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Research Article
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ALIEN APHIDS (HEMIPTERA: APHIDOMORPHA) OF TÜRKİYE

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Abstract: This study aims to show results of a prospective study on the relationship and the variation between the number of aphid species and the number of alien aphid species in Türkiye, the taxonomic diversity of alien aphids, their distribution in Türkiye and the regions of origin of alien aphids. The study showed the presence of 57 alien aphid species belonging to 32 genera from the Aphidomorpha infraorder (Hemiptera) recorded in Türkiye between 1903 and 2021. It was shown that the alien aphid constitute about 10% of the aphid fauna of Türkiye including 592 species belonging to 148 genera. Based on 119 years of data, the average introduction rate of alien aphids into the aphid fauna of Türkiye was calculated as 0.48 species per year. It was shown that the alien aphids are found in 60 to 81 different provinces in Türkiye. We conclude that more local and territorial studies should be carried out in order to evaluate details of the current status and distribution of alien aphids in Türkiye.

Özet: Bu çalışma Türkiye'deki afit ve yabancı afit türlerinin sayıları arasındaki ilişki ve değişim, yabancı afitlerin taksonomik çeşitliliği, Türkiye'deki dağılımı ve orijin bölgeleri üzerine önemli sonuçları göstermeyi amaçlamaktadır. Bu kapsamlı çalışma 1903 ve 2021 yılları arasında Türkiye'de kayıt edilen Aphidomorpha alttakımından (Hemiptera) 32 cinse ait 57 yabancı afit türünün varlığını ortaya koymaktadır. Yabancı afit türlerinin 148 cinse ait 592 türü barındıran Türkiye afit faunasının yaklaşık %10'unu oluşturduğu gösterilmiştir. 119 yıllık verilere dayanarak, yabancı afitlerin Türkiye afit faunasına giriş oranı yıllık 0,48 tür olarak hesaplanmıştır. Ayrıca, yabancı afitlerin Türkiye'nin 81 ilinin 60'ında bulunduğu gösterilmiştir. Sonuç olarak, Türkiye'de yabancı afitlerin güncel statüleri ve dağılımlarının detaylı olarak değerlendirilebilmesi için daha fazla bölgesel ve ülkesel çalışmanın yürütülmesi gerektiği düşünülmektedir.

Introduction

Alien species, which are non-native plants, animals, pathogens, and other organisms introduced into a new ecosystem, are one of the major threats to the environment, economy and biodiversity worldwide. In recent years, globalization and climate change have caused the transfer, establishment and reproduction of alien species in different regions of the world. More than 11,000 alien species, including aphids, are distributed throughout the European continent (Hulme *et al.* 2009). A temperature rise of 1.1 - 6.4°C by 2100 due to the emission of greenhouse gases in the world (IPCC 2007) is predicted to cause adverse effects on the biology, ecology and habitats of insects.

In the light of the above predictions, aphids which are highly sensitive to climatic changes have become more important due to their biological features that are rapidly affected by global warming. Aphids are one of the major agricultural pests that damage a large number of cultivated crops and forestry by sucking plant sap and secreting honeydew. They also vector more than 270 phytopathogenic viruses that cause serious economic damage to agricultural crops (Katis *et al.* 2007). These insects are mostly distributed in terrestrial ecosystems worldwide (Jouraeva *et al.* 2006, van Emden & Harrington 2007, Alford 2011, Diehl *et al.* 2013). Some biological functions of aphids such as survival, distribution and reproduction are influenced by temperature. Aphids are represented by 5321 extanct species mostly distributed in the temperate regions in the northern hemisphere (Favret 2022) due to the effect of temperature on their geographic distribution. Also, sexual reproduction in some aphid species is affected by temperature and this causes parthenogenetic reproduction to continue throughout the year. Higher temperatures (above 20°C) might delay or even totally prevent sexual

reproduction in some aphids (Blackman 1974). This means the emergence of new generations that reproduce and are active parthenogenetically throughout the year (Hullé *et al.* 2010). In addition, it was reported that there are strong relationships between the phenology of native or alien aphids and environmental variables for many species (Harrington *et al.* 2007).

Considering the effect of climatic factors on the aphids, there is a need for comprehensive detection and evaluation of alien aphids of Türkiye. The first studies on the aphid fauna of Türkiye date back to the beginning of the 20th century (Trotter 1903, Fahringer 1922, Houard 1922). In later years, Çanakçıoğlu (1975), Tuatay (1988, 1990, 1991, 1993, 1999), Remaudière *et al.* (2006), Görür *et al.* (2012), Kök & Özdemir (2021) reviewed and listed aphids of Türkiye including some alien species records. With the latest new records, the aphid fauna of Türkiye has reached 592 species belonging to 148 genera in the Aphidomorpha infraorder (Kök & Özdemir 2021, Oğuzoğlu *et al.* 2021). Also, Akyıldırım *et al.* (2013) revealed some information about the composition of the aphid fauna of Türkiye and the alien species.

Although many studies have been carried out on aphid fauna in different regions of Türkiye, detailed information about alien aphids is still very limited. This study aimed to present a comprehensive list of alien aphids and to show the alienness of aphid species recorded between 1903 and 2021 for the fauna of Türkiye.

Materials and Methods

The data on aphids used in this study is based on published papers of aphid and alien aphid species recorded in Türkiye between 1903 and 2021. The publications were obtained by searching Web of Science, Google Scholar and Google. Current taxonomic status and nomenclature of aphid species in "Aphids on the World's Plants. An Online Identification and Information Guide (http://www.aphidsonworldsplants.info)" (Blackman & Eastop 2022) and "The Aphid Species File (http://www.Aphid. SpeciesFile.org)" were followed (Favret 2022).

To determine the alien status of the aphid species, Coeur d'acier *et al.* (2010), Görür *et al.* (2012), Wieczorek (2011), Kök & Özdemir (2021), Oğuzoğlu *et al.* (2021), Blackman & Eastop (2022) were used. To reveal the relationship between the number of aphid species and alien aphid species in Türkiye between 1903 and 2021, Spearman's correlation test was applied by using Minitab 17.

Results

The results of our study revealed the presence of 57 alien aphid species belonging to 32 genera from the Aphidomorpha infraorder (Hemiptera) recorded in Türkiye between 1903 and 2021. The comprehensive checklist including the alien aphid species sorted by taxonomic order, their distribution in Türkiye and the origin regions is presented below.

Order HEMIPTERA Linnaeus

Suborder Sternorrhyncha Amyot & Serville

Infraorder Aphidomorpha Bekker-Migdisova & Aizenberg

Superfamily Adelgoidea Schouteden

Family Adelgidae Schouteden

Genus *Adelges* Vallot

Subgenus *Gilletteella* Börner

Adelges (*Gilletteella*) *cooleyi* (Gillette, 1907)

Distribution in Türkiye: Artvin, Rize (Görür *et al.* 2009a).

Origin region: North America.

Superfamily Aphidoidea Latreille

Family Aphididae Latreille

Subfamily Aphidinae Latreille

Tribe Aphidini Latreille

Subtribe Aphidina Latreille

Genus *Aphis* Linnaeus

Subgenus *Aphis* Linnaeus

Aphis (*Aphis*) *asclepiadis* Fitch, 1851

Distribution in Türkiye: Samsun (Akyürek *et al.* 2010), Artvin, Trabzon (Görür *et al.* 2009b), Yalova (Kuloğlu & Özder 2017), Erzurum (Başer & Tozlu 2020).

Origin region: North America.

Aphis (*Aphis*) *forbesi* Weed, 1889

Distribution in Türkiye: İzmir (Tuatay 1993), Mersin (Toros *et al.* 2002), Bursa (Kovancı *et al.* 2004).

Origin region: North America.

Aphis (*Aphis*) *illinoisensis* Shimer, 1866

Distribution in Türkiye: Adana, Hatay, Kilis (Remaudière *et al.* 2003), Niğde (Görür 2004a), İzmir (Eser *et al.* 2009), Isparta (Barjadze *et al.* 2011a), Mersin (Yanpar 2013), Afyonkarahisar, Kütahya (Görür 2014).

Origin region: North America.

Aphis (*Aphis*) *impatientis* Thomas, 1878

Distribution in Türkiye: Artvin, Trabzon (Görür *et al.* 2009a).

Origin region: North America.

Aphis (*Aphis*) *maculatae* Oestlund, 1887

Distribution in Türkiye: Karabük (Tepecik *et al.* 2011).

Origin region: North America.

Aphis (*Aphis*) *spiraecola* Patch, 1914

Distribution in Türkiye: Adana (Tuatay & Remaudière 1964), Hatay, Mersin (Toros *et al.* 2002), Diyarbakır (Ölmez Bayhan *et al.* 2003), Niğde (Görür 2004a),

Kahramanmaraş (Aslan & Uygun 2005), Denizli (Çıraklı *et al.* 2008), Bartın (Toper Kaygın *et al.* 2009), İzmir (Eser *et al.* 2009), Samsun (Akyürek *et al.* 2012), Artvin, Trabzon (Akyıldırım *et al.* 2014), Afyonkarahisar, Kütahya, Uşak (Görür 2014), Antalya (Saraç *et al.* 2015), Erzincan (Alaserhat 2015), Aydın (Yerlikaya *et al.* 2016), Balıkesir, Çanakkale (Kök & Kasap 2019), Erzurum (Başer & Tozlu 2020).

Origin region: East Asia.

Genus *Protaphis* Börner

Protaphis middletonii (Thomas, 1879)

Distribution in Türkiye: Samsun (Akyürek *et al.* 2011), Afyonkarahisar (Görür 2014).

Origin region: North America.

Genus *Siphonatrophia* Swain

Subgenus *Siphonatrophia* Swain

Siphonatrophia (*Siphonatrophia*) *cupressi* (Swain, 1918)

Distribution in Türkiye: Antalya, Burdur, Bilecik, Isparta (Oğuzoğlu *et al.* 2021).

Origin region: North America.

Subtribe *Rhopalosiphina* Mordvilko

Genus *Hysteroneura* Davis

Hysteroneura setariae (Thomas, 1878)

Distribution in Türkiye: Niğde (Görür 2004a), Artvin (Görür *et al.* 2009b), Afyonkarahisar (Görür 2014).

Origin region: North America.

Genus *Melanaphis* van der Goot

Melanaphis bambusae (Fullaway, 1910)

Distribution in Türkiye: Adıyaman (Şenol *et al.* 2017).

Origin region: East Asia.

Melanaphis sacchari (Zehntner, 1897)

Distribution in Türkiye: Adana (Toros *et al.* 2002), Antalya (Güleç 2011).

Origin region: Southeast Asia.

Genus *Rhopalosiphum* Koch

Rhopalosiphum oxyacanthae (Schrank, 1801)

Distribution in Türkiye: Ankara, Bitlis (Tuatay & Remaudière 1964), Denizli (Çıraklı *et al.* 2008), Niğde (Görür 2004b), Bursa, Sakarya (Hantaş *et al.* 2014), Kütahya (Görür 2014).

Origin region: North America.

Rhopalosiphum rufulum Richards, 1960

Distribution in Türkiye: Kütahya (Şenol *et al.* 2015b).

Origin region: North America.

Tribe Macrosiphini Wilson

Genus *Acyrthosiphon* Mordvilko

Subgenus *Acyrthosiphon* Mordvilko

Acyrthosiphon (Acyrthosiphon) *caraganae* Cholodkovsky, 1908

Distribution in Türkiye: Ankara (Düzgüneş *et al.* 1982).

Origin region: Middle Asia.

Acyrthosiphon (*Acyrthosiphon*) *kondoi* Shinji, 1938

Distribution in Türkiye: İstanbul (Akyıldırım *et al.* 2011), Kayseri (Özdemir 2020).

Origin region: East Asia.

Genus *Brachycaudus* van der Goot

Subgenus *Thuleaphis* Hille Ris Lambers

Brachycaudus (*Thuleaphis*) *rumexicolens* (Patch, 1917)

Distribution in Türkiye: Bitlis (Tuatay & Remaudière 1964).

Origin region: North America.

Genus *Cavariella* Del Guercio

Subgenus *Cavariella* Del Guercio

Cavariella (*Cavariella*) *digitata* Hille Ris Lambers, 1969

Distribution in Türkiye: Trabzon (Görür *et al.* 2011a), Afyonkarahisar, Kütahya (Görür 2014).

Origin region: North America.

Genus *Chaetosiphon* Mordvilko

Subgenus *Pentatrichopus* Börner

Chaetosiphon (*Pentatrichopus*) *fragaefolii* (Cockerell, 1901)

Distribution in Türkiye: Ankara (Bodenheimer & Swirski 1957), Aydın, Elazığ, Giresun, Mersin, İzmir, Manisa (Tuatay 1988), Bursa (Kovancı *et al.* 2004).

Origin region: North America.

Genus *Illinoia* Wilson

Subgenus *Masonaphis* Hille Ris Lambers

Illinoia (*Masonaphis*) *lambersi* (MacGillivray, 1960)

Distribution in Türkiye: Rize (Görür *et al.* 2011a).

Origin region: North America.

Genus *Macrosiphoniella* Del Guercio

Subgenus *Macrosiphoniella* Del Guercio

Macrosiphoniella (*Macrosiphoniella*) *sanborni* (Gillette, 1908)

Distribution in Türkiye: Türkiye (Düzgüneş & Tuatay 1956), Ankara (Bodenheimer & Swirski 1957, Özdemir & Toros 1997), Gaziantep, Sakarya (Tuatay *et al.* 1972), İzmir (Giray 1974), Bolu, Eskişehir, Konya, Malatya,

Manisa, Rize, Samsun, Şanlıurfa (Tuatay 1990), Aksaray (Geneci & Görür 2007), Bartın (Toper Kaygın *et al.* 2009), Artvin, Trabzon (Görür *et al.* 2009b), Antalya (Güleç 2011), Adana (Çalışkan 2015), Yalova (Kuloğlu & Özder 2017), Çanakkale (Kök & Kasap 2019).

Origin region: East Asia.

Macrosiphoniella (*Macrosiphoniella*) *tapuskae* (Hottes & Frison, 1931)

Distribution in Türkiye: Ankara, Bitlis, Niğde (Tuatay & Remaudière 1964), Erzurum, Van (Tuatay 1990).

Origin region: North America.

Genus *Macrosiphum* Passerini

Subgenus *Macrosiphum* Passerini

Macrosiphum (*Macrosiphum*) *euphorbiae* (Thomas, 1878)

Distribution in Türkiye: Ankara, İstanbul (Tuatay & Remaudière 1964, Özdemir & Toros 1997), İzmir (Giray 1974), Amasya, Erzurum, Sakarya (Tuatay 1990), Adana, Hatay, Mersin (Toros *et al.* 2002), Konya (Altay & Uysal 2005), Balıkesir (Ayyıldız & Atlıhan 2006), Aksaray (Geneci & Görür 2007), Denizli (Çıraklı *et al.* 2008), Artvin, Rize, Trabzon (Görür *et al.* 2009b), Bartın (Toper Kaygın *et al.* 2009), Antalya (Güleç 2011), Samsun (Akyürek 2013), Afyonkarahisar, Kütahya, Uşak (Görür 2014), Çanakkale (Kök *et al.* 2016), Kay (Öztürk & Muştu 2017), Yalova (Kuloğlu & Özder 2017), Isparta (Bayındır Erol *et al.* 2018).

Origin region: North America.

Macrosiphum (*Macrosiphum*) *impatientis* (Williams, 1911)

Distribution in Türkiye: Samsun (Akyürek 2006), Rize, Trabzon (Görür *et al.* 2009b).

Origin region: North America.

Macrosiphum (*Macrosiphum*) *pachysiphon* Hille Ris Lambers, 1966

Distribution in Türkiye: Kütahya (Şenol *et al.* 2015a).

Origin region: Southeast Asia.

Macrosiphum (*Macrosiphum*) *pallidum* (Oestlund, 1887)

Distribution in Türkiye: Samsun (Akyürek 2006), Rize, Trabzon (Görür *et al.* 2009b).

Origin region: North America.

Genus *Myzus* Passerini

Subgenus *Myzus* Passerini

Myzus (*Myzus*) *varians* Davidson, 1912

Distribution in Türkiye: Adana, Hatay (Toros *et al.* 2002), Samsun (Akyürek 2013), Gümüşhane (Alaserhat 2015).

Origin region: East Asia.

Subgenus *Nectarosiphon* Schoute

Myzus (*Nectarosiphon*) *persicae* (Sulzer, 1776)

Distribution in Türkiye: Türkiye (Alkan 1952), Ankara, İstanbul (Bodenheimer & Swirski 1957, Özdemir & Toros 1997), İzmir (Tuatay *et al.* 1972), Bolu (Çanakçıoğlu 1975), Amasya, Aydın, Balıkesir, Bursa, Çanakkale, Düzce, Eskişehir, Giresun, Mersin, Kocaeli, Konya, Kırklareli, Manisa, Muş, Sakarya, Samsun, Sinop, Tekirdağ, Trabzon, Tokat, Tunceli, Uşak (Tuatay 1991), Adana (Toros *et al.* 2002), Van (Toros *et al.* 1996), Diyarbakır (Ölmez Bayhan *et al.* 2003), Isparta (Aslan & Karaca 2005), Kahramanmaraş (Aslan & Uygun 2005), Malatya (Ölmez Bayhan *et al.* 2006), Aksaray (Geneci & Görür 2007), Artvin, Rize (Görür *et al.* 2009b), Bartın (Toper Kaygın *et al.* 2009), Antalya (Güleç 2011), Afyonkarahisar, Kütahya (Görür 2014), Erzincan, Gümüşhane (Alaserhat 2015), Kayseri (Öztürk & Muştu 2017), Yalova (Kuloğlu & Özder 2017).

Origin region: Cryptogenic.

Genus *Nearctaphis* Shaposhnikov

Nearctaphis bakeri (Cowen, 1895)

Distribution in Türkiye: Adana (Toros *et al.* 2002), Niğde (Görür 2002), Artvin, Rize, Trabzon (Görür *et al.* 2009b), Afyonkarahisar, Kütahya (Görür 2014), Erzurum (Başer & Tozlu 2020).

Origin region: North America.

Genus *Rhodobium* Hille Ris Lambers

Rhodobium porosum (Sanderson, 1900)

Distribution in Türkiye: Isparta (Barjadze *et al.* 2011b), Adana (Çalışkan 2015), Yalova (Kuloğlu & Özder 2017), Çanakkale (Kök & Kasap 2019).

Origin region: Tropical – Subtropical.

Genus *Rhopalosiphoninus* Baker

Subgenus: *Rhopalosiphoninus* Baker

Rhopalosiphoninus (*Rhopalosiphoninus*) *latysiphon* (Davidson, 1912)

Distribution in Türkiye: Sakarya (Tuatay 1991).

Origin region: North America.

Genus *Trichosiphonaphis* Takahashi

Subgenus *Xenomyzus* Aizenberg

Trichosiphonaphis (*Xenomyzus*) *polygonifoliae* Shinji, 1944

Distribution in Türkiye: Ankara (Özdemir *et al.* 2005).

Origin region: East Asia.

Genus *Uroleucon* Mordvilko

Subgenus *Lambersius* Olive

Uroleucon (*Lambersius*) *erigeronense* (Thomas, 1878)

Distribution in Türkiye: Ankara (Düzgüneş *et al.* 1982), Antalya (Güleç 2011).

Origin region: North America.

Uroleucon (*Uroleucon*) *ambrosiae* (Thomas, 1878)

Distribution in Türkiye: Trabzon (Görür *et al.* 2011b), Samsun (Akyürek 2013), Afyonkarahisar, Kütahya (Görür 2014), Erzurum (Başer & Tozlu 2020).

Origin region: North America.

Uroleucon (*Uroleucon*) *pseudambrosiae* (Olive, 1963)

Distribution in Türkiye: Samsun (Akyurek *et al.* 2010).

Origin region: North America.

Subgenus *Uromelan* Mordvilko

Uroleucon (*Uromelan*) *compositae* (Theobald, 1915)

Distribution in Türkiye: Artvin, Trabzon (Görür *et al.* 2011b), Yalova (Kuloğlu & Özder 2017), Erzurum (Başer & Tozlu 2020).

Origin region: Africa.

Genus *Wahlgreniella* Hille Ris Lambers

Wahlgreniella nervata nervata (Gillette, 1908)

Distribution in Türkiye: Denizli (Çıraklı *et al.* 2008), Bartın (Toper Kaygın *et al.* 2008), Artvin, Rize, Trabzon (Görür *et al.* 2009b), İzmir (Eser *et al.* 2009), Samsun (Akyürek *et al.* 2012), Afyonkarahisar (Görür 2014), Isparta (Barjadze *et al.* 2014).

Origin region: North America.

Wahlgreniella nervata arbuti (Davidson, 1910)

Distribution in Türkiye: Burdur, Zonguldak (Tuatay & Remaudière 1964), İzmir (Tuatay 1991), Çanakkale (Kök & Kasap 2019).

Origin region: North America.

Subfamily Calaphidinae Oestlund

Tribe Calaphidini Oestlund

Genus *Neobetulaphis* Basu

Neobetulaphis pusilla Basu, 1964

Distribution in Türkiye: Artvin, Rize, Trabzon (Görür *et al.* 2011a), Samsun (Akyürek 2013).

Origin region: South Asia.

Tribe Myzocallidini Börner

Genus *Myzocallis* Passerini

Subgenus *Lineomyzocallis* Richards

Myzocallis (*Lineomyzocallis*) *walshii* (Monell, 1879)

Distribution in Türkiye: Adana (Çalışkan *et al.* 2012).

Origin region: North America.

Tribe Panaphidini Oestlund

Genus *Monellia* Oestlund

Monellia caryella (Fitch, 1855)

Distribution in Türkiye: Antalya (Özkan & Türkyılmaz 1990), Mersin (Toros *et al.* 2002), Aydın (Kaya Apak & Akşit 2016).

Origin region: North America.

Tribe Therioaphidini Börner

Genus *Tinocallis* Matsumura

Subgenus *Sappocallis* Matsumura

Tinocallis (*Sappocallis*) *takachihoensis* Higuchi, 1972

Distribution in Türkiye: Trabzon (Görür *et al.* 2011a), Samsun (Akyürek 2013).

Origin region: East Asia.

Subfamily Chaitophorinae Mordvilko

Tribe Chaitophorini Mordvilko

Genus *Chaitophorus* Koch

Chaitophorus indicus Ghosh, Ghosh & Raychaudhuri, 1970

Distribution in Türkiye: Afyonkarahisar, Kütahya (Şenol *et al.* 2015b).

Origin region: Southeast Asia.

Chaitophorus populifolii (Essig, 1912)

Distribution in Türkiye: Niğde (Görür 2004a).

Origin region: North America.

Chaitophorus saliciniger (Knowlton, 1927)

Distribution in Türkiye: İzmir (Eser *et al.* 2009), Trabzon (Görür *et al.* 2009b), Samsun (Akyürek 2013), Afyonkarahisar, Kütahya (Görür 2014).

Origin region: North America.

Subfamily Eriosomatinae Kirkaldy

Tribe Eriosomatini Kirkaldy

Genus *Eriosoma* Leach

Eriosoma lanigerum Hausmann, 1802

Distribution in Türkiye: Trabzon (Schimitschek 1944), Ankara, Bursa, İstanbul (Bodenheimer & Swirski 1957), Adana, Hatay, Mersin, Osmaniye (Toros *et al.* 2002), Diyarbakır (Ölmez Bayhan *et al.* 2003), Isparta (Aslan & Karaca 2005), Kahramanmaraş (Aslan & Uygun 2005) Denizli (Çıraklı *et al.* 2008), Artvin (Görür *et al.* 2009b), Elazığ (Ayaz & Yücel 2010), Antalya (Güleç 2011), Samsun (Akyürek 2013), Aydın (Karakaya 2014), Kütahya (Görür 2014), Yalova (Hantaş *et al.* 2014), Erzincan, Gümüşhane (Alaserhat 2015), Kayseri (Öztürk & Muştu 2017), Bolu (Kaçar 2019).

Origin region: North America.

Tribe *Pemphigini* Herrich-Schaeffer

Genus *Mordwilkoja* Del Guercio

Mordwilkoja vagabunda (Walsh, 1863)

Distribution in Türkiye: Bartın (Yıldız & Toper Kaygın 2010).

Origin region: North America.

Subfamily Hormaphidinae Mordvilko

Tribe Nipponaphidini Ghosh

Genus *Thoracaphis* van der Goot

Thoracaphis flava Takahashi, 1950

Distribution in Türkiye: Kütahya (Şenol *et al.* 2014).

Origin region: Southeast Asia.

Subfamily Lachninae Herrich-Schaeffer

Tribe Eulachnini Baker

Genus *Cinara* Curtis

Subgenus *Cedrobium* Remaudière

Cinara (*Cedrobium*) *laportei* (Remaudière, 1954)

Distribution in Türkiye: Antalya, Burdur, Muğla (Fabre & Chalon 2005), Samsun (Akyürek 2006), Afyonkarahisar (Görür 2014).

Origin region: Africa.

Subgenus *Cinara* Curtis

Cinara (*Cinara*) *cedri* Mimeur, 1936

Distribution in Türkiye: Ankara, Gaziantep, Konya (Tuatay & Remaudière 1964), Afyonkarahisar, Antalya, Burdur, Eskişehir, İstanbul (Çanakçıoğlu 1966), Samsun, Tekirdağ (Tuatay 1999), Hatay (Toros *et al.* 2002), Kahramanmaraş (Aslan & Uygun 2005), Kastamonu (Ünal & Özcan 2005), Bartın (Toper Kaygın *et al.* 2008), Artvin (Görür *et al.* 2009b), Kütahya, Uşak (Görür 2014), Kayseri (Öztürk & Muştu 2017), Çanakkale (Kök & Kasap 2019), Isparta (Oğuzoğlu & Avcı 2019).

Origin region: Africa.

Cinara (*Cinara*) *curvipes* (Patch, 1912)

Distribution in Türkiye: Afyonkarahisar, Bartın, Kütahya (Görür *et al.* 2015).

Origin region: North America.

Cinara (*Cinara*) *indica* Verma, 1970

Distribution in Türkiye: Afyonkarahisar (Şenol *et al.* 2015b).

Origin region: Southeast Asia.

Cinara (*Cinara*) *juniperensis* (Gillette & Palmer, 1925)

Distribution in Türkiye: Kütahya (Şenol *et al.* 2015b).

Origin region: North America.

Cinara (*Cinara*) *pinivora* (Wilson, 1919)

Distribution in Türkiye: Artvin (Görür *et al.* 2011a), Afyonkarahisar, Kütahya, Uşak (Görür 2014).

Origin region: North America.

Cinara (*Cinara*) *wahluca* Hottes, 1952

Distribution in Türkiye: Samsun (Akyürek *et al.* 2010), Kütahya (Görür 2014).

Origin region: North America.

Subfamily Mindarinae Tullgren

Genus *Mindarus* Koch

Mindarus kinseyi Voegtlin, 1995

Distribution in Türkiye: Afyonkarahisar, Uşak (Şenol *et al.* 2015b).

Origin region: North America.

Subfamily Thelaxinae Baker

Tribe Thelaxini Baker, 1920

Genus *Thelaxes* Westwood, 1840

Thelaxes californica (Davidson, 1919)

Distribution in Türkiye: Trabzon (Görür *et al.* 2011a), Samsun (Akyürek 2013), Afyonkarahisar, Kütahya, Uşak (Görür 2014).

Origin region: North America.

Considering the taxonomic diversity of alien aphids, it appears that the aphid fauna of Türkiye includes 592 species belonging to 148 genus in 16 subfamily from the Aphidomorpha infraorder (Hemiptera) (Kök & Özdemir 2021). The highest taxonomic diversity is found in the subfamily Aphidinae with 361 species (60.98%) in 74 genera (50.00%), followed by the subfamily Lachninae with 59 species (9.97%) in 10 genera (6.76%) and the subfamily Calaphidinae with 57 species (9.63%) in 22 genera (14.86%). Similar to these results, the highest taxonomic diversity in the ailen aphid species in Türkiye is seen in the Aphidinae subfamily with 37 species (64.91%) in 20 genera (62.50%), followed by the subfamily Lachninae with seven species (12.28%) in one genus (3.13%) (Table 1).

The number of alien aphid species recorded in Türkiye between 1903 and 2021 significantly and positively correlates with the number of native aphid species in Türkiye ($r=0.980$, $p<0.000$) (Fig. 1). It can be thought that this result may reflect the differences in sampling frequency and in the number of local aphid taxonomists. Accordingly, it can be estimated that in parallel with the increase in the number of aphid species in Türkiye, the number of alien aphid species may increase at the same rate.

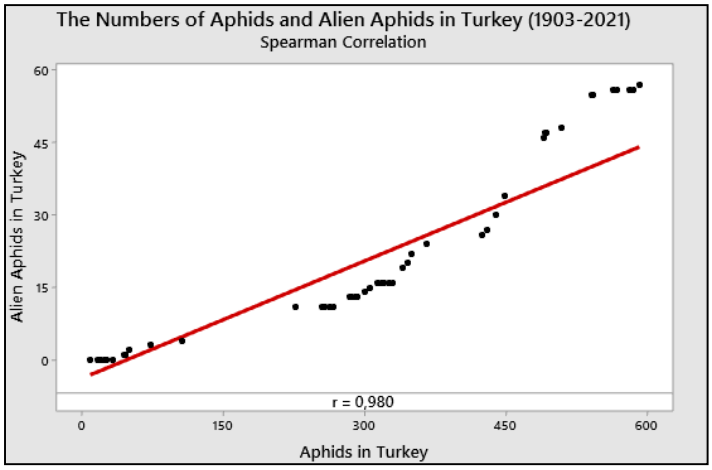

Fig. 1. The relationship between the number aphid species and alien aphid species in Türkiye

Table 1. Taxonomic diversity of aphid species and alien aphid species in Türkiye

	Aphid Species 1903-2021				Alien Aphid Species 1903-2021			
Subfamily	**Genus**	**Genus (%)**	**Species**	**Species (%)**	**Genus**	**Genus (%)**	**Species**	**Species (%)**
Adelgidae	2	1.35	7	1.18	1	3.13	1	1.75
Phylloxerinae	2	1.35	4	0.68	0	0.00	0	0.00
Phylloxerininae	1	0.68	1	0.17	0	0.00	0	0.00
Anoeciinae	1	0.68	3	0.51	0	0.00	0	0.00
Aphidinae	74	50.00	361	60.98	20	62.50	37	64.91
Calaphidinae	22	14.86	57	9.63	4	12.50	4	7.02
Chaitophorinae	5	3.38	35	5.91	1	3.13	3	5.26
Drepanosiphinae	2	1.35	5	0.84	0	0.00	0	0.00
Eriosomatinae	19	12.84	43	7.26	2	6.25	2	3.51
Hormaphidinae	2	1.35	2	0.34	1	3.13	1	1.75
Lachninae	10	6.76	59	9.97	1	3.13	7	12.28
Mindarinae	1	0.68	3	0.51	1	3.13	1	1.75
Phloeomyzinae	1	0.68	1	0.17	0	0.00	0	0.00
Phyllaphidinae	2	1.35	3	0.51	0	0.00	0	0.00
Saltusaphidinae	3	2.03	4	0.68	0	0.00	0	0.00
Thelaxinae	1	0.68	4	0.68	1	3.13	1	1.75
Total	148		592		32		57	

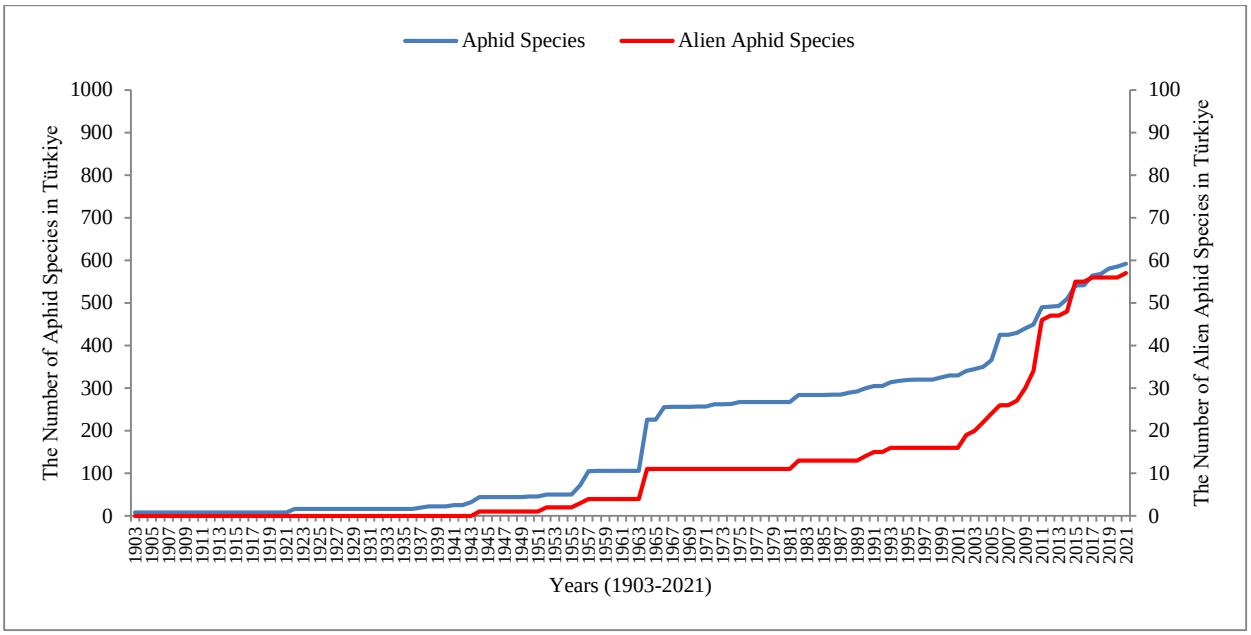

Fig. 2. The number of aphid species and alien aphid species in Türkiye (1903-2021)

The first data on the aphid fauna of Türkiye emerged with 16 aphid species, of which only one is an alien species reported by Trotter (1903), Houard (1922) and Fahringer (1922) in the first quarter of the 20th century. The increase in the aphid fauna of Türkiye continued at a low level until the middle of this century, and reaching 105 aphid species, of which only four were alien species in 1957 (Bodenheimer & Swirski 1957). From that time to the present, the aphid fauna of Türkiye has reached 592 aphid species, 57 of which are alien species; this increase is due to the increased number of native and foreign aphid taxonomists researching in Türkiye as well as the increase in the number of comprehensive faunal studies carried out in different regions. Based on 119 years of data on aphids and alien aphids in Türkiye, the average introduction rate of alien aphids into Türkiye was calculated as 0.48 species per year (Fig. 2).

The alien aphids are distributed in 60 of 81 provinces in Türkiye. The provinces with the highest number of alien aphids were Kütahya, Afyonkarahisar, Samsun, Trabzon and Artvin provinces. Only one alien aphid species was recorded in each of Adıyaman, Bilecik, Edirne, Kastamonu, Kırklareli, Kocaeli, Muğla, Muş, Sinop, Tokat, Tunceli, Zonguldak, Karabük, Kilis, Osmaniye and Düzce provinces (Fig. 3). Provinces with a large number of recorded alien aphid had more comprehensive faunal and taxonomic studies on aphids (Görür *et al.* 2009b, Görür 2014). Also, since the 2000s, the number of alien aphid species has increased significantly due to the rapid increase in the comprehensive faunal and taxonomic studies on aphids in Türkiye. The fact that no alien aphids has been recorded from some provinces of Türkiye can be due to the lack of studies on aphids in these provinces.

The continent origin of 96.5% (55 species) of the alien aphid species belonging to the Aphidomorpha infraorder recorded in Türkiye has been determined, and 1.75% (one species) of the remaining species are of tropical and subtropical origin, and 1.75% (one species) are cryptogenic (unknown origin) such as *Myzus* (*Nectarosiphon*) *persicae* (Sulzer, 1776) which is a serious polyphagous aphid in crop and non-crop areas worldwide. Also, this alien aphid migrates to many herbaceous secondary plants in about 40 plant families, and transmits numerous plant pathogenic viruses (Blackman & Eastop 2022). In Türkiye, 38 of 57 alien aphid species recorded originated from North America. This is followed by the Asian continent with 14 alien aphid species, and African continent with three alien aphid species. It is clear that the continents of Asia and North America have significantly contributed to the number of alien aphid species recorded in Türkiye. Considering the aphids diversity of North America with over 1400 species (Foottit *et al.* 2006) and only China located in Asia continent with over 1,000 species (Qiao & Zhang 2004), it can be thought that the origins of alien aphid species in Türkiye clearly reflect the aphid diversity in these regions.

Discussion

Aphids are phytophagous species distributed worldwide and about 10% of them are serious pests of economically important crops (Blackman & Eastop 2000). In addition, aphids constitute one of the insect groups that are most rapidly affected by global warming and climate change. These changes have caused the emergence of first individuals of aphids in spring to occur 2-3 days earlier every decade (Harrington *et al.* 2007) and led to an increase in the distribution areas of aphids day by day. Aphids can reproduce both parthenogenetically in temperate climates and sexually in cold climates. As a

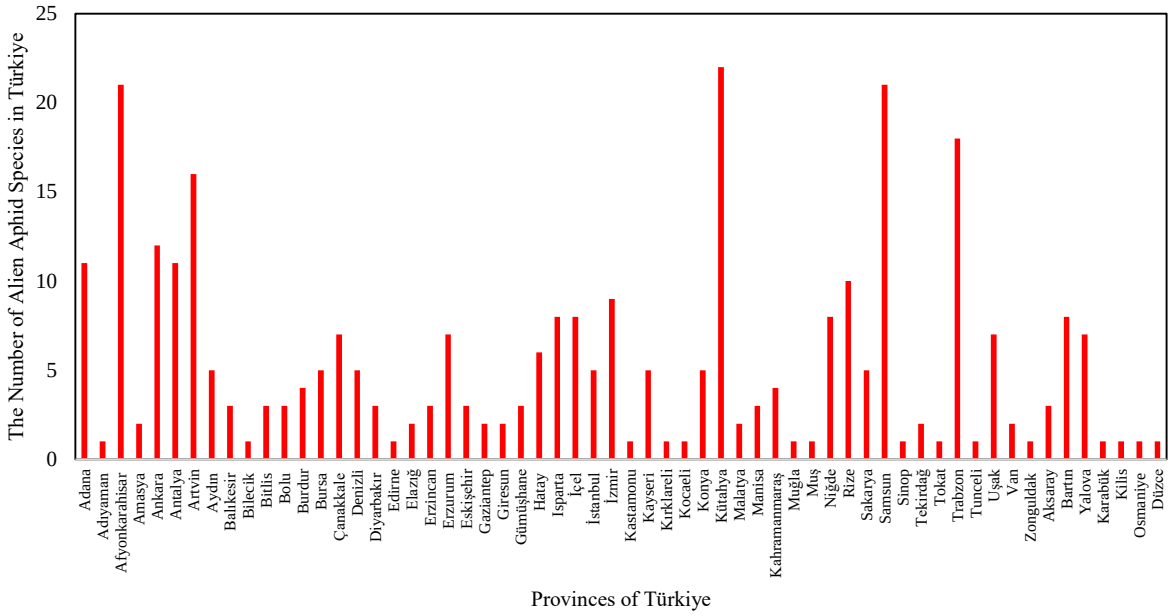

Fig. 3. The distribution of alien aphid species in the provinces of Türkiye

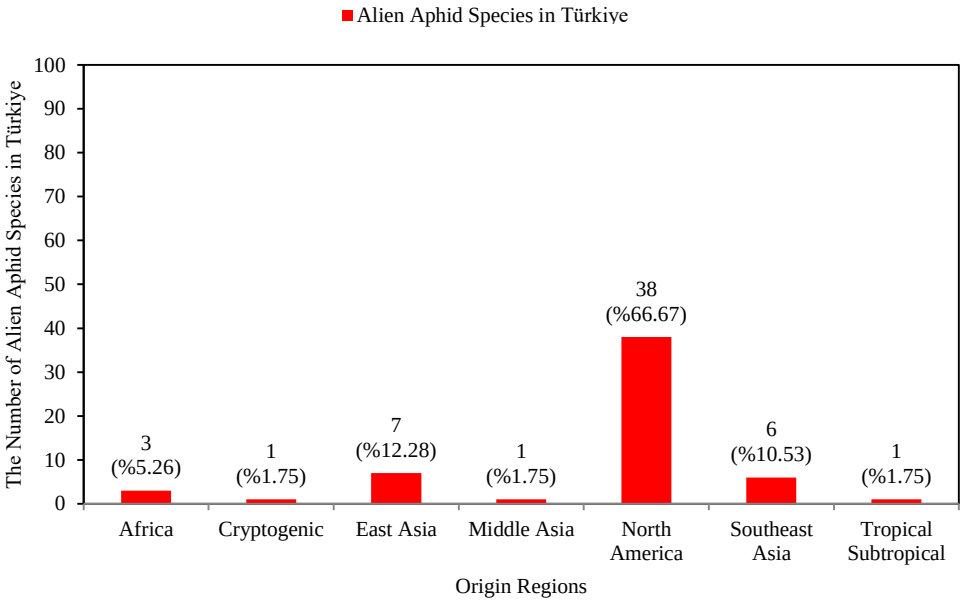

Fig. 4. Origin regions of alien aphid species in Türkiye

result, the introduction of very few or even a single individual female may lead to the rapid development of an aphid population and the increase in alien species. Beside this, aphids with their very small size can be distributed globally in a short time with plant materials (Coeur d'acier *et al.* 2010). For these above mentioned reasons, aphids are one of the most investigated insect groups in terms of taxonomic, biological, ecological and physiological aspects. Recently, the comprehensive studies on alien aphids have also increased. For instance, Coeur d'acier *et al.* (2010) presented a comprehensive list including 102 alien aphid species in 58 genera belonging to 12 subfamilies from the family Aphididae that are distributed in the European continent. In the study, the rate of introduction of alien aphids to the Europe based on 210 years of data was calculated as 0.50 species per year. It was reported that 43.1% of the origins of alien aphid species were reported to be from North America, 43.1% from the Asian continent and the rest from other regions.

Also, a significant positive correlation between aphid species and alien aphid species distributed in the European continent was calculated ($r=0.6226$, $p<0.001$). These results are highly similar to the results of our study

conducted in Türkiye. In a smaller region, Wieczorek (2011) presented a list including 35 alien aphid species originating from other continents into Poland. The author reported that 16 species were Asian, 14 species were North American, two species were tropical Asian, two species were tropical or subtropical regions of the world and one species was cryptogenic. Considering the Polish fauna has a total of 764 aphid taxa (Wojciechowski *et al.* 2015), it can be interpreted that the number of alien aphid species may be closely related to both the number of aphid fauna and the surface area of the countries.

Considering the agricultural importance of alien aphids, *E. lanigerum*, an important apple pest of North America origin, was first reported in nurseries in London in 1787 on the European continent (Balachowsky & Mesnil 1935). The identification of this species was made in Germany by Hausmann (1802). In later years, *E. lanigerum* has spread to many countries in Europe. In Türkiye, this alien aphid was recorded for the first time in Trabzon province by Schimitschek (1944). From this time to the present, *E. lanigerum* has been recorded in most parts of Türkiye except for the provinces where comprehensive faunal studies on aphids have not yet been carried out (Bodenheimer & Swirski 1957, Toros *et al.* 2002, Ölmez Bayhan *et al.* 2003, Aslan & Karaca 2005, Aslan & Uygun 2005, Çıraklı *et al.* 2008, Görür *et al.* 2009, Ayaz & Yücel 2010, Güleç 2011, Akyürek 2013, Karakaya 2014, Görür 2014, Hantaş *et al.* 2014, Alaserhat 2015, Öztürk & Muştu 2017, Kaçar 2019). In addition, *Aphis* (*Aphis*) *illinoisensis* Shimer, 1866, one of the most important pests in vineyard areas in the Mediterranean Basin, was reported in Adana, Afyonkarahisar, Hatay, Isparta, İzmir, Kilis, Kütahya, Mersin and Niğde provinces of Türkiye (Remaudière *et al.* 2003, Görür 2004a, Eser *et al.* 2009, Barjadze *et al.* 2011a, Yanpar 2013, Görür 2014). Of the aphid species reported as aliens for Türkiye in this study are *Myzus* (*Nectarosiphon*) *persicae* (Sulzer, 1776), *Aphis* (*Aphis*) *spiraecola* Patch, 1914, *Macrosiphum* (*Macrosiphum*) *euphorbiae* (Thomas, 1878), *A.* (*A.*) *illinoisensis*, *Acyrthosiphon* (*Acyrthosiphon*) *kondoi* Shinji, 1938, *Myzocallis* (*Lineomyzocallis*) *walshii* (Monell, 1879), *Eriosoma lanigerum* (Hausmann, 1802), *Cinara* (*Cinara*) *cedri* Mimeur, 1936 are important species because they cause serious economic damage every year in crop areas such as fruit and vegetable growing, ornamental plants and viticulture in the worldwide.

As a result, it is expected that the spread of alien species such as aphids, and their settlement in new regions will increasingly continue as long as climate changes caused by global warming, globalization, expanding markets and transportation continue increasingly worldwide. More comprehensive local and territorial faunal studies on alien species should be carried out in order to determine the distribution of these pests and to ensure that measures are taken within the scope of pest control strategies.

Ethics Committee Approval: Since the article does not contain any studies with human or animal subject, its approval to the ethics committee was not required.

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