5 black dots in M shape, or with large trapezoid black patch in center leaving only lateral margins white. Elytra black, each elytron with 2 or 4 yellow-reddish spots; or elytra yellow to red, each elytron with maximum 10 black spots in 4 rows (2½–3–3–1) (Figs 1–4). Prosternal process carinate (Fig. 6). Male genitalia as in Figs 14–16. Penis with tip after constriction about two times longer than wide. Penis guide from lateral view with apex clearly bent upwards. Body length 6.5–7.2 mm. *H. axyridis* (Pallas, 1773)
- Body slightly convex. Pronotum white to yellowish, with 11 black dots; 5 large in M shape in center, 6 small laterally. Elytra yellow, each elytron with maximum 8 black spots in 4 rows (1–3–3–1) (Fig. 5). Prosternal process without carinae (Fig. 7). Male genitalia as in Figs 17–19. Penis with tip after constriction about four times longer than wide. Penis guide from lateral view straight. Body length 5.1–6.6 mm. *H. quadripunctata* (Pontoppidan, 1763)*

*Elytral background color is a complicated mixture of reddish brown and cream in European specimens. Prosternal carinae can be found in Central European specimens, but not in Middle Eastern populations.



Figs 1–5. Comparison of dorsal habitus of *H. axyridis* (Pallas, 1773) (1–4) and *H. quadripunctata* (Pontoppidan, 1763) (5). *Harmonia axyridis*: 1, 2 – forma *succinea* (which we collected in Iran and Turkey); 3 – forma *spectabilis* (Iran and Turkey); 4 – forma *conspicua* (Saudi Arabia and Turkey).

Harmonia axyridis (Pallas, 1773)

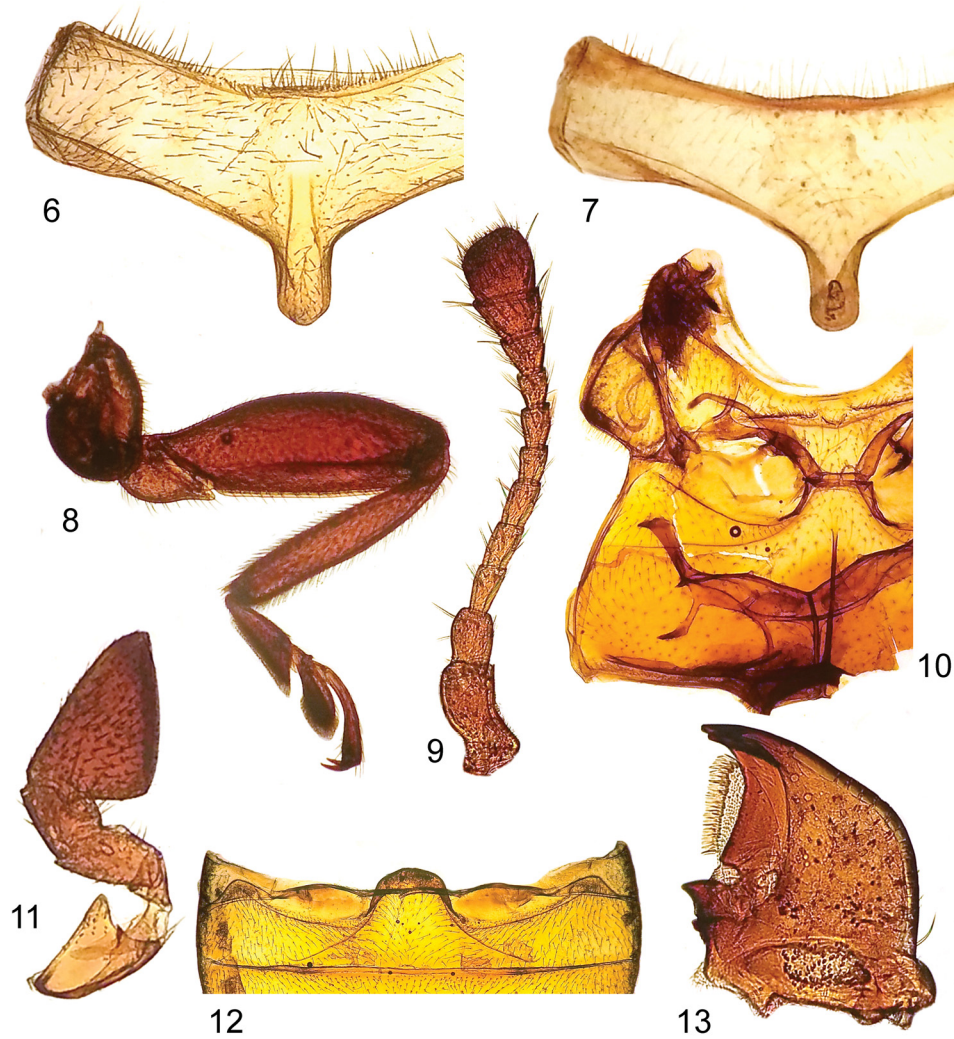
Figs 1–4, 6, 14–16, 20

Coccinella axyridis Pallas, 1773.

Material examined. **IRAN:** GILAN PROVINCE: Rudсар County, Rudсар, 37°8'11.739"N, 50°16'55.037"E, vi.2016, 2 spec., ex *Corylus* sp., Z. M. Hagghadam leg., A. Biranvand det.; Rasht County, Rasht, Melat Park, 37°17'27.151"N, 49°35'47.65"E, iii.–ix.2016 + 2017, 85 ♂♂, 230 ♀♀, ex *Corylus* sp., *Hibiscus* sp., *Lagerstroemia* sp., *Nerium* sp., *Populus* sp., *Prunus* sp., *Robinia* sp., Z. M. Hagghadam & M. Mardani-Talae leg., A. Biranvand & O. Nedved det.; Fuman County, Fuman, Shahr Park, 37°13'51.45"N, 49°19'6.134"E, viii.2017, 1 spec., ex *Lagerstroemia* sp., Z. M. Hagghadam leg., A. Biranvand det.; Langarud County, Langarud, 37°11'33.1"N, 50°09'09.2"E, vii.2017, 5 spec., ex *Citrus* sp., Z. M. Hagghadam leg., A. Biranvand det.; Lahijan County, Lahijan, 37°11'22.652"N, 50°1'10.229"E, viii.2017, 2 spec., ex *Quora* sp., Z. M. Hagghadam leg., A. Biranvand det. **MAZANDARAN PROVINCE:** Nur County, Chamestan, vii.2017, 1 spec., E. Shafiee & E. Dehghan leg., M. Z. Khormizi det.; Ramsar County, Sadat Shahr, 36°53'21.449"N, 50°41'45.658"E, vii.2017, 1 spec., E. Shafiee & E. Dehghan leg., M. Z. Khormizi det. **SAUDI ARABIA:** RIYADH PROVINCE: Diriyah, 24°48'43.39"N 46°31'17.27"E, v.2005, 1 spec. (forma *conspicua*), S. A. Turkestani leg., A. N. Al Ansi det. **TURKEY:** BILECIK PROVINCE: Bilecik Central District, Pelitözü, 40°11'6.9756"N, 29°58'5.5704"E, xi.2014, ix.–xi.2015, iii.–viii.2016, 55 spec., ex *Cydonia* sp., *Juglans* sp.,

Malus sp., *Medicago* sp., *Morus* sp., *Phaseolus* sp., *Prunus* sp., weeds, inside buildings, D. Şenal leg. et det.; Osmaneli District, Sarıyazı village, 40°27'19.188"N, 29°56'22.56"E, xi.2014, xi.2015, vi.2016, 10 spec., ex *Abelmoschus* sp., *Cydonia* sp., *Paliurus* sp., *Solanum* sp., *Triticum* sp., D. Şenal leg. et det.; Yenipazar District, 2.5 km NW Yenipazar, Gölpazarı Yenipazar Yolu, 40°11'30.048"N, 30°30'5.184"E, vi.–xi.2015, vi.–x.2016, 46 spec., ex *Helianthus* sp., *Medicago* sp., *Paliurus* sp., *Prunus* sp., *Pyrus* sp., *Triticum* sp., *Vitis* sp., D. Şenal leg. et det.; Söğüt District, Küre, 40°5'14.892"N, 30°9'2.7936"E, vii.–xi.2015, vi.–viii.2016, 20 spec., ex *Abelmoschus* sp., *Capsicum* sp., *Cucurbita* sp., *Juglans* sp., *Medicago* sp., *Mentha* sp., *Phaseolus* sp., *Prunus* sp., *Solanum* sp., weeds, D. Şenal leg. et det.; Pazaryeri District, Arapdede, 39°59'40.92"N, 29°52'44.328"E, viii.–xi.2015, vi.–viii.2016, 25 spec., ex *Humulus* sp., *Juglans* sp., *Malus* sp., *Medicago* sp., *Pinus* sp., D. Şenal leg. et det.; Bozüyük District, 1.6 km NW Çokçapınar, Çokçapınar Eceköy Yolu, 39°46'19.2"N, 29°58'3.9"E, ix.2015, viii.2016, 4 spec., ex *Medicago* sp., *Quercus* sp., D. Şenal leg. et det.; Gölpazarı District, 4.2 km SW Gölpazarı, Reşadiye Mahallesi, 40°15'53.2764"N, 30°16'26.5044"E, viii.–xi.2015, vii.2016, 25 spec., ex *Helianthus* sp., *Malus* sp., *Prunus* sp., weeds, D. Şenal leg. et det.; İnhisar District, Karağaça Mahallesi, Mihalgazi – İnhisar Yolu, 40°2'42.36"N, 30°24'9.684"E, vii.–xi.2015, vi.2016, 67 spec., ex *Capsicum* sp., *Paliurus* sp., *Punica* sp., *Solanum* sp., weeds, D. Şenal leg. et det.

Notes. The specimen of *H. axyridis* from Saudi Arabia was already collected in 2005 but remained unidentified



Figs 6–13. Morphological characters of *Harmonia* species: 6 – *H. axyridis* (Pallas, 1773), prosternum. 7–13 – *Harmonia quadripunctata* (Pontoppidan, 1763): 7 – prosternum; 8 – hind leg; 9 – antenna; 10 – meso- and metaventrites; 11 – maxillary palp; 12 – abdominal ventrite 1 with postcoxal lines; 13 – mandible.

until now. As a result, this is the first formal report of *H. axyridis* from Saudi Arabia.

The first published reports of this species in Turkey were from 2011, collected in the European part of the country, in Tekirdağ Province (AYSAL & KIVAN 2014). Other recent collections were made in several localities in the provinces of Bartın (TOPER KAYGIN & SOBUTAY KAPTAN 2017), Çanakkale (BAŞTUĞ & KASAP 2015), Düzce (ÖZTEMİZ & YAYLA 2018), Isparta (OĞUZUĞLU 2017), Tekirdağ (AYSAL & KIVAN 2014), and Yozgat (TİFTİKÇİ 2017). A single specimen has been found in Nevşehir Province, in the vicinity of Göreme (BUKEJS & TELNOV 2015). This was suggested to be the first report of *H. axyridis* for Turkey but it was only collected in July 2013, whereas several specimens from Tekirdağ Province were collected in 2011–2012 (AYSAL & KIVAN 2014).

In Iran, *H. axyridis* was for the first time collected in April 2016, from the city of Rasht in Gilan Province (MARDANI-TALAEI et al. 2019). Similar to what these authors found, we collected many adults from various host plants. Moreover, *H. axyridis* was reported from Israel based on a single specimen (forma *succinea*) collected in 2017 from Kibbutz Netzer Sereni (MIENIS 2017). All

known records of *H. axyridis* from the Middle East are summarized in Fig. 20.

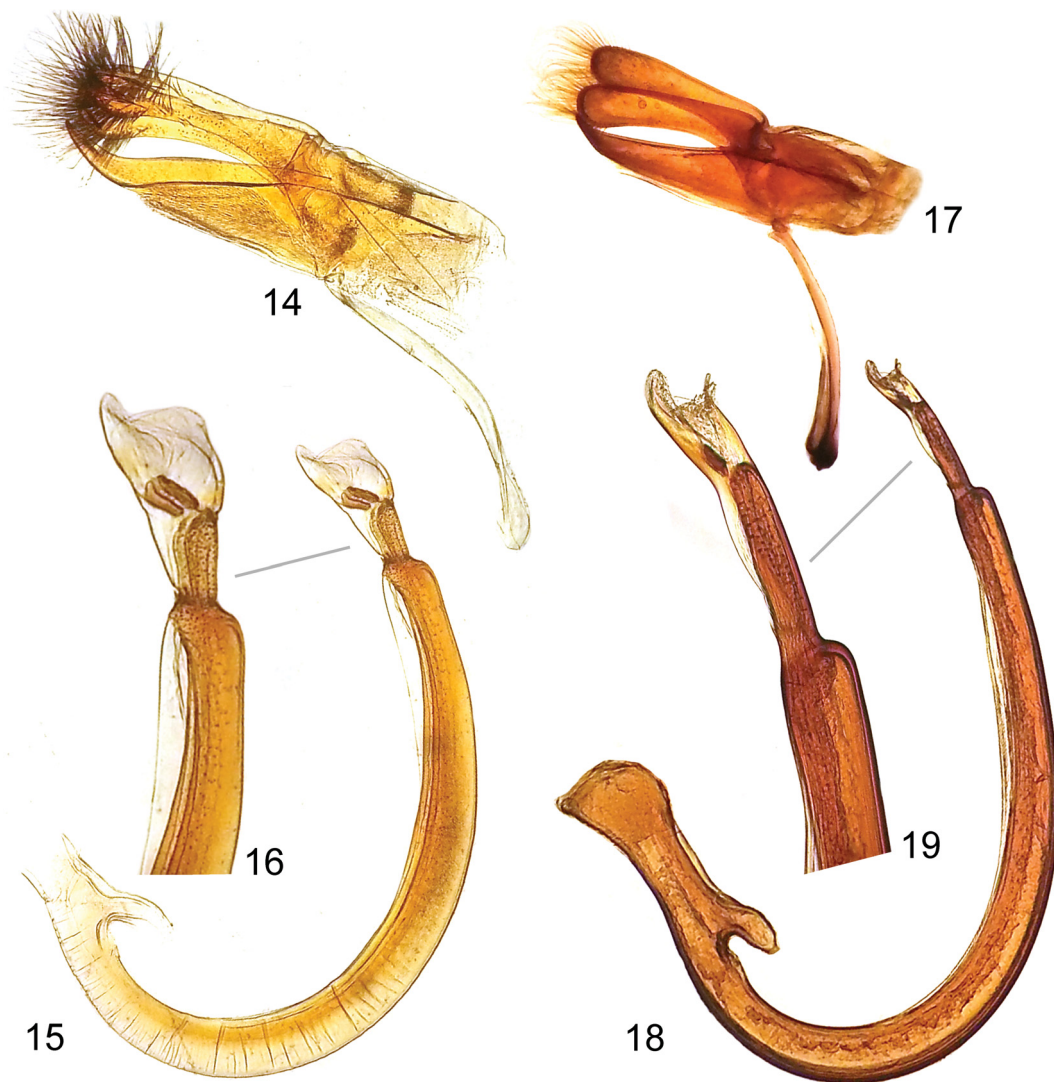
Harmonia quadripunctata (Pontoppidan, 1763)

Figs 5, 7–13, 17–19

Coccinella quadripunctata Pontoppidan, 1763; *C. albida* Gmelin, 1790; *C. marginella* Müller, 1776; *C. marginepunctata* Schaller, 1783; *C. notata* Olivier, 1791; *C. sedecimpunctata* Fabricius, 1781.

Material examined. IRAN: NORTH KHORASAN PROVINCE: Bojnord County, Bojnurd, Baba Aman Park, 37°29.338'N, 57°26.123'E, vi.2013, 4 ♂♂ 4 ♀♀, (3 ♂♂ 2 ♀♀ ex *Hordeum* sp.), E. Hamidi leg., O. Nedvď & C. Canepari det. SEMNAN PROVINCE: Shahrud County, Bastam, 36°30.314'N, 55°00.290'E, v.2014, 2 ♂♂ 1 ♀, M. Toozandjani leg., A. Biranvand det. TURKEY: BILECİK PROVINCE: Bilecik Central District, Pelitözü, 40°11'06.9756"N, 29°58'05.5704"E, iv.–xi.2015, vii.2016, 31 spec., ex *Malus* sp., *Pinus* sp., *Prunus* sp., weeds, D. Şenal leg. et det.; Osmanieli District, 2.6 km NE Düzmeşe, 40°23'55.5"N, 29°56'40.092"E, vi.–ix.2015, vi.–viii.2016, 5 spec., ex *Olea* sp., *Paliurus* sp., *Prunus* spp., D. Şenal leg. et det.; İnhisar District, Güner Orbay Mahallesi, 1.9 km NW İnhisar, 40°03'37.116"N, 30°22'5.088"E, vi.2016, 1 spec., ex *Paliurus* sp., D. Şenal leg. et det.

Notes. *Harmonia quadripunctata* was originally described from Denmark (PONTOPPIDAN 1763). It is native to the



Figs 14–19. Comparison of male genitalia of *H. axyridis* (Pallas, 1773) (14–16) and *H. quadripunctata* (Pontoppidan, 1763) (17–19): 14, 17 – tegmen; 15, 18 – penis; 16, 19 – penis apex. All in lateral view.

Palaearctic Region, distributed especially in Europe and eastern Asia – Russia, China, and Korea (BIELAWSKI 1963, 1980; VANDENBERG 1990; PANG et al. 2004; KOVÁŘ 2007). However, there are some reports of this species from other countries of the Palaearctic Region including Syria (KHALIL & MOURAD 2006), Israel (HALPERIN et al. 1995), Lebanon and Turkey (GÜNTHER 1958, BIELAWSKI 1963). *Harmonia quadripunctata* was introduced into the USA and reported there since 1924 (VANDENBERG 1990). In southern America, introduced populations have only been reported from Argentina and Chile so far (GONZÁLEZ 2006).

The earliest record of *H. quadripunctata* in Turkey was provided by GÜNTHER (1958). Since then, many studies reported *H. quadripunctata* in 22 of Turkey's 81 provinces: Ankara (GÜNTHER 1958, UYGUN 1981, ÜLGENTÜRK & TOROS 2000), Kayseri (GÜNTHER 1958), Konya (GÜNTHER 1958, ŞAHBAZ & UYSAL 2006), Adana, Afyon, Bursa, Denizli (UYGUN 1981), Isparta (UYGUN, 1981, ASLAN & KARACA 2005, KARACA et al. 2006, KAYA BAŞAR & YAŞAR 2011, OĞUZOĞLU 2017), Amasya, Samsun, Tokat (KILIÇ & AYKAÇ 1989), Erzurum (ÖZBEK & ÇETİN 1991), İzmir,

Manisa (TEZCAN & UYGUN 2003), Kahramanmaraş (ASLAN & UYGUN 2005), Balıkesir (VURAL VARLI et al. 2013), Artvin (PORTAKALDALI & SATAR 2010), Çanakkale (BAŞTUĞ & KASAP 2015), Bartın (TOPER KAYGIN & SOBUTAY KAPTAN 2017), Yozgat (TİFTİKÇİ 2017), Düzce (ÖZTEMİZ & YAYLA 2018), and Bilecik (this study).

In Iran, *H. quadripunctata* was first reported from North Khorasan Province in 2013 (BIRANVAND et al. 2017). It was subsequently reported from Mazandaran Province, in northern Iran (PAHLAVAN YALI et al. 2017). Here, we present the first report from Semnan Province.

Discussion

Predatory insects, especially members of the family Coccinellidae, play a principal role in natural pest control regulating the population density of insect pests. Sometimes, however, the introduction of invasive predators into new ecosystems, either accidentally or through biological controlling programs, can induce unanticipated and undesirable effects (KOCH et al. 2006, ROY et al. 2016). These



Fig 20. Currently known distribution of *H. axyridis* in the Middle East region, with reports in Iran, Israel, Saudi Arabia, and Turkey.

include unwanted impact on endemic natural enemies. Monitoring of new (alien or invasive) species in the Middle East is important for biosecurity – considering their either detrimental or beneficial role in agriculture – and for ecosystem services.

Until now, two species of the genus *Harmonia* were recorded from various countries in the Middle East region: *H. axyridis* and *H. quadripunctata*. RAIMUNDO & VAN HARTEN (2000) also reported *H. pardalina* (Gerstäcker, 1871) from Yemen but we are convinced that this species is incorrectly classified in the genus *Harmonia* based on morphological characters. For example, species of *Harmonia* are characterized by the lack of tibial spurs (see Fig. 8) but *H. pardalina* clearly shows tibial spurs (O. Nedvěd et al., unpubl. data). The formal reclassification of this species in another genus based on morphological and molecular data will be done in a subsequent study.

A recent study (GREZ et al. 2017) reported *H. axyridis* at high altitudes in the Chilean Andes between 2790 and 3578 m a.s.l. The authors highlighted two important issues: 1) the presence of *H. axyridis* in an extreme environment, and 2) the dispersal of *H. axyridis* during summer from alfalfa crops in central Chile to higher altitudes, where temperatures are lower and more favorable. Here, we reported *H. axyridis* in arguably one of the hottest and driest areas on Earth (Saudi Arabia, with a hot desert climate; PEEL et al. 2007). The single record from Diriyah is most likely the result of high volume of international trade in this area. The introduction of invasive species – as well as the co-introduction of their natural enemies – in non-native areas has become a serious concern with ever-expanding world trade practices and climate change (e.g., PIMENTEL et al. 2005, ROSSMAN 2009, PFLIEGLER et al. 2018).

BENELLI et al. (2015) found that both fecundity and fertility of Italian *H. axyridis* were significantly lower at 30°C than at 25°C. Similarly, KNAPP & NEDVĚD (2013) showed that exposing Central European *H. axyridis* specimens to 33°C significantly decreases hatching and survival rates of different developmental stages (except for fourth instar larvae and pupae). The average temperature in July is 35°C (with average maxima up to 48°C) in Saudi Arabia's capital Riyadh, of which Diriyah is located at the northwestern outskirts. Even when multiple individuals are unintentionally released, these high summer temperatures likely limit successful spreading of *H. axyridis* in Saudi Arabia (but see AMEIXA et al. 2019). Another factor in halting the southern spreading of *H. axyridis* is scarcity of prey (HONĚK et al. 2017, SOARES et al. 2017). Aphids in abundance only seem to occur in large patches of major crops (e.g., cereals, alfalfa, sugar beet) and weeds, typical for temperate regions. To date, we have not observed other adults or individuals of other developmental stages (eggs, larvae, pupae) in Saudi Arabia. This is contrary to MARDANI-TALLAEI et al. (2019) who collected all developmental stages in Gilan Province, Iran where *H. axyridis* is considered established for this reason. According to our surveys, the species is spreading in most cities of Gilan Province along the Caspian Sea. In Turkey, the dominance of *H. axyridis* in Bartın Province (82 specimens, total $n = 137$) (TOPER KAYGIN & SOBUTAY KAPTAN 2017), in combination with the 100s of specimens collected in Bilecik Province (this study), leads us to hypothesizing that this species is fastly spreading in the Asian parts of Turkey.

Strong bias of sex ratio in the invasive population of *H. axyridis* in Rasht (Iran) suggests high prevalence of male-killing bacteria in the population. These are bacterial endosymbionts in the genera *Rickettsia*, *Spiroplasma*,

and *Wolbachia*, which are common among ladybirds but generally only infect a small proportion of populations (WEINERT et al. 2007). GORYACHEVA et al. (2017) found no infection of invasive populations (in Czech Republic, Germany, Italy, Russia, and the USA) with *Spiroplasma*, whereas all native populations were found with the bacterium. *Rickettsia* and *Wolbachia*, on the other hand, were found in both invasive (1.12% of females infected for both bacteria, $n = 179$) and native populations (0.51% and 1.02% of females infected, respectively; $n = 196$). Continued collecting efforts in the Middle East region will be accompanied by efforts to screen female ladybirds for presence of bacteria using amplification of the *fbpA* (for *Wolbachia*) and *gltA* (for *Rickettsia* and *Spiroplasma*) genes with specific primers (BALDO et al. 2006, GORYACHEVA et al. 2017).

Online supporting information

Additional Supporting Information may be found in the Zenodo Archive under the DOI reference <https://doi.org/10.5281/zenodo.2641797>.

Table S1. List of Middle Eastern cities with available temperature and precipitation data, usually from between 1961 and 1990.

Acknowledgements

The authors are thankful to Andris Bukejs (Daugavpils University, Latvia), Morelia Camacho-Cervantes (Universidad Nacional Autónoma de México), Guillermo González (La Reine, Chile), Zvi Mendel (Agricultural Research Organization, Israel), Vincent Nicolas (Saint-Junien, France), Özge Özden (Near East University, Northern Cyprus), and Mona Toozandejani (Shahrood University of Technology, Iran) for general support and assistance in data collection. Shayan Khorshidvand is acknowledged for preparing the illustrations in Figs 1–5. Four anonymous reviewers are thanked for providing many constructive suggestions, without which the manuscript would have been a lot more meager.

References

- AMEIXA O. M. C. C., ŠIPOŠ J., BURDA M., SOARES A. M. V. M. & SOARES A. O. 2019: Factors influencing the introduction and spread of *Harmonia axyridis* in the Iberian Peninsula. *Biological Invasions* **21**: 323–331.
- ASLAN B. & KARACA İ. 2005: Fruit tree aphids and their natural enemies in Isparta region, Turkey. *Journal of Pest Science* **78**: 227–229.
- ASLAN M. M. & UYGUN N. 2005: The aphidophagous coccinellid (Coleoptera: Coccinellidae) species in Kahramanmaraş, Turkey. *Turkish Journal of Zoology* **29**: 1–8.
- AYSAL T. & KIVAN M. 2014: Occurrence of an invasive alien species *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in Turkey. *Türkiye Entomoloji Bülteni* **4**: 141–146.
- BALDOL., DUNNING HOTOPP J. C., JOLLEY K. A., BORDENSTEIN S. R., BIBER S. A., CHOUDHURY R. R., HAYASHI C., MAIDEN M. C. J., TETTELIN H. & WERREN J. H. 2006: Multilocus sequence typing system for the endosymbiont *Wolbachia pipientis*. *Applied and Environmental Microbiology* **72**: 7098–7110.
- BAŞTUĞ G. & KASAP İ. 2015: Faunistic studies on Coccinellidae (Coleoptera) family in the province of Çanakkale. *Turkish Journal of Biological Control* **6**: 41–50.
- BENELLI M., LEATHER S. R., FRANCATI S., MARCHETTI E. & DINDO M. L. 2015: Effect of two temperatures on biological traits and susceptibility to a pyrethroid insecticide in an exotic and native coccinellid species. *Bulletin of Insectology* **68**: 23–29.
- BIELAWSKI R. 1963: Coccinellidae (Coleoptera) iz Bliźnego Vostoka. *Fragmenta Faunistica* (Warszawa) **10**: 391–398.
- BIELAWSKI R. 1980: Die Marienkäfer (Coleoptera: Coccinellidae) der Koreanischen Volksdemokratischen Republik. *Fragmenta Faunistica* (Warszawa) **25**: 221–254.
- BIRANVANDA., NEDVĚD O., SHAKARAMI J., FEKRAT L., HAMI-DI E., VOLF M. & HANLEY G. A. 2017: The ladybeetle community (Coleoptera: Coccinellidae) in North East of Iran. *Baltic Journal of Coleopterology* **17**: 49–67.
- BUKEJS A. & TELNOV D. 2015: The first record of the invasive lady beetle *Harmonia axyridis* (Pallas, 1773) (Coleoptera: Coccinellidae) in Turkey. *Zoology and Ecology* **25**: 59–62.
- CAMACHO-CERVANTES M., ORTEGA-ITURRIAGAA. & DEL-VAL E. 2017: From effective biocontrol agent to successful invader: the harlequin ladybird (*Harmonia axyridis*) as an example of good ideas that could go wrong. *PeerJ* **5** (e3296): 1–16.
- CERYNGIER P., NEDVĚD O., GREZ A. A., RIDDICK E. W., ROY H. E., SAN MARTIN G., STEENBERG T., VESELÝ P., ZAVIEZO T., ZÚÑIGA-REINOSO Á. & HAELEWATERS D. 2018: Predators and parasitoids of the harlequin ladybird, *Harmonia axyridis*, in its native range and invaded areas. *Biological Invasions* **20**: 1009–1031.
- GONZÁLEZ G. 2006: *Los Coccinellidae de Chile*. Permanent electronic publication available at <http://www.coccinellidae.cl> (Accessed on 23 December 2017).
- GORYACHEVA I., BLEKHMANA., ANDRIANOV B. & ZAKHAROV I. 2017: Heritable bacterial endosymbionts in native and invasive populations of *Harmonia axyridis*. *Biological Invasions* **19**: 493–502.
- GREZ A. A., ZAVIEZO T., ROY H. E., BROWN P. M. J. & BIZAMA G. 2016: Rapid spread of *Harmonia axyridis* in Chile and its effects on local coccinellid biodiversity. *Diversity and Distributions* **22**: 982–994.
- GREZ A. A., ZAVIEZO T., ROY H. E., BROWN P. M. J. & SEGURA B. 2017: In the shadow of the condor: invasive *Harmonia axyridis* found at very high altitude in the Chilean Andes. *Insect Conservation and Diversity* **10**: 483–487.
- GÜNTHER V. 1958: Ergebnisse der zoologischen Expedition des National Museums in Prag nach der Türkei. 22. Coleoptera Coccinellidae. *Acta Entomologica Musei Nationalis Pragae* **32**: 19–36.
- HAELEWATERS D. & DE KESELA. 2017: De schimmel *Hesperomyces virescens*, een natuurlijke vijand van lieveheersbeestjes. [The fungus *Hesperomyces virescens*, a natural enemy of ladybirds]. *Entomologische Berichten* **77**: 106–118 (in Dutch, English abstract).
- HAELEWATERS D., ZHAO S. Y., CLUSELLA-TRULLAS S., COTTELL T. E., DE KESELA., FIEDLER L., HERZ A., HESKETH H., HUI C., KLEESPIES R. G., LOSEY J. E., MINNAAR I. A., MURRAY K. M., NEDVĚD O., PFLIEGLER W. P., RAAK-VAN DEN BERG C. L., RIDDICK E. W., SHAPIRO-ILAN D. I., SMYTH R. R., STEENBERG T., VAN WIELINK P. S., VIGLÁŠOVÁ S., ZHAO Z., CERYNGIER P. & ROY H. E. 2017: Parasites of *Harmonia axyridis*: current research and perspectives. *BioControl* **62**: 355–371.
- HALPERIN J., MERKL O. & KEHAT M. 1995: An annotated list of the Coccinellidae (Coleoptera) of Israel and adjacent areas. *Phytoparasitica* **23**: 127–137.
- HONĚK A., DIXON A. F., SOARES A. O., SKUHROVEC J. & MARTINKOVA Z. 2017: Spatial and temporal changes in the abundance and composition of ladybird (Coleoptera: Coccinellidae) communities. *Current Opinion in Insect Science* **20**: 61–67.
- HONĚK A., MARTINKOVA Z., DIXON A. F. G., ROY H. E. & PEKÁR S. 2016: Long-term changes in communities of native coccinellids: population fluctuations and the effect of competition from an invasive non-native species. *Insect Conservation and Diversity* **9**: 202–209.
- KARACA İ., KARSAVURAN Y., AVCI M., DEMİRÖZER O., ASLAN B., SÖKELİ E. & BULUTH S. 2006: Faunistic studies on Coleoptera species of Isparta province (Turkey). *Süleyman Demirel University, Journal of Science and Technology Institute* **10**: 180–184.
- KATSANIS A., BABENDREIER D., NENTWIG W. & KENIS M. 2013: Intraguild predation between the invasive ladybird *Harmonia axyridis* and non-target European coccinellid species. *BioControl* **58**: 73–83.

- KAYA BAŞAR M. & YAŞAR B. 2011: Determination of ladybird species (Coleoptera: Coccinellidae) on fruit trees in Isparta, Turkey. *Turkish Journal of Entomology* **35**: 519–534.
- KHALIL N. & MOURADA A. R. 2006: A preliminary survey of ladybirds (Coccinellidae) on coniferales in south of Syria. *Bassel Al-Assad Journal for Engineering Sciences* **22**: 147–165.
- KILIÇ M. & AYKAÇ M. K. 1989: Karadeniz bölgesi şeftali bahçelerindeki zararlılarla mücadelenin yönetimi üzerinde araştırmalar. [Investigations on the pest management in peach orchards in the black sea region of Turkey]. *Bitki Koruma Bülteni* **29**: 211–241 (in Turkish, English summary).
- KNAPP M. & NEDVĚD O. 2013: Gender and timing during ontogeny matter: effects of a temporary high temperature on survival, body size and colouration in *Harmonia axyridis*. *Plos One* **8** (9) (e74984): 1–9.
- KOCH R. L., VENETTE R. C. & HUTCHISON W. D. 2006: Invasions by *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in the Western Hemisphere: implications for South America. *Neotropical Entomology* **35**: 421–434.
- KOVÁŘ I. 2007: Family Coccinellidae Latreille 1807. Pp. 568–631. In: LÖBLI & SMETANAA. (eds): *Catalogue of Palaearctic Coleoptera. Volume 4. Elateroidea, Derodontoidea, Bostrichoidea, Lymexyloidea, Cleroidea, Cucujoidea*. Apollo Books, Stenstrup, 935 pp.
- LOMBAERT E., GUILLEMAUD T., CORNUET J.-M., MALAUSA T., FACON B. & ESTOUP A. 2010: Bridgehead effect in the worldwide invasion of the biocontrol harlequin ladybird. *Plos One* **5** (e9743): 1–7.
- LOMBAERT E., GUILLEMAUD T., LUNDGREN J., KOCH R., FACON B., GREZ A., LOOMANS A., MALAUSA T., NEDVĚD O., RHULE E., STAVERLOKK A., STEENBERG T. & ESTOUP A. 2014: Complementarity of statistical treatments to reconstruct worldwide routes of invasion: the case of the Asian ladybird *Harmonia axyridis*. *Molecular Ecology* **23**: 5979–5997.
- MARDANI-TALAE M., ZIBAE A., RAHIMI V., KHORMIZI M. Z., MOZAFAR MANSOURI S. & NEDVĚD O. 2019: Occurrence of invasive lady beetle *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in Iran. *Coleopterists Bulletin* **73**: 1–7.
- MIENIS H. K. 2017: A first record of the harlequin ladybird *Harmonia axyridis* from Israel (Coleoptera, Coccinellidae). *Natural History and Other Notes* **14**: 5–7.
- NEDVĚD O. & HÁVA J. 2016: New record of the invasive ladybeetle *Harmonia axyridis* in afro-tropical region: Tanzania, Zanzibar. *African Entomology* **24**: 247–249.
- NEDVĚD O., HÁVA J. & KULÍKOVÁ D. 2011: Record of the invasive alien ladybird *Harmonia axyridis* (Coleoptera, Coccinellidae) from Kenya. *ZooKeys* **106**: 77–81.
- OĞUZOĞLU Ş. 2017. *Cinara cedri* 'nin Isparta Orman Bölge Müdürlüğü Sedir Ormanlarında Yayılışı, Zararı, Biyolojisi ve Doğal Düşmanları. [Distribution, damage, biology and natural enemies of *Cinara cedri* in Isparta forest regional directorate cedar forests]. Thesis deposited at Department of Forest Engineering, Süleyman Demirel University, Isparta, 116 pp.
- ÖZBEK H. & ÇETİN G. 1991: Contribution to the fauna Coccinellidae (Coleoptera) from eastern Anatolia along with some new records from Turkey. *Turkish Journal of Entomology* **15**: 193–202.
- ÖZTEMİZ S. & YAYLA Ş. 2018: Two new species of *Harmonia* (Coleoptera: Coccinellidae) from Düzce, Turkey. *Munis Entomology & Zoology* **13**: 318–322.
- PAHLAVAN YALI K., PASHAI RAD S., KHORMIZI M. Z., HAGHGHADAM Z. M., HEIDARI LATIBARI M., HANLY G. 2017: Research on Coccinellidae (Coleoptera) fauna in Mazandaran province, Iran. *Journal of Biological Control* **31**: 123–127.
- PANG H., PANG X. F., REN S. X. & ZENG T. 2004: *Biodiversity and their utilization of Coccinellidae in China*. Guangdong Science and Technology Press, Guangzhou, 168 pp.
- PEEL M. C., FINLAYSON B. L. & McMAHON T. A. 2007: Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences Discussions* **4**: 439–473.
- PFLIEGLER W. P., BÁTHORIF., WANG T. W., TARTALLY A. & HAELEWATERS D. 2018: Herpomyces ectoparasitic fungi (Ascomycota, Laboulbeniales) are globally distributed by their invasive cockroach hosts and through the pet trade industry. *Mycologia* **110**: 39–46.
- PIMENTEL D., ZUNIGA R. & MORRISON D. 2005: Update on the environmental and economic costs associated with alien-invasive species in the U.S. *Ecological Economics* **52**: 273–288.
- PONTOPIPIDAN E. 1763: *Den Danske Atlas, eller Konge-Riget Dan-nemark. Efter Høy-Kongelig allernaadigst Befaling. Tomus I. A. H.* Godiche, Copenhagen, 723 pp.
- PORTAKALDALI M. & SATAR S. 2010: Research on Coccinellidae (Coleoptera) fauna in Artvin and Rize province. *Bulletin of Plant Protection* **50**: 89–99.
- RAIMUNDO A. A. & VAN HARTEN A. 2000: An annotated checklist of the Coccinellidae (Insecta: Coleoptera) of Yemen. *Fauna Arabia* **18**: 211–243.
- ROSSMAN A.Y. 2009: The impact of invasive fungi on agricultural ecosystems in the United States. *Biological Invasions* **11**: 97–107.
- ROY H. E., BROWN P. M. J., ADRIAENS T., BERKVENNS N., BORGES I., CLUSELLA-TRULLAS S., COMONT R. F., DE CLERCQ P., ESCHEN R., ESTOUP A., EVANS E. W., FACON B., GARDINER M. M., GIL A., GREZ A. A., GUILLEMAUD T., HAELEWATERS D., HERZ A., HONĚK A., HOWE A. G., HUI C., HUTCHISON W. D., KENIS M., KOCH R. L., KULFAN J., LAWSON HANDLEY L., LOMBAERT E., LOOMANS A., LOSEY J., LUKASHUK A. O., MAES D., MAGRO A., MURRAY K. M., MARTIN G. S., MARTINKOVA Z., MINNAAR I. A., NEDVĚD O., ORLOVA-BIENKOWSKAJA M. J., OSAWA N., RABITSCH W., RAVN H. P., RONDONI G., RORKE S. L., RYNDEVICH S. K., SAETHRE M.-G., SLOGGETT J. J., SOARES A. O., STALS R., TINSLEY M. C., VANDEREYCKEN A., VAN WIELINK P., VIGLÁŠOVÁ S., ZACH P., ZAKHAROV I. A., ZAVIEZO T. & ZHAO Z. 2016: The harlequin ladybird, *Harmonia axyridis*: global perspectives on invasion history and ecology. *Biological Invasions* **18**: 997–1044.
- ŞAHBAZ A. & UYSAL M. 2006: The predators and parasitoids of the aphid species (Homoptera: Aphididae) on poplars in Konya province of Turkey. *Selcuk Journal of Agriculture and Food Sciences* **20**: 119–125.
- ŚLIPIŃSKIA. 2007: *Australian ladybird beetles (Coleoptera: Coccinellidae): their biology and classification*. Australian Biological Resources Study, Canberra, 286 pp.
- SOARES A. O., HONĚK A., MARTINKOVA Z., SKUHROVEC J., CARDOSO P. & BORGES I. 2017: *Harmonia axyridis* failed to establish in the Azores: the role of species richness, intraguild interactions and resource availability. *BioControl* **62**: 423–434.
- TEZCAN S. & UYGUN N. 2003: Evaluation of the Coccinellidae (Coleoptera) fauna of ecologically managed cherry orchards in İzmir and Manisa provinces of Turkey. *Turkish Journal of Entomology* **27**: 73–79.
- TIFTİKÇİ P. 2017: Studies on Coccinellidae species identified on sugar beet production areas in Yozgat province. *Journal of Natural and Applied Sciences* **33**: 79–90 (in Turkish, English abstract).
- TOPER KAYGIN A. & SOBUTAY KAPTAN U. 2017: Coccinellidae (Insecta: Coleoptera) species of Bartın Province. *Journal of Bartın Faculty of Forestry* **19**: 227–236.
- ÜLGENTÜRK S. & TOROS S. 2000: Preliminary studies on parasitoids and predators of Diaspididae (Homoptera: Coccoidea) species on park plants. *Journal of Agricultural Science* **6**: 106–110.
- UYGUN N. 1981: *Taksonomische Untersuchungen über die Coccinelliden Fauna (Coleoptera) der Türkei*. Çukurova University, Faculty of Agriculture Res. Publ. no. 157/48. Adana, Turkey.
- VANDENBERG N. J. 1990: First North American records for *Harmonia quadripunctata* (Pontopiddian) (Coleoptera: Coccinellidae), a lady beetle native to the Palaearctic. *Proceedings of the Entomological Society of Washington* **92**: 407–410.
- VURAL VARLI S., SAKIN G. & ÖNCÜL ABACIGİL T. 2013: The Coccinellidae (Coleoptera) species collected by different trap methods in olive orchards of Edremit Bay's (Balıkesir/Turkey). *Turkish Bulletin of Entomology* **3**: 151–160.
- WEINERT L. A., TINSLEY M. C., TEMPERLEY M. & JIGGINS F. M. 2007: Are we underestimating the diversity and incidence of insect bacterial symbionts? A case study in ladybird beetles. *Biology Letters* **3**: 678–681.
- WORLD METEOROLOGICAL ORGANIZATION. 1998: *1961–1990 global climate normals*. Available at <ftp://ftp.atdd.noaa.gov/pub/GCOS/WMO-Normals/> (accessed on 23rd December 2017).