Pest species of Coccoidea (Hemiptera; Coccomorpha) in forest of Turkey

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Abstract: Forest area of Turkey is 22.6 million hectares, which constitutes 28.8% of the overall land area. 47% of the forests is coniferous, 32% is broad-leaved tree species and 21% mixed species. The Scale insects (Hemiptera: Coccomorpha) are cryptic and mostly invisible insects which are mostly small less than 5 mm long. Many scale insects are economically important pests of agriculture, horticulture, and forestry. Around 400 scale insect species are known in Turkey, totally 119 Coccoidea species are fed on forest trees and shrubs; among 45 species of them on conifers and 74 species on broad-leaves trees and shrubs. Gennadius (Marchalinae) is a famous and economically important species that resourced honeydew called “pine honey”. This study examines scale insects, their distribution, host plants, natural enemies, damages, and role of forest biodiversity in Turkey.

Keywords: Scale insect, Biodiversity, Conifer, Biology, Damage

Türkiye ormanlarında zararlı Coccoidea (Hemiptera; Coccomorpha) türleri

Özet: Türkiye 22.6 milyon hektar orman alanı sahiptir. Türkiye’nin yüzölçümünün %28.8’ini kaplayan bu ormanların %47’sini içine yapraklar, %32’ini geniş yapraklı ağaç ve %21’i karışık ormanlar oluşturmaktadır. Kabuklubitler (Hemiptera: Coccoidea), küçük ve genellikle 5 mm’den daha küçük olduğu için gözden kaçırılan böceklerdir. Birçoğu kabuklut türe tannır ve orman bitkilerinin ekonomik önemde zarar meydana getirmektedir. Türkiye’de varlığı bilinen 400 circa çökelimde kabuklut türünde, 45 tür koniferlerde, 74 tür ise geniş yapraklı ağaç ve çalılarda bakılmaktadır. Marchalina hellenica Gennadius (Marchalinae) bu türlerden en bilinen ve ekonomik öneme sahip bir tür olup, “çam balı” olarak bilinen bilinen salgınları kaynaklı etmektedir. Bu çalışmada Türkiye ormanlarında görülen kabuklut türlerinin yayılışları, konukçuları, doğal düşmanları, zararları ve orman biyoçeşitliliğindeki rolleri incelenmiştir.

Anahtar kelimeler: Kabuklubitler, Biyoçeşitlilik, Konifer, Biyoloji, Zarar

1. Introduction

The total forest area of Turkey is 22,342,935 hectares and it consists of 29% of the country (TOD, 2019). Forests are generally located on mountainous areas and they are usually natural and semi-natural with high biodiversity value. Turkey has 9000 plant species of which 3649 (31.8%) is endemic (FAO, 2019). Most of these plants are located in forest areas. Approximately 800 woody taxa occur in the country's forests. The predominant species are Pinus brutia Ten., Pinus halepensis Mill., Pinus nigra Arnold, Pinus pinea L., Pinus sylvestris L., Abies spp., A. cypriaca (Ant. and Kotschy), A. nordmannia (Steven), Picea orientalis (L.), Cedrus libani A. Rich (Pinaceae), Cupressus sempervirens L., Juniperus spp. (Cupressaceae), Fagus orientalis Lipsky, Quercus spp., Castanea sativa Mill. (Fagaceae), Alnus spp. and Carpinus betulus L. (Betulaceae). Main tree species of the Turkey forest are oaks (26.25%), Turkish pine (25.13%), Crimena pine (19.02%), Beech (8.55%), Scots pine (6.80%), Juniper (4.29%), Cedar (2.16%), Fir (2.62%) and Spruce trees (1.45%). These plants occur as pure stand or mix stand in forests (Anonymous, 2019).

Insects and plant diseases are the important factors that damage forest trees. Scale insects (Hemiptera; Coccomorpha) feed by sucking the sap of plants from either the phloem or parenchyma and cause reduced host vigor, reduced productivity, defoliation, premature falling of leaves and dieback of branches. In addition, feeding by these insects may cause discoloration and disfiguration and gall formations. They are often cryptic in habitat and mostly small size (less than 5 mm long) therefore undetectable until plant damage is substantial. This point is very important in quarantine and plant protection. There are estimated to be almost 8000 Coccoidea species in the world (Garcia et al., 2016). They are economically important pests of agriculture, horticulture and forest plants (Kosztarab and Kozar, 1988).

2. Scale insects

Scale insects have protective covering such as powdery, waxy, and hardy scales. The wax is produced by epidermal glands (mostly cuticular pores, ducts). Scale insects have very specific morphological and biological features. Male scale insects display complete metamorphosis, whereas female is paedomorphic. Female scale insects have often sedentary habit and have four or five biological stages (egg, two or three nymph instars and adult). The female either lays eggs in a cavity under her body or in a waxy sac (ovisac). Crawlers (first instar nymphs) are mobile and play

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very important role in dispersing to other plants. Male scale insects have five or six biological stages (egg, two or three nymph stages, prepupa, pupa and adult). Adult males are tiny flies that do not feed and live only a few days. Depending on species and the climate, the number of generations is variable between one to seven or eight in a year (Kosztarab and Kozar, 1988). Scale insects on forest plants are studied in Turkey by some authors (Bodenheimer, 1949; 1953; Schmitschek, 1953; Çanakçıoğlu, 1977; Selmi, 1979; Ülgentürk et al., 2004; Ülgentürk et al., 2012a,b). The number of forest trees used as park trees and new plant species imported as ornamental plants may lead to new insect species to enter the new regions. Insect species which are not cause a serious damage in their natural habitat may reproduce uncontrollably and inflict damage in a new ecosystem as they may not have natural enemies (Sahin and Ülgentürk, 2011). While Torosaspis cedricola (Balachowsky & Alkan) (Diaspididae), for example, sustaining their existence in low populations in natural cedar forests, it is the major pest of cedar trees in urban greenbelts (Dostbil and Ülgentürk, 2016; Ülgentürk et al., 2012a; Ülgentürk et al., 2019a). The maritime pine bark scale, Matsucoccus fyt Madden (Matsucoccidae), occurs in the western part of the Mediterranean basin and causes damage in South Eastern France and Italy, where it was accidentally introduced (Foldi, 2004).

Generally, mostly scale insects leave honeydew that covers all parts of the plant, and causing sooty mould. This may be indirectly detrimental to plants by excluding sunlight and interfering with photosynthesis in the leaves as well plants lose their aesthetic and economic value (Kosztarab and Kozar, 1988; Ülgentürk et al., 2019a,b). On the other hand, honeydew is important nutrient for many species such as insects, birds, and also humans. Honeydew is collected and used in producing of honeydew honey by honeybees. For examples honeydew of Marchalina helenica Gennadius (Marchaliniidae) is one of the important source of pine honey in Greece and Turkey (Gürkan, 2005; Ülgentürk et al., 2012a). Pine honey has economic importance for many beekeepers and for forest villagers, as well. In addition to M. helenica, many other hemipters are known as honeydew producer on cedar, chestnut, oaks, linden, and pine trees in Turkey (Ülgentürk et al., 2012b; Ülgentürk et al., 2013a, b; Ülgentürk et al., 2019b). Some scale insects are also known as the vector of plant diseases (Le Maguet et al., 2012). For example, the bee scale Cryptococcus fagus (Douglas) (Eriococcidae) feeds on beech trees (Fagus spp.). Attack by bee scale alone does not seriously damage beece trees; however, the feeding punctures in the bark allow beech bark disease, [Nectria coccinea var. faginata or N. galligena (Hypocreales: Nectriaceae)] a serious threat to the timber industry in Europe and in North America, to gain access to the cambium and phloem tissues (Houston, 1994).

Unfortunately, most of the studies which examine mostly host plants and distribution of scale insects occurring on forest areas in Turkey. There is very limited research on their biology, damage and natural enemies in forests. In this study, scale insects that feed on conifers (Table 1) and species that feed on broad-leaved trees and shrubs (Table 2) in Turkey are taken separately. Information of some important species on their biology, damage and natural enemies in urban green areas (forest, parks and gardens) are also given.

Table 1. Scale insects on conifer trees in Turkey

| Species                        | Host plants                  | Coccidae          | Distribution*** | References                      |
|--------------------------------|------------------------------|-------------------|----------------|---------------------------------|
| Ceroplastes floridensis Comstock | C. libani                    | Me                | Ülgentürk et al., 2012b |
|                                | Abies bornmuelleriana Mattf., |                   |                |                                 |
|                                | C. pseudomagnoliarum (Kuwana) |                   |                |                                 |
|                                | P. sylvestris                 |                   |                |                                 |
| Nemolecanium abietis (Bodheimer) | A. bornmuelleriana, A. nordmanniana (Steven) | |                |                                 |
| Eulecanium sericium (Lindinger) | Abies ciliica (Antoine & Kotschy), A. bornmuelleriana | |                |                                 |
| Physokermes helenicus (Kozar and | A. bornmuelleriana, A. ciliica | |                |                                 |
| Gonnari                        |                              |                   |                |                                 |
| Physokermes piceae (Schrank)    | Picea abies (L.), P. pungens Engl., P. pungens var. glauca Beissn., P. orientalis | |                |                                 |
| Pousapis intermedia (Goux)      | P. brutia                     | Ma                | Ülgentürk et al., 2012c |
| Pulvinaria floccifera (Westwood) | Taxus baccata L., T. baccata var. fastigiata | |                |                                 |
| Aonidia mediterranea (Lindinger)| Cupressus sempervirens L., Juniperus sp. Pinus sp., P. brutia | |                | Yaşar, 1995; Kaydan et al., 2013 |
| Aspidotus nerii (Bouché)        | C. libani, P. abies, T. baccata | Ma, Me            | Selmi, 1979   |
| Chionaspis babyloniensis (Balachowsky) | C. libani | Me | Ülgentürk et al., 2012b |
| Carulaespis juniperi (Bouché)   | Plateclothus orientalis (L.), Calocedrus decurrens (Torrey), Chaumeecarpys lawsoniana (A. Murray), Cupressus sp., C. arizonica Greene, Juniperus sabina var. tamarisci folia Ait. | |                | Kaydan et al., 2013; Ülgentürk et al., 2019a |

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| Species | Host plants | Distribution*** | References |
|---------|-------------|-----------------|------------|
| Carulaspis minima (Signoret) | Arceuthos drupacea Ant. & Kotschy, B. orientalis C. lavoisiana, C.deconverts, Cupressus spp., C. semprevirens L., C. semprevires var. horizontalis (Mill.), C. semprevires var. pyramidalis Nym., C. goweniana (Gordon), C. arizonica Junipers oxycedrus L., J. communis L., J. foetidissima Willd., J. sabina L., J. sabina var. nana Syme., J. excelsa, P. orientalis | Ae, Bs, Ma, Me | Bodenheimer, 1949, 1952; Kaydan et al., 2013 |
| Diaspidiotus jaupi Leonardi | Palaecoccus fuscipennis | Ae | Ülgentürk et al., 2012b |
| Chrysomphalus dictyoisperm (Morgan) | M. pini | Ma | Selmi, 1979 |
| Dynaspidiotus britannicus (Newstead) | A. hormuelleriana, A. equi-trojani Ascher & Sint., C. atlanticus, C. libani, P. pungens | Bs, Ca, Ma | Selmi, 1979; Ülgentürk et al., 2019a |
| Dynaspidiotus abietis (Schrank) | Abies sp., Pinus sp. | Bs, Ca, Me, Ma | Özkazanç and Yücel, 1985; Yaşar, 1995 |
| Dynaspidiotus abiectica (Koreneos) | A. hormuelleriana, A. concolor (Gord.), A. equi-trojani, C. libani, C. pumila | Ca, Me | Yaşar, 1995; Ülgentürk et al., 2012b; |
| Gomezmenaraspis pinicola Leonardi | P. brutia, P. pinea, P. sylvestris | Ae, Bs, Me, Ma | Ülgentürk et al., 2012b; Kaydan et al., 2014 |
| Gomezmenaraspis nr pinicola Leonardi | C. libani | Me | Ülgentürk et al., 2012c |
| Leucaspis lewii Colvée | L. pini Hartung | P. brutia, L. halapennis, P. nigra, P. pinaea | Ae, Bs, Ca, Ea, | Çanakçıoğlu, 1977; Selmi, 1979; Ülgentürk et al., 2004, 2019a |
| Leucaspis knemion Hoke | Pinus sp., P. brutia | Ma, Me | Bodenheimer, 1952; Ülgentürk et al., 2012b; 2019 Bodenheimer, 1952; Ülgentürk et al., 2012b, 2019 |
| L. pini Hartung | C. libani, P. brutia, L. halapennis, P. nigra, P. pinaea | Ae, Bs, Me, Ma | Bodenheimer, 1949,1952; Selmi, 1979; Kaydan et al., 2014; Ülgentürk et al., 2012b,c 2019 |
| L. pusilla Löw | P. brutia, P. elderica Medv., P. halepensis, P. maritima, P. nigra, P. nigra subsp. pallasiana, P. pandarosa | Ae, Cu, Me, Ma | Çanakçıoğlu, 1977; Selmi, 1979; Kaydan et al., 2014; Ülgentürk et al., 2012b,c 2019 |
| Lepidosaphes newsteadi (Sulc) | Abies sp., A. bormuelleriana, A. pinsapo Boiss., P. pungens, P. nigra | Bs, Ca, Ma | Kaydan et al., 2013, 2014 |
| Lepidosaphes juniperi Lindinger | Juniperus sp., J. excelsa Bieb., Cedrus libani, Pinus nigra, P. brutia, T. occidentalis | Ae, Bs, Ca | Kaydan et al., 2013, 2017; Ülgentürk et al., 2019a |
| Lepidosaphes ulmi Linnæus | P. brutia | Ae | Ülgentürk et al., 2012a |
| Lineaspis striata (Newstead) | Arceuthobium spp., Cupressus sp. C. semprevirens, Thuja spp., T. occidentalis | Ca, Me | Yaşar, 1995; Ülgentürk et al., 2019a |
| Torosaspis farsianus (Balachowski & Kaussari) | Carizonica, C. semprevirens var. horizontalis, C. semprevirens var. pyramidalis | Me | Keçeci Çalışkan and Ulusoy, 2017 |
| T. cedricola Balachowski & Alkan | C. atlantica Manetti, C. atlantica var. glauca Carr., C. deodora (Roxb.), Cedrus libani | Ae, Bs, Ca, Ea, Me, Ma, Sea | Yaşar 1995; Ülgentürk et al., 2012b, 2019a; Kaydan et al., 2014 |

**Erinococcidae**

| Species | Host plants | Distribution*** | References |
|---------|-------------|-----------------|------------|
| Ülgeria araucariae Maskell | Arocaria sp. | ? | Kozar et al., 2013 |
| Marchaliniidae | | | |
| Marchalina cancasca Hadzibeji | normanniana, Piceae orientalis | Bs | Ülgentürk et al., 2019b |
| Marchalina helvatica Gennadius | . libani, P. brutia, P. halepensis, P. pinaea | Ae, Bs, Me, Ma | Bodenheimer, 1953; Ülgentürk et al., 2012a, 2013a |

**Massococcidae**

| Species | Host plants | Distribution*** | References |
|---------|-------------|-----------------|------------|
| Matsucoccus Josephi Bodenheimer & Harpaz | Pinus spp., P. brutia, P. pinea | Ae, Ma, Me | Ülgentürk et al., 2012c; Ülgentürk et al., 2016 |
| M. pinii Green | Pinus sylvestris | Ca | Ülgentürk et al., 2019a |

**Monophlebidae**

| Species | Host plants | Distribution*** | References |
|---------|-------------|-----------------|------------|
| Palaecoccus fuscipennis Burnmeister | Pinus sp. P. brutia, P. pinea | Ae, Ma, Me | Bodenheimer, 1953; Ülgentürk et al., 2012c |

**Pseudococcidae**

| Species | Host plants | Distribution*** | References |
|---------|-------------|-----------------|------------|
| Phenacoccus arnouraggi Balachowsky | C. libani | Me | Ülgentürk et al., 2012b |
| Phenacoccus piceae Löw | P. orientalis | Bs | Ülgentürk and Özdemir, 2019 |
| Phenacoccus yezedalni Ben-Dov | P. brutia, P. sylvestris | Ae, Me | Ben-Dov et al., 2006; Ülgentürk et al., 2012c |
| Planococcus vocae (Nasonov) | Cupressus sp. C. semprevirens, C. semprevirens var. horizontalis, C. semprevirens var. pyramidalis, C. goweniana, Junipers excels Bieb., Libocedrus decurrens Torr., T. baccata, Thuja occidentalis L. | Ae, Bs, Ca, Me, Ma | Düzgün, 1982; Selmi, 1979; Ülgentürk et al., 2013b |
| Pseudococcus pines (Signoret) | Cupra spacea | Ma | Selmi, 1979 |

***Aegean (Ae), Blacksea (Bs), Mediterranean (Me), Marmara (Ma), Central Anatolia (Ca), Eastern Anatolia (Ea) and Southeastern Anatolia (Sea)
| Species | Host plants | Distribution | References |
|---------|-------------|--------------|------------|
| Acanthococcus aceris Signoret | Quercus sp., Platanus orientalis L. | Ea | Kaydan and Kozár, 2008; Ülgentürk et al., 2013a |
| A. melinensis Hodgson and Trencheva | Myrist communis L. | Ae | Ülgentürk et al., 2013b |
| A. roboris Goux | Castanea sp., Quercus sp., Q. cerris L., Q. suber L. | Ae, Bs | Kaydan and Kozár, 1988; Kaydan and Kozár, 2008 |
| A. salicis (Borchsenius) | Salix alba L. | Ea | Kozár et al., 2013 |
| Gossyparia spurias (Moree) | Quercus sp., Ulmus spp., Viscum album L. | Ae, Ca, Ma | Çanakçıoğlu, 1977; Ülgentürk et al., 2003 |
| Kotejacoccus turcis Kaydan & Kozár | Quercus sp. | Ea | Kaydan and Kozár, 2008 |
| Neoacanthococcus attiliani Kaydan & Kozár | Tamarix sp. | 2 | Kaydan and Kozár, 2010 |
| Orontecoccus lauri (Erkilç) | Laurus nobilis L. | Me | Erkilç et al., 2011 |

**Asterolecaniidae**

| Species | Host plants | Distribution | References |
|---------|-------------|--------------|------------|
| Asterodiaspis bella (Russell) | Quercus sp., Q. robur L. | Ca, Ea | Zeki et al. 2005; Ülgentürk et al., 2013a |
| A. hadzibyeliae Borchsenius | Quercus sp. | Ca, Ea | Ülgentürk et al., 2013a |
| A. illicola (Targioni Tozzetti) | Quercus sp., Q. coccifera L. | Ae, Me | Bodenheimer, 1953; Ülgentürk et al., 2013a |
| A. mina (Russell) | Q. coccifera | Bs, Ea | Kaydan et al., 2013; Ülgentürk et al., 2013a |
| A. minus Lindinger | Q. coccifera | Ca, Ma, Me | Bodenheimer, 1953 |
| A. quercicola (Bouché) | Quercus sp., Q. brauntii Lindl., Q. robur | Ca, Me | Zeki et al., 2005; Ülgentürk et al., 2013a |
| A. repugnans (Russell) | Quercus sp. | Bs, Ea | Ülgentürk et al., 2013a; Kaydan et al., 2014 |
| A. variolosa (Ratzburg) | Quercus sp., Q. aegilops L., Q. coccifera, Q. robur v. fastiata | Ae, Ca, Me, Ma | Yasar, 1991; Ülgentürk et al., 2013a |

**Coccidae**

| Species | Host plants | Distribution | References |
|---------|-------------|--------------|------------|
| Ceroplastes floridensis Comstock ** | Arbutus unedo L., L. nobilis, M. communis | Ae, Me | Bodenheimer, 1953; Ülgentürk et al., 2013b |
| C. japonicus Green* | Acer negundo L., A. pseudoplatanus L., Aesculus hippocastanum L., Morus alba L., Nerium oleander L., Piptaciae terebinthina L., L. nobilis, Ulmus sp. | Ma | Ülgentürk et al., 2008 |
| Ceroplastes rusci (Linnaeus)** | Quercus sp., Q. coccifera | Ae, Bs | Kaydan et al., 2013, 2014; Ülgentürk et al., 2013b |
| Coccus hesperidum L.** | Quercus sp., P. penduculiflorum K. Koch, Jasminum fruticans L., Acer campestre L., A. pseudoplatanus, C. monogyna, C. oxycahna L., Ribes sp., Cydonia sp., Malus sp. | Ma | Bodenheimer, 1953; Ülgentürk et al., 2008 |
| Eulecanium ciliatum (Douglas)* | Quercus sp., Q. penduculiflorum K. Koch, Jasminum fruticans L., Acer campestre L., A. pseudoplatanus, C. monogyna, C. oxycahna L., Ribes sp., Cydonia sp., Malus sp. | Ca | Bodenheimer, 1953; Ülgentürk and Toros, 1999a; Zeki et al., 2005 |
| Eulecanium cerasorum (Cockerell)* | Qu. robur | Ca | Ülgentürk et al., 2013a |
| Eulecanium tiliae (Linnaeus) | A. pseudoplatanus, A. hippocastanum, Crateagus sp., N. oleander, Quercus sp., Q. robur, Q. coccifera, Q. penduculiflorum K. Koch, Ulmus minor Mill. (A. U. campestre), Tilia sp. | Bs, Ma, Ca | Bodenheimer, 1953; Ülgentürk and Toros, 1999a; Ülgentürk et al., 2013b; Zeki et al., 2005 |
| Filippia follicularis (Targioni-Tozzetti) | Fraxinus americana L., F. excelsior L., Jasminium sp., Olea sp., Olea europea L., Phillyrea sp., Prunus avium L., P. dulcis (Mill), Quercus sp., Viburnum sp., V. m | Ae, Bs, Ca, Ma | Bodenheimer, 1953; Ülgentürk and Toros, 1999a; Ülgentürk et al., 2013b |
| Lichthensia viburni Signoret | Ceratonia silique L., Hedera helix L., Phillyrea sp., Pistaciae sp., Viburnum tinus L. | Ae | Yasar, 1990; Ülgentürk et al., 2008; |
| Neopulvinaria innumerabilis Rathorn* | Quercus sp., P. penduculiflorum K. Koch, Jasminum fruticans L., Acer campestre L., A. pseudoplatanus, C. monogyna, C. oxycahna L., Ribes sp., Cydonia sp., Malus sp. | Ca, Ma | Ülgentürk and Ayhan, 2011 |
| Parthenoecium corni (Bouche)* | Crataegus sp., Corylus avellana L., Fagus sp., Fraxinus sp., M. alba, Quercus sp., Salix sp., Ulmus sp. | Bs, Ma, Ca | Bodenheimer, 1953; Ülgentürk and Toros, 1999a, Kaydan et al., 2014 |
| P. rufalum (Cockerell) | C. avellana, Quercus sp. | Ae, Bs, Ca, Ma | Kaydan et al., 2013; Kaplan and Turanlı, 2016 |
| Parthenoecium tamaricis (Bodenhimer) | Tamarix pallasi Desv. | Ca? | Bodenheimer, 1953 |
| Pulvinaria floccifera (Westwood) | Prunus laurocerasus L., Camellia sinensis (L.) | Bs, Ma | Alkan, 1957; Ülgentürk et al., 2008 |
| P. terrestris Borchsenius | Crataegus sp. | Ae, Bs, Ca, Ma, Me | Kaydan et al., 2013 |
| Pulvinaria vittis (Linnaeus) | Crataegus sp., Populus nigra L., P. tremula L., Quercus sp., Salix sp., S. alba, Ulmus sp. | Ae, B, Ca | Kaydan et al., 2013 |
| Rhodococcus perornatus (Cockerell & Parrott) | Rosa sp., R. cinnamomea L., R. canina L., R. damascena Mill., Rosa pimpinellifolia L. | Ca, Me | Zeki et al., 2005 |
| Saissetia oleae (Olivier) | A. unedo, Phillyrea sp., O. europaea, N. oleander | Ae, Bs, Ma, Me | Kaydan et al., 2013, 2014 |
| Species | Host plants | Distribution | References |
|---------|-------------|--------------|------------|
| Cryptococcus fagisuga Lindinger | *F. orientalis* | Bs | Kozár et al. 2013 |
| *Pseudothecomeria fraxini* (Kaltenbach) | *F. excelsior* | Ma | Bodenheimer, 1953; Kozár et al. 2013 |
| **Cryptococcidae** | | | |
| *Aonidia lauri* (Bouche) | *L. nobilis* | Ma, Me, Sea | Kaydan et al., 2013 |
| *Aonidiella aurantii* (Maskell) | *Cerotionia siliqua L., L. nobilis* | Me | Kaydan et al., 2013, 2014 |
| *Aspidiotus hedericola* Leonardi | *L. nobilis, H. helix* | Ae, Me, Ma | Kaydan et al., 2013 |
| *A. nerii* Bouché | *Acacia celtiformis G. Domm., A. cyanothylla Lindley* | Ae, B, Me, | Kaydan et al., 2013, 2014 |
| *Chionaspis etrusca* Leonardi | *Tamarix sp.* | Ca, Ea, Me | Bodenheimer, 1953 |
| *Chionaspis salicis* (Linnaeus) | *P. alba, P. x canadensis Moench, P. nigra L., P. tremula, Salix alba, S. babylonica L., Ulmus sp.* | Bs, Ca, Ea, | Kaydan et al., 2013, 2014 |
| *C. lepinea* Balachowsky | *Quercus sp.* | Ea | Kaydan et al., 2013, 2014 |
| *Chrysomphalus dictyospermi* (Morgan)** | *B. sempervirens, C. siliqua, H. helix, Ilex aquifolium L., Jasminium sambuc (L.), L. nobilis, M. sylvestris, M. communis, N. oleander* | Ae, Ma | Yaşar, 1995; Erözmen and Yaşar, 2018 |
| *Comstockaspis perniciosus* (Comstock)** | *Crataegus orientalis M.Bieb, Prunus spinose L., Spurthum, juncemum L.* | Bs, Ca, Ea, Ma | Kaydan et al., 2013, 2014; |
| *Diapsidiotus armenicus* (Borchsenius) | *P. alba, P. nigra, Salix sp., Ulmus sp.* | Ma | Kaydan et al., 2013, 2014 |
| *D. caucasicus* (Borchsenius) | *Populus sp., P. nigra var. pyramidalis, Quercus sp., Salix sp.* | Ma | Kaydan et al., 2013, 2014 |
| *D. gigas* (Thienck & Gerneck) | *Populus nigra, Salix sp.* | Ba, Ea, Ma | Kaydan et al., 2013, 2014 |
| *D. lenticularis* (Lindinger) | *Prunus avium L.* | Ma | Kaydan et al., 2013 |
| *D. kauauri Balachowsky* | *Fraxinus sp., M. sylvestris, P. orientalis* | Ea | Kaydan et al., 2013, 2014 |
| *D. marani* (Zahradnik) | *Fraxinus sp., M. sylvestris, P. orientalis, P. avium, Ulmus americana L.* | Bs, Ca, Ea, Ma, Sea | Kaydan et al., 2013 |
| *D. ostreaformis* (Curtis) | *A. negundo, C. avellana, Liquidambar orientalis Miller, M. sylvestris, Populus sp., P. x canadensis-sp.* | Ae, Ba, Ca, Ma, Sea | Kaydan et al., 2013 |
| *D. osborni* (Newell & Cockerell) | *Salix sp.* | Sea | Kaydan et al., 2013 |
| *D. pyri* (Lichtenstein) | *Salix sp.* | Bs, Ca, Ea, Ma | Kaydan et al., 2013 |
| *D. uvar* (Comstock) | *Celisii siliquasrum L., F. excelsior, P. orientalis, Paulownia tomentosa (Thunb.). Jacaranda mimosifolia* | Ae | Keçe- Çalışkan and Ulusoy, 2017 |
| *D. venni* (Lindinger) | *Alnus sp., Quercus sp.* | Ma | Kaydan et al., 2013, 2014 |
| *D. zonatus* (Frauenfeld) | *F. orientalis, Quercus sp., Q. coccifera, Salix sp., Ulmus americana* | Ba, Ca, Ea | Kaydan et al., 2013; 2014 |
| **Diaspididae** | | | |
| *Dynamispis britannicus* (Newstead) | *C. siliqua, Daphne sp., H. helix, L. nobilis, M. communis* | Bs, Ca, Me | Bodenheimer, 1953; Ülgentürk et al., 2012a, 2019 |
| *Epidiaspis leprieri* (Signoret) | *A. hippocastaneum, Pistacia sp., Prunus sp., R. pseudoacacia, Malus sp., Pyrus communis L.* | Ae, Bs, Ca, Ma | Kaydan et al., 2009; Erözmen and Yaşar, 2018 |
| *Gonasiapitis minimus* (Leonardi) | *Quercus coccifera, Q. dschrochensis, Q. ilex, Thuja sp.* | Ae, Me | Bodenheimer, 1952 |
| *Lepidosaphes granati* Koroneos | *Quercus sp., P. orientalis, Ulmus sp., U. glabra* | Ea | Kaydan et al., 2009 |
| *Lepidosaphes salicis* (Borchsenius) | *Alnus sp., Quercus sp., Salix sp.* | Ea | Kaydan et al., 2013 |
| *L. ulmi* (Linnaeus)** | *Acer sp., A. negundo, Fagus sp., Gleditschia sp., Ilex sp., Populus sp., Quercus sp., Rosa sp., R. canina, R. damascena, Salix sp., S. junceum* | Bs, Ca, Ea, Ma | Kaydan et al., 2013; Erözmen and Yaşar, 2018 |
| *Melanaspis inopinata* (Leonardi) | *A. hippocastaneum, A. smedo, Bauhinia sp., C. siliquastrum, Fraxinus sp., P. avium, Ulmus sp.* | Ca, Ma | Bodenheimer, 1949; Ülgentürk and Torres, 1996; Ayten and Ülgentürk, 2007 |
| *Parlatoria oleae* (Colvée)** | *Eriobotrya sp., Fraxinus sp., Rosa sp., M. sylvestris, Prunus sp., R. pseudoacacia* | Ae, Ca, Me, Ma | Kaydan et al., 2013 |
| *P. persandii* (Comstock)** | *C. siliqua, L. nobilis* | Ma | Kaydan et al., 2013 |
| *Pseudoaulacaspis pentagona* (Targioni-Tozzetti)** | *Aesculus carnea Brüttis, C. bignonoides, Cornus alba L., Forsythia x intermedia, F. americana, F. excelsior, M. alba, Prunus sp., Paulownia tomentosa (Thunb.), P. avium, P. cerasus, Quercus sp., Rhus typhina L., S. babylonica, S. syringii vulgaris L.* | Ae, Bs, Ca, Ma, Me | Bodenheimer, 1949; Erkülç and Uğun 1995; Mohammed et al. 2016 |
| *Salicicola ancherangelikae* (Lindinger) | *C. monogyna, C. oxyacantha, C. orientalis, F. excelsior* | Ae, Ca, Ea | Yaşar, 1995; Kaydan et al., 2014 |
| *S. kerzhanensis* (Lindinger) | *Populus sp., P. nigra, Quercus sp.* | Ca, Ea | Yaşar, 1995 |
| *Targioni vitis* (Signoret) | *A. hippocastaneum, Castanea crenata L., Quercus sp.* | Ea, Ca, Me | Kaydan et al., 2013 |
| **Eriococcidae** | | | |
| *Eriococcus baxi* (Boyer de Fonscolombe) | *Buxus sempervirens L.* | Bs, Ma | Kaydan and Kozár, 2008; Ülgentürk et al., 2008 |
| **Kermesidae** | | | |
2.1. Scale insects on conifer plants in Turkey

About 42 species of scale insects on conifer trees were reported in Turkey (Kaydan et al., 2013; Keço and Ulusoy, 2017; Ülgentürk et al., 2019a,b; Ülgentürk and Özdemir 2019). Pine trees vary according to climate and region. They also have the richest fauna of scale insects (twenty species). In forests of Turkey, Leucaspis pusilla Löw, Gomezmenornaspis cedricola Leonardi, M. helenica, Matsucoccus josephi Bodenheimer and Harpaz (Matsucoccidae) and Paleococcus fuscipennis Burmeister (Monophlebidae) are the most common species on pines, however Torosaspis cedricola (Balachowsky & Alkan) on cedar trees (Ülgentürk et al., 2012a,b). Except Leucaspis spp., the other species are fed on woody part of Conifer trees (Ülgentürk et al., 2012b). Although M. helenica is accepted as useful since its honeydew is a resource of Pine honey, actually it is a phloem sap feeder and cause yellow spots, early falling of needles, die back branches and destroyed young pine trees (Ülgentürk et al., 2012b, Ülgentürk et al., 2013b). M. helenica has one generation in a year and overwinters mostly third instar nymph in Aegean pine forest in Turkey (Bodenheimer, 1953; Gürkan, 2005, Ülgentürk et al., 2011). Many predators play an important role on plant health, through regulating M. helenica populations. Among those predators Neoleucopis cartiliana (Tanasijsihshuk) (Diptera: Chamaemyiidae) is the most efficient and common predator of M. helenica (Ülgentürk et al., 2013c). Recently, M. caucasia Hadzibejli was found on Abies nordmanniana and Picea orientalis in Blacksea forest (Ülgentürk et al., 2019b). The Israel Pine Blast Scale M. josephi was recorded on P. brutia, P. halepensis and P. pinea in forest of southern and Western Anatolia (Ülgentürk et al., 2013c). Afterwards Ülgentürk et al. (2016) determined that M. josephi has at least 4 generations per year and overwinters as second stage (cyst) underneath the bark of pine trees. Male and female with eggs were observed four times in March–April, May–June, July–August and the end of September. The adult females were settled for oviposition on the lower stems at the base of needle-bunches, on old cones and underneath the bark. Female produced a loose white ovisac and deposited 188-293 eggs. Elatophilus hebraicus Pericart (Hemiptera: Anthocoridae) is common and effective predator in Turkey (Ülgentürk, 2016). P. fuscipennis is a common monophlebid in Mediterranean and Aegean pine forests in Turkey (Ülgentürk et al., 2011). Like other monophlebids, it feeds on phloem and secretes honeydew (Ülgentürk et al., 2012a).

The range of cedar (Cedrus spp.) forest presently covers about 600,000 ha in Turkey (Boydak and Çalışoğlu, 2008).
Cedar trees are generally used for commercial purpose in Turkey. The most common and harmful pest of cedar is *T. cedrícíla* whereas totally 13 scale insect were recorded on cedar trees in Turkey (Ülgentürk et al., 2012a; Ülgentürk et al., 2013b). High population of *T. cedrícíla* has a very harmful effect on cedar trees, especially young cedar trees in urban green areas. High levels of sulphur dioxide and dust limit the activity of natural enemies in urban planting cedar (Dostbíl, 2012). *T. cedrícíla* has 2 generations in a year and overwinters as fertilized female on needles of cedar (Dostbíl and Ülgentürk, 2016). *Díaspsiáditos brítánícís* (Newstead) (Diaspididae) feeds on cedar, fir and spruce species while *T. cedrícíla* occurs only cedar species in Turkey. *D. brítánícís* has two generations and overwinters as second nymph instar on needle of cedar (Ayan and Ülgentürk, 2011). *Fisýksomérs hélíncílus* Kozár and Gounári (Coccidae) is distributed both natural fir forest and urban belts. It hibernates as third nymph stage and has one generation in a year in urban areas of Ankara (Ülgentürk, 2016). On the other hand, *Fisýksomérs pícíae* (Schránk) is found only on urban spruce trees of Ankara, Eskeçiher and Istanbul (Çanaççoğlu, 1977; Ülgentürk et al., 2008). *P. pícíae* is the main pest of spruce in parks and gardens of Ankara (Ülgentürk and Toros, 1999a; Ülgentürk et al., 2019a). It has one generation in a year and overwinters as second nymph stage (Turguter and Ülgentürk, 2006). Both species have potential of honeydew honey production in Turkey. *Fisýkocóscóccus clávállátus* (Dalman) (Hymenoptera: Encytádtia) is dominant parasitoids of *P. pícíae* and *Hélíncílus* in Ankara. *P. hélíncílus* is associated with a few number predators namely; *Anthríbus nubélus* Forster (Coleoptera: Anthribidae), *Chílócorúscus renípustulátus* Scriba (Coleoptera: Coccinellídae) and *Anthríbus nebulósus* (Hemiptera: Anthocorídae) in Turkey (Ülgentürk, 2001; 2016). *Anthríbus fasciátus* Forster (Coleoptera: Anthribidae) was the most abundant natural enemy of *P. hélíncílus* in Greece (Papanastasiou et al., 2018).

*Phenáccus pícíae* Löwb (Pseudócoccidae) is a widespread soft scale insect on Aceraceae (*Acer campsestre* L., *A. negándo* L., *Acer pseudoplatánus* L.), and Rosaceae (*Crataégus monógýna* Jacq., *C. oxyácántba* L., *Ribës sp.*, *Cyódónia sp.*) in the parks and gardens of Ankara (Ülgentürk and Toros, 1999a). Following heavy infestations, branches dried up and sometimes the whole tree died. It has one generation per year and overwinters as second nymph stage on the host plants in Ankara (Ülgentürk and Toros, 1999c). The most common parasitoid of *E. cíliáttum* was *Encyrús infídus* (Rossi) (Hymenoptera: Encytádtia) which made up of 66% of all parasitoids and the common predator was *Anthríbus fasciátáts* (Förster) Coleoptera: Anthribidae) in Ankara (Ülgentürk and Toros, 1999b). The maple mealybug *Phenáccos acérís* (Signoret) (Pseudócoccidae) is a polyphagous species recorded mostly on urban plants in Turkey. It has one generation in a year and overwinters as third nymph stage in the bark and other hidden places on the plant. At the end of February and in early March, the nymphs started to move to the one year old twigs. The female started egg laying in the middle of April in both years. Hatching started at the beginning of the June and first-instars nymphs settled on the leaf and remained there until the end of September. After this period, the nymphs moved to the bark to overwinter. The population was affected by natural enemies and by environmental conditions throughout the year (Kaydan et al., 2006; Kaydanet al., 2015). This mealybug is supposed to be of European origin where occasionally becomes a pest on ornamental or fruit trees (Kosztarab and Kozár, 1988). *P. acérís* was verified as the vector of the Little Cherry Virus 2 (LChV-2) and GLRaV species, Grapevine virus A and Grapevine virus B (GVA and GVB) in Europe (Le Maguet et al., 2012; Garcia et al., 2016). *Melánsáspís inópinátá* Leanárdi (Diaspididae) is a common pest on ash, horse chestnut and other park and forest plants (Ülgentürk and Toros, 1996; Kaydan et al., 2013). It has one generation annually, and overwinters as adult female in Ankara (Aytén and Ülgentürk, 2007). *Kermés sp.*, *P. rufulum*, *P. corní*, *Púto isráëlënsís* Ben-Dov are considered to be the sources of honeydew honey in oak forest in Turkey (Ülgentürk et al., 2013a, b).

Many species that are very common and serious pest on agriculture and horticulture plants are found on forest plants too. For example, olive scale insect *Parlatoríá oléae* (Colvéé) (Diaspididae) is an important pest on olive trees.

2.2. Scale insects on broad-leaved trees and shrubs in Turkey

Main broad–leaved trees of the Turkey forest are oak species (Anonymous, 2019). Over 40 scale insect species on oak trees were recorded in Turkey. Only 20 species are belonging to Asterolecaniádæ (8) and Kermsiádæ (12) families, and are feeding only on oak trees (Table 2). First record of scale insect on oaks was *Kermés ilícis* L. (Kermesidae) on *Quercus cocciféra* which is called as Kermes oak (Fahringer, 1922). *K. ilícis* were used commonly to dying silk and wool materials in Mediterranean and Middle East Regions in ancient times (Bodenheimer, 1953). Recently *Kermés hermónsís* Spódek & Ben-Dov was detected on *Quercus infectória* Oliv. in Díyarbakír (Kaydan et al., 2014). Beside chesnut and hazelnut, *Parthenolecánium rufulum* (Coccidae) is a pest of oaks in Turkey (Ecevit et al., 1987). It has one generation in a year and overwinters as second nymph instar on branches (Kaplán et al., 2016). *Parthenolecánium corní* (Bouché) (Coccidae) is polyphagous species that is common on fruits, ornamental and forest trees including oaks, beechn, ash, maple, elm, pólár and willow (Kaydan et al., 2013). On the other hand, *Eulecánium clíáttum* (Douglaus) (Coccidae) is a widespread soft scale insect on *Acer campsestre* L., *A. negándo* L., *Acer pseudoplatánus* L., and *Rosacea* (*Crataégus monógýna* Jacq., *C. oxyácántba* L., *Ribës sp.*, *Cyódónia sp.*) in the parks and gardens of Ankara (Ülgentürk and Toros, 1999a). Following heavy infestations, branches dried up and sometimes the whole tree died. It has one generation per year and overwinters as second nymph stage on the host plants in Ankara (Ülgentürk and Toros, 1999c). The most common parasitoid of *E. cíliáttum* was *Encyrús infídus* (Rossi) (Hymenoptera: Encytádtia) which made up of 66% of all parasitoids and the common predator was *Anthríbus fasciátáts* (Förster) Coleoptera: Anthribidae) in Ankara (Ülgentürk and Toros, 1999b). The maple mealybug *Phenáccos acérís* (Signoret) (Pseudócoccidae) is a polyphagous species recorded mostly on urban plants in Turkey. It has one generation in a year and overwinters as third nymph stage in the bark and other hidden places on the plant. At the end of February and in early March, the nymphs started to move to the one year old twigs. The female started egg laying in the middle of April in both years. Hatching started at the beginning of the June and first-instars nymphs settled on the leaf and remained there until the end of September. After this period, the nymphs moved to the bark to overwinter. The population was affected by natural enemies and by environmental conditions throughout the year (Kaydan et al., 2006; Kaydan et al., 2015). This mealybug is supposed to be of European origin where occasionally becomes a pest on ornamental or fruit trees (Kosztarab and Kozár, 1988). *P. acérís* was verified as the vector of the Little Cherry Virus 2 (LChV-2) and GLRaV species, Grapevine virus A and Grapevine virus B (GVA and GVB) in Europe (Le Maguet et al., 2012; Garcia et al., 2016). *Melánsáspís inópinátá* Leanárdi (Diaspididae) is a common pest on ash, horse chestnut and other park and forest plants (Ülgentürk and Toros, 1996; Kaydan et al., 2013). It has one generation annually, and overwinters as adult female in Ankara (Aytén and Ülgentürk, 2007). *Kermés sp.*, *P. rufulum*, *P. corní*, *Púto isráëlënsís* Ben-Dov are considered to be the sources of honeydew honey in oak forest in Turkey (Ülgentürk et al., 2013a, b).

Many species that are very common and serious pest on agriculture and horticulture plants are found on forest plants too. For example, olive scale insect *Parlatoríá oléae* (Colvéé) (Diaspididae) is an important pest on olive trees.
and apple, pear, quince and other species of Rosaceae. It has two generations in a year and overwinters as female in Turkey (Uygun et al., 2010). White peach scale Pseudaulacaspis pentagona (Targioni Tozzetti) (Diaspididae) is a pest of economic importance for mulberry, peach trees and woody ornamentals and it is widespread all the fruit-growing areas of Turkey (Yaşar, 1995; Uygun et al., 2010). It feeds on the trunks, branches and twigs. In heavy infestations, dieback and death of trees occur (Erkıç and Uygun, 1995). It is recorded on twenty-two host plant species in Ankara (Mohammed et al. 2016). Saissetia oleae (Olivier) (Coccidae) is polyphagous and important pest species on citrus and olive orchards. S. oleae is recorded on wild olive and oleander in maquis of Aegean and Mediterranean forests (Uygun et al., 2010). Planococcus citri (Risso) (Pseudococcidae) is the most cosmopolitan mealybug species that infested over 300 plant species in tropics and subtropics as well as in greenhouse (Williams, 2004). It is considered as one of the most major pest of citrus orchards in Turkey, due to the fact that its chemical control has not been achieved successfully yet. It has 3 generations per year and can be controlled using the parasitoid Leptomastix dactylopii Howard (Hymenoptera: Encyrtidae) and the predator Chrysochroa monticola Mulsant (Coleoptera: Coccinellidae) on the cedar (Cedrus libani Thunb) (Bodendeiner, F.S., 1949). The Coccoidea of Turkey, Diaspididae. A monographic study. Güney Matbaacılık ve Gazetecilik T.A.O., Ankara.

Acanthococcus melnikensis (Coccidae) is recorded on Tamaricaceae in Turkey (Kaydan et al., 2013; Kaydan and Kozar, 2008).

3. Conclusions

In this study is determined totally 137 scale insect in forest trees in Turkey. Among of them 43 scale insects [Coccidae (10), Diaspididae (22), Erococcidae (1), Marchalimidae (2), Matsucoccidae (2), Monophasidae (1) and Pseudococcidae (5)] are occured on conifer in Turkey. In addition, totally 95 scale insect species belonging to Acanthococcidae (8), Asterolecaniidae (8), Coccidae (18), Cryptococcidae (2), Diaspididae (34), Eriococcidae (1), Kermsidae (12), Lecanospidae (1) Monophasidae (1), Pseudoococcidae (8) and Putoidae (2) are reported on broad-leaved trees and shrubs in forest and urban areas in Turkey. Most of them infest agriculture and horticulture plants. Insects in forests and other natural areas have the potential to become a source of contamination for cultivated plants. On the other hand, natural enemies that we can use against insect pests of cultivated plants can maintain themselves only in natural areas. In this regard, knowledge on destructive and beneficial species no doubt will help us understand, protect and use the ecosystem without destroying it.

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