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Influence of Host Plant Associations on the Composition and Structure of Scale Insect (Hemiptera: Coccomorpha) Communities in Semi-arid Mediterranean-type Forests

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ABSTRACT

The Scale insect (Hemiptera: Coccomorpha) fauna of Algeria in forest environment is little known, as few studies have been conducted in these areas. The various studies conducted on scale insects in Algeria have shown the presence of 207 species to date. Most of these species (106) belong to the family Diaspididae. Coccomorpha species on forest woody species (*Cedrus atlantica*, *Ilex aquifolium*, *Juniperus oxycedrus*, *Juniperus phoenicea*, *Olea europaea*, *Pinus halepensis*, *Pistacia lentiscus*, *and Quercus ilex*) were collected from various sites in the Belezma National Park (Algeria) during the period 2013−2017. A total of 24 species were identified from six scale insect families: Diaspididae (70.83%), Kermesidae (8.33%), Pseudococcidae (8.33%), Asterolecaniidae (4.17%), Coccidae (4.17%), and Putoidae (4.17%). The species *Gomezmenoraspis pinicola* (Diaspididae) is recorded for the first time in Africa, and three

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species, are recorded for the first time in Algeria: *Quernaspis lepineyi* (Diaspididae), *G. pinicola* and *Planococcus vovae* (Pseudococcidae). According to zoogeographical groups, 8 species are endemic, 13 are Mediterranean, and 3 are cosmopolitan.

Keywords: Coccomorpha fauna, Scale insects, Forest woody species, Belezma National Park, Algeria, Africa.

INTRODUCTION

The recognition of the forest Coccomorpha fauna in North Africa is very limited. This fauna has been the subject of few studies (Marchal, 1908; Balachowsky, 1926, 1948; 1950; 1953; 1954). The first records of scale insects in Algeria were started by Boisduval (1867), followed by Newstead (1897), Lindinger (1910), Trabut (1910), Marchal (1911), Trabut (1911), and Balachowsky (1926−1958). These studies focused on the inventory and identification of the Coccomorpha fauna. More recent research has concentrated on the bioecology of the most harmful species affecting crops (Piguet, 1960; Husseini, 1977; Jafjaf, 1978; Klaa, 1985; Doumandji & Biche, 1986; Karahacene, 1986; Biche, 1987; Moumen, 1989; Mouandza, 1990; Chouchaoui, 1991; Idder, 1992; Ouatassou, 1993; Merahi, 2002; Belguendouz et al., 2013).

In Algeria, the first studies on forest entomology began with Seurat (1924) in his work “Forest Zoology in Algeria”. Research on forest insects in Algeria has primarily focused on the study of Coleoptera (Chakali, 2007; Abdelhamid et al., 2017), the processionary caterpillar (Zamoum et al., 2006; Chenchouni et al., 2010: Sbabdji et al., 2015; Mecheri et al., 2018), damage caused by cone-boring insects (Abdelhamid et al., 2023), and defoliating Lepidoptera (Chamboni et al., 1992; Khous & Demolin, 1997). Although 207 species of scale insects are currently known in Algeria (García Morales et al., 2016), it is certain that many new species remain to be discovered, both for Algeria and the world, especially species with cryptic lifestyles in the families Pseudococcidae, Eriococcidae, and Coccidae. These species often live hidden in roots, leaf sheaths, or bark crevices (Kosztarab & Kozár, 1988).

Scale insects, sap-sucking insects, are generally considered less harmful to forest species; however, in cases of massive infestations, they can kill trees. They cause discoloration, premature leaf drop, reduced shoot growth, death of branches, and even the entire tree. An example of this is the serious beech dieback caused by the cochineal insect (*Cryptococcus fagisuga* Lindinger, 1936) associated with a fungus (*Nectria coccinea* (Pers.) Fr. (1849)) in northwestern France, and *Matsucoccus feytaudi* Ducasse, 1941, which was responsible for the destruction of several hectares of maritime pine forests in the southeast of the country (Becker et al., 1981).

The Belezma Mountain Forest was designated as a national park in 1986. Prior to this, the Belezma Forest had been subjected to illegal logging for 71 years (BNP, 2014). In addition to degradation caused by human activities (such as clearing and fires), the forest has faced the problem of the decline of the Atlas cedar, which has reached alarming proportions since 2001, affecting increasingly larger areas. The exact cause remains uncertain and is still hypothetical; however, trees weakened by years of drought have been more susceptible to attack by secondary pests, such as bark beetles (Coleoptera,

Curculionidae). This regressive trend has favored the spread of holm oak maquis, replacing decayed cedar trees. These environmental changes, along with alterations in forest characteristics, have impacted the diversity and density of insect populations.

The predominance of studies focusing on scale insects in cultivated environments (Belguendouz & Biche, 2015), combined with the scarcity of research in remote or inaccessible regions of Algeria, particularly in mountainous areas, motivated us to conduct a comprehensive inventory and identification of scale insect species potentially inhabiting forest woody species within Belezma National Park. This investigation seeks to determine whether the occurrence of a scale insect species in forest ecosystems is primarily driven by the presence of its specific host plant, or rather by the broader plant community to which that host belongs, in conjunction with the surrounding ecological and bioclimatic conditions. Recent studies have shown that the distribution and outbreaks of insects, including scale insects, are not solely determined by host availability but are also influenced by plant community structure and ecological parameters such as microclimatic variations, which strongly affect population dynamics and infestation intensity (Jactel et al., 2021; Luo et al., 2021; Santos-Neto et al., 2022). Furthermore, biogeographical research has emphasized that the interplay between host plants, associated vegetation, and climatic context plays a crucial role in shaping the spatial distribution of insect populations within forest habitats (Garibaldi et al., 2011; Franić et al., 2023).

This study aims to characterize the diversity and taxonomic composition of scale insect (Coccomorpha) communities associated with semi-arid Mediterranean forest ecosystems in Belezma National Park (Algeria), through a comprehensive faunistic inventory, and to examine their distribution across different forest types and host plants, as well as to explore patterns of species composition using statistical and multivariate analyses in order to provide a clearer understanding of their spatial organization and contribution to regional biodiversity. We hypothesize that species composition may vary among forest types in relation to differences in vegetation structure, host plant availability, and environmental conditions.

MATERIALS AND METHODS

Study area

This study was conducted in the Belezma National Park, located in the eastern part of northern Algeria, approximately 7 km northwest of the city of Batna. The park features mountainous massifs with an elongated configuration, oriented southwest to northeast (Fig. 1). It covers mountainous areas of high and medium, including Djebel Tichaou (2136 m), Djebel Tuggurt (2090 m), Djebel Kasserou (1641 m), and Djebel Mâaguel (1500 m), with a total area of 26,250 hectares. The Belezma Mountains are characterized by rugged terrain, narrow valleys, and peaks reaching heights of 2136 m (Djebel Tichaou) and 2178 m (Djebel Refaâ).

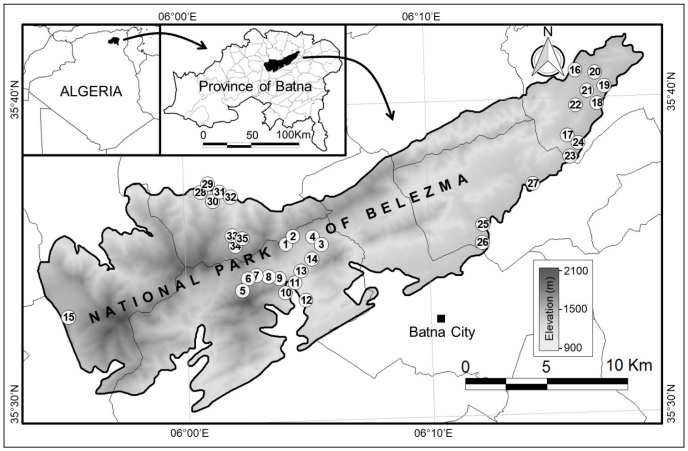

Figure 1. Elevation map and location of sampled forest sites in the national Park of Belezma, northeastern Algeria. Descriptive characteristics and tree species composition of the sampled sites (solid white circles numbered 1-35) are reported in Table 1.

The climate of the study area is semi-arid with cold winters. Over a 29-year period (from 1989 to 2017), July is the warmest month, with an average temperature of 37.9°C, while January is the coldest, with an average of -3.1°C. The region experiences a pronounced thermal amplitude, with high heat alternating with severe cold. This type of climate, influenced by both continental and montane aspects, is characterized by abrupt seasonal temperature variations. Annual rainfall ranges from 180 to 596.8 mm, with significant fluctuations in precipitation throughout the months and from year to year, a trend also observed during the study period (Fig. 2). Between 2013 and 2017, the number of freeze days varied from 32 to 50 per year, recorded between November and March.

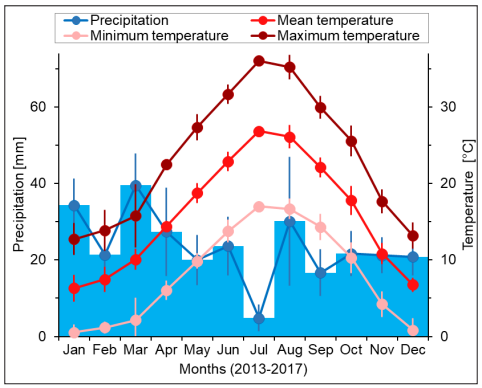

Figure 2. Ombrothermic diagram showing monthly precipitation (mm) and variation of minimum, maximum, and mean temperatures (°C) recorded from 2013 to 2017.

Collecting specimens

Sampling was conducted between the years 2013 and 2017. During this period, 35 sites were surveyed for the presence of scale insects on forest species within the

Belezma National Park (BNP). These sites included either sclerophyllous forest of Atlas cedar (*Cedrus atlantica* (Endl.) G. Manetti ex Carrière), holm oak (*Quercus ilex* L.), and cade juniper (*Juniperus oxycedrus* L.), or areas with Aleppo pine (*Pinus halepensis* Mill.), wild olive (*Olea europaea* L., as well as maquis and garrigue dominated by holm oak. This vegetation cover was divided into plant communities according to its floristic composition and structure, in order to identify homogeneous sampling units. Sites exhibiting similar plant communities were grouped under the same vegetation category (Table 1). However, the number of visits (2-3 per month) and the extent of each site varied depending on the homogeneity and continuity of the floristic composition, and more often, on the accessibility of the site (due to factors like fires and other obstacles). The sites were visited primarily in autumn (September-November), but more frequently in spring (March-May) and summer (June-August) throughout the period (2013-2017).

All specimens were collected from forest woody species, including trees and shrubs. Since species identification in this group of insects is possible only from adult female specimens (except for certain families where larvae can be used for identification), and adult females are generally sessile or immobile on their host plants, the most efficient method of collection involved sampling branches, leaves, petioles, and fruits, alongside observations on tree trunks. The collected plant parts were taken to the laboratory in large plastic bags and examined individually under a binocular stereomicroscope for the presence of scale insects. The materials examined in this study were collected by the first author, Bouguenna S.

For each species, collection data included the location, date of collection, and host plant. After photographing the specimens, they were placed in 70% alcohol and taken to the Plant Health Laboratory, Entomology and Invasive Plants Unit, in Montpellier, France, for identification. In the laboratory, the specimens were mounted on microscope slides following the method described by Ben-Dov & Hodgson (1997): The insects were macerated in 10% KOH, cleaned with distilled water, stained with a mixture of acid fuchsin, distilled water, glycerol, and lactic acid, then dehydrated in acetic acid and lavender oil, and finally mounted in Canada balsam. All specimens were identified by the late entomologist Jean-François Germain, and all slides are preserved in the Coccomorpha Collection at the Entomology and Invasive Plants Unit, Plant Health Laboratory, Montpellier, France.

RESULTS AND DISCUSSION

Composition of the scale insect families per forest

As a result of the inventory conducted between 2013 and 2017 on the scale insect (Coccomorpha) fauna in the Belezma National Park (eastern Algeria), 35 species were collected, of which 11 could not be identified to species level due to difficulties in obtaining suitable adult females required for reliable taxonomic identification. The unidentified specimens included: two Diaspididae, two Kermesidae, and one Pseudococcidae collected on *Quercus ilex*; one Eriococcidae on *Juniperus phoenicea* L.; one Diaspididae, one Pseudococcidae, and one Monophlebidae on *Pinus halepensis*; one Diaspididae on *Olea europaea*; and one Diaspididae on *Phillyrea angustifolia* L. (Fig. 3). A total of 24 species

and 19 genera were identified, belonging to the families Diaspididae (70.83%), Kermesidae (8.33%), Pseudococcidae (8.33%), Asterolecaniidae (4.17%), Coccidae (4.17%), and Putoidae (4.17%). The dominance of Diaspididae in the present study is consistent with their broad host range and frequent occurrence on woody plants, particularly in Mediterranean ecosystems (Miller & Davidson, 2006; Mansour et al., 2017).

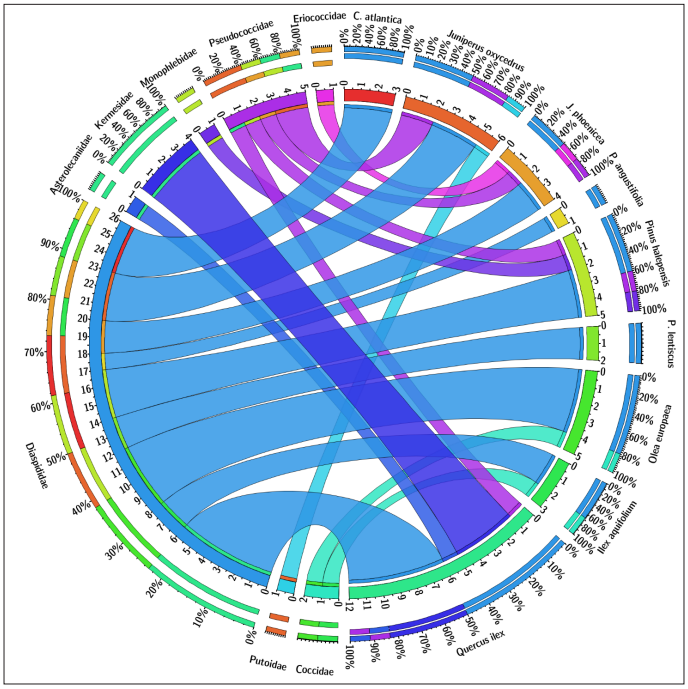

Figure 3. Chord diagram displaying the distribution of scale insect species by family associated with the main forest tree and shrubby species in National Park of Belezma (East of Algeria) from 2013-2017 survey.

A Pearson's chi-square test showed no significant association between the distribution of scale insect families and the nine forest types ($\chi^2 = 50.26$, $df = 56$, $p = 0.69$), indicating that community composition does not differ statistically among forest ecosystems at the family level. Similar outcomes have been reported in ecological studies where apparent variation is not statistically supported, suggesting that observed differences may reflect stochastic processes, sampling effects, or broad ecological tolerances rather than strong habitat filtering (Gotelli & Colwell, 2001; Chase, 2007; Vellend, 2010).

Descriptive patterns nevertheless show that Diaspididae occurred in all forest types and consistently dominated the assemblages, whereas other families were recorded less frequently. For instance, *Quercus ilex* forests hosted multiple families (e.g., Diaspididae (50%), Kermesidae (34%)), while *Pistacia lentiscus* L. and *Phillyrea angustifolia* were represented only by Diaspididae in the present dataset. Additional families such as Pseudococcidae, Eriococcidae, and Putoidae were recorded sporadically in coniferous stands (e.g., *Pinus halepensis* and *Juniperus* spp.). These differences likely reflect variation in host plant

availability and sampling coverage, as many scale insects show strong associations with particular host taxa and plant structures (Gullan & Kosztarab, 1997; Miller & Davidson, 2006).

The UpSet plot (Fig. 4) confirms that Diaspididae is shared across all nine plant communities, whereas the remaining families occurred in fewer habitats. This widespread distribution is consistent with their broad host associations within woody plant communities and their ability to occupy diverse microhabitats on stems, branches, and leaves (Gullan & Kosztarab, 1997; Miller & Davidson, 2006). However, this apparent ubiquity should not be interpreted as ecological uniformity, as detection probability in scale insects is strongly influenced by their cryptic morphology and uneven sampling of host plants. Conversely, the restricted distribution of other families is more likely explained by incomplete host sampling, fine-scale specialization, and spatial heterogeneity in vegetation structure rather than strict habitat limitation (Colwell & Coddington, 1994; Gullan & Cook, 2007). Accordingly, presence-absence patterns should be interpreted in relation to sampling completeness and host-plant representation rather than as direct indicators of habitat specificity.

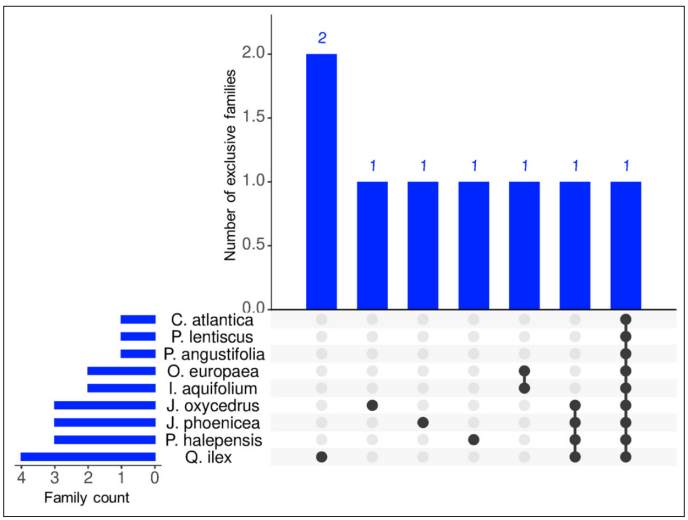

Figure 4. UpSet plot of shared scale insect families among the nine studied forest types.

Similarly, hierarchical clustering and heatmap analyses (Fig. 5) reveal groupings of forest types based on similarities in family composition. Some forests (e.g., *Pistacia lentiscus*, *Cedrus atlantica*, and *Phillyrea angustifolia*) appear highly similar due to the dominance of Diaspididae, whereas others show moderate differentiation. However, these groupings remain exploratory and may be influenced by differences in species richness and sampling intensity rather than reflecting clear ecological separation among forest types.

Despite some variation in family representation, the absence of significant associations indicates that scale insect communities are not strongly differentiated among forest types at the family level. This pattern likely reflects the dominance of widely distributed taxa such as Diaspididae and the influence of host plant distribution across forests. Finer-scale ecological differentiation may nevertheless occur at the species level, where host specificity is typically more pronounced in scale insects.

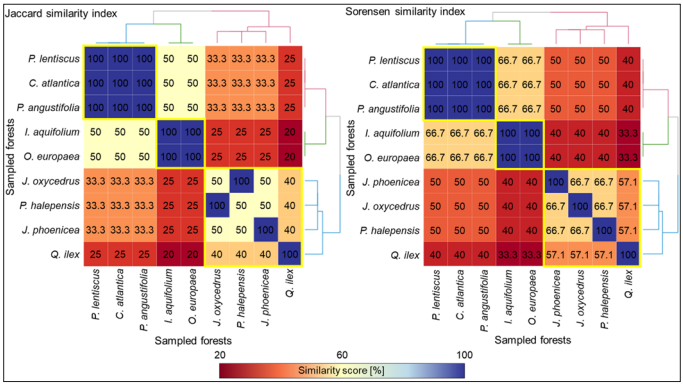

Figure 5. Heatmaps, with two-way clustering analysis (Complete linkage), displaying the matrices of similarity of scale insect families among the studied forests in the National Park of Belezma, Algeria. The similarity analysis used the qualitative index of Jaccard (top matrix) and Sorensen (bottom matrix).

Annotated list of forest scale species

The following section presents an annotated list of scale insect species collected from various forest tree and shrubby species within BNP. Each taxon is organized according to its respective family and is accompanied by detailed information to facilitate taxonomic, ecological, and biogeographical interpretation. For each species, we provided: (i) the material examined, including the host plant and the forest sites where the specimens were collected; (ii) the known distribution of the species worldwide based on available literature; (iii) the host range, indicating plant taxa previously recorded as hosts; and (iv) remarks specific to the current study, which include new observations on host associations, infestation patterns, and ecological notes relevant to the Algerian forest context. This systematic documentation contributes to expanding the knowledge of scale insect diversity in natural forest habitats and enhances understanding of their ecological relationships within Mediterranean forest ecosystems.

ASTEROLECANIIDAE

Asterodiaspis ilicicola (Targioni Tozzetti, 1888) (Figs. S1: S1a$_1$-S1a$_4$)

Material examined: *Quercus ilex*, S17, 21/04/2016, 13 ♀♀; S18, 15/04/2014, 13 ♀♀; 14/01/2016, 5 ♀♀; 03/03/2016, 5 ♀♀; S8, 22/04/2016, 8 ♀♀.

Distribution: Palaearctic: Algeria, Corsica, Croatia, France, Greece, Italy, Malta, Portugal, Sardinia, Spain and Turkey (García Morales et al., 2016).

Host: Fagaceae: *Quercus* spp., *Q. coccifera* L., *Q. ilex*, *Q. rotundifolia* L., *Q. suber* L. (García Morales et al., 2016).

Remarks: The colonies of this species settled exclusively on the upper side of the leaves of *Q. ilex* (Fig. S1a$_1$). We observed one generation per year in April. Although the infestation level of *A. ilicicola* on *Q. ilex* is considered significant, and some stunting has been observed on the infested oaks, the damage caused by this cochineal does not currently appear to be severe for the oak coppices. This is likely due to natural control by

a parasitoid wasp (*Marietta* sp.) (Figs. S1a$_2$, S1a$_4$), which attacks 90% of the cochineal population. However, monitoring is still necessary, as potential hyper-proliferation of this species due to environmental changes could lead to the dieback of holm oak in the future, which is a very important forest species for Algeria.

COCCIDAE

Coccus hesperidum Linnaeus, 1758 (Figs. S1: S1b$_1$−S1b$_3$)

Material examined: S35, Leaves of *Ilex aquifolium*, 05/10/2017, 3 ♀♀; S23, *Olea europaea*, 15/08/2017, 1 ♀♀.

Distribution: Cosmopolitan. Ülgentürk & Dokuyucu (2019) reports that this species is widely distributed in the Mediterranean region, but in continental climate it can survive only in indoors conditions. It is regarded as one of the highly polyphagous soft scale species (García Morales et al., 2016).

Host: Polyphagous. Observed on various fruit trees, ornamentals, forest trees and in green houses (García Morales et al., 2016).

Remarks: *Coccus hesperidum* was collected from large trees of *Ilex aquifolium*, occurring on both sides of the leaves. It settles on the leaf veins, especially along the main vein. Adult females were observed bearing crawlers within a chamber beneath the ventral derm (Figs. S1b$_1$, S1b$_2$).

DIASPIDIDAE

Cupressaspis mediterranea (Lindinger, 1910) (syn. *Aonidia mediterranea*) (Figs. S1: S1c$_1$- S1c$_5$)

Material examined: S13, *Juniperus phoenicea* 22/04/2017, 25 ♀♀; S34, *J. oxycedrus*, 10/05/2017, 5 ♀♀; S13, *J. oxycedrus*, 27/03/2013, 4 ♀♀; S22, *J. oxycedrus*, 15/08/2017, 2 ♀♀, 1 ♂♂.

Distribution: Palaearctic: Algeria, Armenia, Crete, France, Georgia, Greece, Morocco, Sardinia, Sicily, Spain, Turkey, Uzbekistan (García Morales et al., 2016).

Host: Three families, mainly Cupressaceae species including species of the genus *Juniperus*. The species *Pittosporum tobira* (Thunb.) W.T.Aiton of the Pittosporaceae family (Szita et al., 2017), and the species *Pinus brutia* Ten. of the family Pinaceae (Ülgentürk et al., 2012a).

Remarks: This species settles on the leaves and galbuli of *Juniperus phoenicea* and *J. oxycedrus* (Figs. S1c$_2$-1c$_5$).

Aspidiotus nerii Bouche, 1833 (Figs. S1: S1d$_1$−S1d$_3$)

Material examined: S35, *Ilex aquifolium*, 05/10/2017, 8 ♀♀.

Distribution: This species is widespread in Afrotropical, Australasian, Nearctic, Neotropical, Oriental and Palaearctic regions of the world (García Morales et al., 2016).

Host: Cosmopolitan, this species is known from 122 plant families, including Aquifoliaceae (García Morales et al., 2016).

Remarks: This species is found on both sides of *Ilex aquifolium* leaves (Figs. S1d$_1$- S1d$_3$).

***Carulaspis atlantica* (Lindinger, 1911)** (Figs. S1: S1e$_1$−S1e$_3$)

Material examined: S13, *Juniperus oxycedrus*, 22/04/2017, 11 ♀♀

Distribution: Palaearctic: Canary Islands, Morocco, Spain (Lindinger, 1911; Matile-Ferrero & Oromí, 2001; Balachowsky, 1954; Gómez-Menor Ortega, 1960). This armored scale was first recorded in Algeria by Belguendouz & Biche (2015); however, this is the second report of this species from Algeria.

Host: Cupressaceae: *Cupressus sempervirens* L., *Juniperus oxycedrus*, *J. phoenicea, Tetraclinis articulata* (Vahl) Mast., *(*Balachowsky, 1954a; Lindinger, 1911). Taxaceae: *Taxus baccata* (Biche et al., 2022).

Remarks: Specimens were commonly found on the galbuli (Figs. S1e$_1$, S1e$_2$) and rarely on the adaxial surface of *J. oxycedrus* leaves.

***Chionaspis kabyliensis* Balachowsky, 1930** (Figs. S1: S1f$_1$−S1f$_3$)

Material examined: S14, *Cedrus atlantica*, 22/04/2017, 7 ♀♀ and 1 larva.

Distribution: This species was first found by Peyerimhoff in the cedar forests of Tikjda (Djurdjura massif, 1500 m), Algeria, on June 8, 1930, and identified by Balachowsky (1930). The same species was reported in Morocco by Mimeur (1933) and has also been recorded in Turkey (Ülgentürk et al., 2012b).

Host: *Cedrus atlantica* (Balachowsky, 1930; Mimeur, 1933; Ülgentürk et al., 2012b). *Pinus pinea* L., *Pinus sylvestris* L. (Biche et al., 2022).

Remarks: This species appears to coexist with *Dynaspidiotus regnieri*, as previously noted by Balachowsky (1929).

****Quernaspis lepineyi* (Balachowsky, 1928) (syn. *Chionaspis lepineyi*)** (Figs. S2: S2a$_1$- S2a$_4$)

Material examined: S10, *Quercus ilex*, 22/04/2017, 10 ♀♀; S34, *Q. ilex*, 07/07/2017, 16 ♀♀.

Distribution: This species is distributed in the Palaearctic region (García Morales et al., 2016); however, this is the first report of the species in Algeria.

Host: Fagaceae: *Castanea sativa* Mill., *Quercus coccifera*, *Q. ilex*, *Q. ithaburensis* Decne., *Q. robur* L., *Q. suber* (García Morales et al., 2016).

Remarks: This scale insect consistently settles only on the trunk and old twigs of *Q. ilex*. It appears to prefer shaded areas within the interior of the tree, as it is never found on young branches at the outer part. The species is primarily detectable by the presence of male assemblages, which are conspicuous due to the white color of their tests, whereas the females are cryptic, resembling the bark of their host plant (Figs. S2a$_2$, S2a$_3$).

***Diaspidiotus labiatarum* (Marchal, 1909)** (Figs. S2: S2b$_1$−S2b$_4$)

Material examined: S17, *Pistacia lentiscus*, 15/05/2017, 4 ♀♀; S26, *P. lentiscus*, 24/11/2014, 1 ♀♀ and 5 larvae.

Distribution: This species is widely distributed in Europe and the Mediterranean regions (García Morales et al., 2016).

Host: Mainly Lamiaceae species including species of the genera *Teucrium* and *Thymus*. Other families include Amaranthaceae, Anacardiaceae, Caryophyllaceae, Cistaceae, Crassulaceae, Euphorbiaceae, Fabaceae, Hypericaceae, Plantaginaceae, Serpulidae and Thymelaeaceae (García Morales et al., 2016).

Remarks: *Diaspidiotus labiatarum* was first recorded in Algeria by Balachowsky (1929) and has not been reported since. This study therefore represents the second record of the species in Algeria. The female test is elongated and reddish-brown, while the adult female is pentagonal and yellow. Oviposition was observed from mid-May onward (Figs. S2b$_2$, S2b$_4$).

***Diaspidiotus laperrinei* (Balachowsky, 1929)** (Figs. S2: S2c$_1$, S2c$_2$)

Material examined: S30, leaves of *Olea europaea*, 10/05/2017, 1 ♀♀.

Distribution: Algeria and Iran (Balachowsky, 1929; Moghaddam, 2013).

Host: Apocynaceae: *Nerium oleander* L., Myrtaceae: *Myrtus nivellei* Batt. & Trab.; Oleaceae: *Olea europaea*; Polygonaceae: *Calligonum* spp.; Tamaricaceae: *Tamarix africana* Poir., *Tamarix aphylla* (L.) H.Karst., *Tamarix gallica* L. (García Morales et al., 2016).

Remarks: Specimens were found on both sides of the *O. europaea* leaves (Figs. S2c$_1$, S2c$_2$). All were desiccated except for a single female, which was identified.

***Diaspidiotus lenticularis* (Lindinger, 1912)** (Figs. S2: S2d$_1$−S2d$_3$)

Material examined: S10, *Quercus ilex*, 22/04/2017, 2 ♀♀ and 7 larvae; S34, *Q. ilex*, 07/07/2017, 2 ♀♀ and 1 larva.

Distribution: Australasian (South Australia) and Palaearctic region (García Morales et al., 2016).

Host: Mainly Fagaceae species including species of the genera *Fagus* and *Quercus*. Other families include Anacardiaceae, Betulaceae, Euphorbiaceae, Fabaceae, Moraceae, Oleaceae, Pinaceae, Rhamnaceae, Rosaceae and Salicaceae (García Morales et al., 2016).

Remarks: Specimens were collected on the twigs and branches of *Q. ilex*, in association with *Quernaspis lepineyi*. This species was first recorded in Algeria as *Quadraspidiotus lenticularis* (Lindinger, 1912) by Doumandji & Biche (1986), on twigs of *O. europaea*.

***Diaspidiotus maleti* (Vayssière, 1920)** (Figs. S2: S2e$_1$, S2e$_2$)

Material examined: S17, *Olea europaea*, 15/05/2017, 1 ♀♀.

Distribution: This species has only been recorded from Algeria and Morocco (García Morales et al., 2016).

Host: Oleaceae: *Fraxinus excelsior* L., *Olea europaea*; Sapotaceae: *Sideroxylon spinosum* L. (García Morales et al., 2016).

Remarks: The specimen was found on the adaxial surface of an *O. europaea* leaf. This species was first recorded in Algeria by Perrin on *O. europaea* in 1931 (Balachowsky & Mesnil, 1935).

***Dynaspidiotus regnieri* (Balachowsky, 1928)** (Figs. S2: S2f$_1$- S2f$_4$)

Material examined: S4, *Cedrus atlantica*, 27/03/2013, 2 ♀♀; S6, 27/03/2013, 1 ♀♀; S7, 27/03/2013, 1 ♀♀; S8, 27/03/2013, 2 ♀♀; S9, *C. atlantica*, 27/03/2013, 1 ♀♀; S14, *C. atlantica*, 22/04/2017, 10 ♀♀; S32, *C. atlantica*, 10/05/2017, 4 ♀♀; S34, *C. atlantica*, 10/05/2017, 3 ♀♀.

Distribution: Palaearctic: Algeria, France, Morocco and Spain (García Morales et al., 2016).

Host: Pinaceae: *Cedrus atlantica.* Oleaceae: *Fraxinus excelsior* (García Morales et al., 2016).

Remarks: This is the second report of *Dynaspidiotus regnieri* from Algeria. Specimens were found on cedar needles, either at the tip or at the base. Individuals of this species were usually isolated, although the diaspidid *Leucaspis pusilla* Löw, 1883 was often observed coexisting and aggregating with it. The waxy covering of *D. regnieri* may mimic the white stomatal bands on *C. atlantica* needles, resulting in a passive mimicry effect (Fig. S2f$_2$). Active viviparous females were observed in early December, with first-instar nymphs expelled through the opening formed by the invaginated pygidium (Fig. S2f$_3$). A hymenopteran endoparasitoid of the female was also recorded as a natural enemy (Fig. S2f$_4$).

***Getulaspis bupleuri* (Marchal, 1904)** (Figs. S3: S3a$_1$−S3a$_3$)

Material examined: S23, *Olea europaea*, 15/08/2017, 4 ♀♀.

Distribution: Palaearctic: Algeria, Canary Islands, Crete, Libya, Morocco, Saudi Arabia and Tunisia (García Morales et al., 2016).

Host: 15 botanical families including species of Amaranthaceae, Apiaceae, Arecaceae, Asparagaceae, Buxaceae, Crassulaceae, Cupressaceae, Fabaceae, Lamiaceae, Oleaceae, Plantaginaceae, Rubiaceae, Rutaceae, Salvadoraceae and Sapotaceae (García Morales et al., 2016).

Remarks: This species is commonly found on the abaxial surface of *Olea europaea* leaves. Females were observed with several dozen male shields, most of which were empty. Some female shields exhibited an exit hole produced by an endoparasitoid. Individuals of both sexes were only rarely observed on the adaxial surface.

****Gomezmenoraspis pinicola* (Leonardi, 1906)** (Figs. S3: S3b$_1$- S3b$_7$)

Material examined: S22, *Pinus halepensis*, 15/05/2017, 10 ♀♀ and 2 larvae.

Distribution: Palaearctic region: Cyprus, Portugal, Spain, and Turkey (Lindinger, 1912; Leonardi, 1906; Franco et al., 2011; Ülgentürk et al., 2012a). This is the first report of this species from Africa.

Host: Pinaceae: *Pinus* spp. including *P. brutia* Ten., *P. halepensis*, *P. pinea* and *P. sylvestris* (Leonardi, 1906; Lindinger, 1912; Ülgentürk & Dokuyucu, 2019; Balachowsky, 1935). Salicaceae: *Populus* spp. (Soria et al., 2020).

Remarks: This is an almost imperceptible species (Fig. S3b$_1$). Second-instar female nymphs are found on young twigs around mid-May, mostly at the insertion points of pine needles. They

have a white shield, with the exuviae of the first-instar larva yellow. At this stage, the female body is oval with a rounded pygidium, pale yellow in color, later turning pale brown as they reach adulthood (Figs. S3b$_4$, S3b$_6$). The adult female body is enclosed within a membranous cuticle (Fig. S3b$_5$). As the female matures, the exuviae becomes eccentric, initially yellow, and eventually darkens to resemble the black bark of twigs. Adult females with shields lacking exuviae, which appear to have detached, can also be observed. The ventral vellum is well developed (Fig. S3b$_5$). On the trunk, individuals are generally sparse, sometimes clustered. Adult and second-instar females are found on the trunk around mid-August, often parasitized. During this period, adult female cuticles become sclerotized, and most larvae desiccate.

***Gonaspidiotus minimus* (Leonardi, 1896)** (Figs. S3: S3c$_1$-S3c$_5$)

Material examined: S13, *Quercus ilex*, 22/04/2017, 2 ♀♀; S34, *Q. ilex*, 10/05/2017, 11 ♀♀; S35, *I. aquifolium*, 10/05/2017, 4 ♀♀; S17, *Q. ilex*, 15/05/2017, 10 ♀♀; S5, *Q. ilex*, 10/07/2017, 2 ♀♀.

Distribution: Mediterranean region: Algeria, Corsica, Crete, Croatia, France, Greece, Israel, Italy, Lebanon, Malta, Morocco, Sardinia, Spain and Turkey (García Morales et al., 2016).

Host: Arecaceae: *Chamaerops humilis* L. Fagaceae: *Quercus coccifera*, *Q. ilex*, *Q. incana* W.Bartram, *Q. ithaburensis* Decne, *Q. petraea* (Matt.) Liebl., and *Q. suber* (García Morales et al., 2016). In this study, *Ilex aquifolium* (family Aquifoliaceae) is recorded for the first time as a host plant of *G. minimus*.

Remarks: *Gonaspidiotus minimus* was recorded on a large *Ilex aquifolium* tree, a host plant not commonly reported for this species. The tree was located near a natural water source in a shaded area dominated by *Cedrus atlantica* and large *Quercus ilex* trees. Individuals were observed on the abaxial surface of *I. aquifolium* leaves.

The body shape and cuticle of this diaspidid exhibit a wavy appearance, likely influenced by the velutinous trichome structures on the leaves of *Q. ilex* and *I. aquifolium*. These trichomes act as physical barriers, shaping the growth pattern of the female body and its wax secretions (Fig. S3c$_4$). *G. minimus* is frequently found in association with *Asterodiaspis ilicicola* on the leaves of *Q. ilex* (Fig. S3c$_3$).

***Lineaspis striata* (Newstead, 1897)** (Figs. S4: S4a$_1$- S4a$_9$)

Material examined: S8, *Juniperus oxycedrus*, 27/03/2013, 9 ♀♀; S25, *J. oxycedrus*, 24/11/2014, 12 ♀♀; S13, *J. oxycedrus*, 22/04/2017, 18 ♀♀, *J. phoenicea* 1 ♀♀; S14, *J. oxycedrus*, 22/04/2017, 3 ♀♀; S28, *J. oxycedrus*, 10/05/2017, 2 ♀♀; S31, *J. oxycedrus*, 10/05/2017, 5 ♀♀; S20, 24/11/2014, *J. oxycedrus* 2 ♀♀; S17, 24/11/2014, *J. phoenicea* 4 ♀♀, *J. oxycedrus* 1 ♀♀; S17, *J. phoenicea*, 15/05/2017, 14 ♀♀.

Distribution: Palaearctic: Algeria, Armenia, Corsica, Crete, Cyprus, Egypt, France, Georgia, Greece, Israel, Jordan, Kazakhstan, Morocco, Sardinia, Spain, Syria and Turkey (García Morales et al., 2016).

Host: Mainly Cupressaceae; Iridaceae: *Iris foetidissima* L.; Pinaceae: *Picea glauca* (Moench) Voss; Santalaceae: *Arceuthobium*; Taxaceae: *Taxus baccata* (García Morales et al., 2016).

Remarks: On *Juniperus phoenicea*, this species is found only on the leaf scales. Females that had laid eggs and L1 larvae were observed in mid-May 2017. On *J. oxycedrus*, the species occurs on leaves and galbuli. Ovipositing females were

observed on the abaxial surface of galbuli, surrounded by numerous white waxy male tests (Figs. S4a$_6$-S4a$_8$). In some specimens, parasitoid emergence was also recorded (Fig. S4a$_9$).

***Leucaspis pusilla* Löw, 1883** (Figs. S4: S4b$_1$- S4b$_6$)

Material examined: S4, *Cedrus atlantica*, 27/03/2013, 7 ♀♀; S6, *C. atlantica*, 27/03/2013, 10 ♀♀; S7, *C. atlantica*, 27/03/2013, 4 ♀♀; S8, *C. atlantica*, 27/03/2013, 11 ♀♀; S9, *C. atlantica*, 27/03/2013, 5 ♀♀; S16, *P. halepensis*, 12/03/2013, 2 ♀♀; S17, *P. halepensis*, 12/03/2013, 8 ♀♀; S20, *P. halepensis*, 14/11/2016, 8 ♀♀; S22, *P. halepensis*, 15/05/2017, 24 ♀♀; S14, *C. atlantica*, 22/04/2017, 2 ♀♀ and 26 larvae; S32, *C. atlantica*, 10/05/2017, 3 ♀♀; S34, *C. atlantica*, 10/05/2017, 27 ♀♀.

Distribution: Palaearctic: widespread in Mediterranean and European countries; also present in Neotropical: Argentina (García Morales et al., 2016).

Host: Pinaceae: Mainly species of the genus *Pinus* also on species of the genera *Cedrus* and *Abies* (García Morales et al., 2016).

Remarks: On *Cedrus atlantica*, this species is found in association with *Dynaspidiotus regnieri* and *Chionaspis kabyliensis*. Pronounced coexistence with *D. regnieri* was also observed. *Leucaspis pusilla* frequently settles on cedar needles, aggregating beneath *D. regnieri* (Figs. S4b$_3$- S4b$_5$), which may represent a strategy to avoid parasitoids (Fig. S4b$_6$).

***Saharaspis ceardi* (Balachowsky, 1928)** (Figs. S4: S4c$_1$- S4c$_4$)

Material examined: S17, *Pistacia lentiscus*, 15/05/2017, 3 ♀♀.

Distribution: The current distribution is limited to five countries in the Palaearctic region: Algeria, Croatia, Italy, Morocco and Sardinia (García Morales et al., 2016).

Host: Anacardiaceae: *Pistacia lentiscus*, *P. vera* L.*;* Fabaceae: *Ceratonia siliqua* L.*;* Moraceae: *Ficus carica* L., *Morus alba* L.*;* Oleaceae: *Olea europaea;* Rhamnaceae: *Ziziphus lotus* (L.) Lam.; Vitaceae: *Vitis vinifera* L. (García Morales et al., 2016).

Remarks: A very low population of this species was found on *Pistacia lentiscus*, occurring on both leaf surfaces and on twigs (Figs. S4c$_2$, S4c$_3$). Most adult females were parasitized.

***Targionia vitis* (Signoret, 1876)** (Figs. S5: S5a$_1$−S5a$_3$)

Material examined: S31**,** *Quercus ilex*, 05/10/2017, 2 ♀♀.

Distribution: Mediterranean, European and eastern Palaearctic (García Morales et al., 2016).

Host: Amaranthaceae: *Atriplex halimus* L.; Ericaceae: *Arbutus unedo* L.; Fagaceae: *Castanea crenata* Siebold & Zucc., *C. sativa*, *Fagus sylvatica* L., *Q. cerris* L., *Q. coccifera*, *Q. dentata* Thunb., *Q. ilex*, *Q. infectoria* Oliv., *Q. ithaburensis*, *Q. petraea*, *Q. pubescens*, *Q. robur*, *Q. suber*; Platanaceae: *Platanus orientalis* L.; Poaceae: *Oplismenus compositus* (L.) P.Beauv.; Salicaceae: *Salix* spp.; Sapindaceae: *Aesculus hippocastanum* L.*;* Vitaceae: *Vitis vinifera* (García Morales et al., 2016).

Remarks: Specimens were collected on twigs of *Q. ilex*. The female scale cover is black, with the white larval exuviae centrally positioned (Figs. S5a$_1$, S5a$_2$).

KERMESIDAE

***Kermes ilicis* (Linnaeus, 1758)** (Figs. S5: S5b$_1$−S5b$_3$)

Material examined: S6, *Quercus ilex*, 22/04/2014, 3 ♀♀; S32, *Q. ilex*, 10/10/2016, 1 ♀♀; S7, *Q. ilex*, 16/05/2017, 20 larvae; S15, *Q. ilex*, 23/05/2017, 1 ♀♀.

Distribution: Palaearctic: Algeria, Austria, France, Greece, Hungary, Italy, Moldova, Portugal, Sardinia, Spain and Turkey (García Morales et al., 2016).

Host: Fagaceae: *Quercus coccifera*, *Q. ilex*, *Q. pubescens* Willd., *Q. pyrenaica* Willd. and *Q. suber* (García Morales et al., 2016).

Remarks: This species was found in association with aphids *Lachnus roboris* (Linnaeus, 1758). One specimen was also observed containing a Melyridae larva that fed on second-instar larvae of *Kermes ilicis* (Fig. S5b$_3$).

***Kermes vermilio* Planchon, 1864** (Figs. S5: S5c$_1$, S5c$_2$)

Material examined: S32, *Quercus ilex*, 10/10/2016, 16 larvae; S31, *Q. ilex*, 10/05/2017, 1 ♀♀.

Distribution: Palaearctic: Algeria, Corsica, Crete, France, Georgia, Greece, Italy, Malta, Morocco, Portugal, Sardinia, Spain, Switzerland and Turkey (García Morales et al., 2016).

Host: Fagaceae: *Quercus aucheri* Jaub. & Spach, *Q. coccifera*, *Q. ilex*, *Q. rotundifolia* and *Q. suber* (García Morales et al., 2016).

Remarks: This species is difficult to detect due to its cryptic coloration and the frequent layer of dust covering its body. It typically perches among the branches of *Q. ilex*, primarily on shaded branches, indicating a preference for shaded microhabitats.

PSEUDOCOCCIDAE

***Planococcus citri* (Risso, 1813)** (Figs. S5: S5d$_1$- S5d$_5$)

Material examined: S17, *Juniperus oxycedrus*, 21/04/2016, 3 ♀♀; S28, *J. oxycedrus*, 10/05/2017, 2 ♀♀; S17, *J. phoenicea*, 15/05/2017, 1 ♀♀.

Distribution: Cosmopolitan (García Morales et al., 2016).

Host: Polyphagous (García Morales et al., 2016). *Juniperus oxycedrus* and *J. phoenicea* are newly recorded as host plants of *P. citri* (Figs. S5d$_2$, S5d$_4$).

Remarks: On *Juniperus oxycedrus*, the mobile adult females of *Planococcus citri* were found protected at the point of attachment between the galbulus and the branch. However, the ovisacs of this mealybug were observed deposited in the axils of the branchlets of *J. oxycedrus* (Fig. S5d$_3$) and within the clusters of scale leaves of *J. phoenicea* (Fig. S5d$_5$).

****Planococcus vovae* (Nasonov, 1909)** (Figs. S5: S5e$_1$, S5e$_2$)

Material examined: S34, *Juniperus oxycedrus*, 05/10/2017, 1 ♀♀.

Distribution: This species is widely distributed in the Palaearctic region and is also present in the Neotropical region, including Brazil (García Morales et al., 2016). This is the first report of this species from Algeria.

Host: Mainly Cupressaceae species, also known on Araceae: *Anthurium* spp., Lauraceae: *Laurus nobilis* L.; Moraceae: *Morus* spp.; Piperaceae: *Piper nigrum* L.; Taxaceae: *Taxus baccata* (García Morales et al., 2016).

Remarks: Only a single individual of this species was observed occurring near the peduncle of the galbulus of *J. oxycedrus*, where it was depositing its ovisac (Fig. S5e$_2$).

PUTOIDAE

Puto peyerimhoffi (Vayssiere, 1923) (Figs. S5: S5f$_1$- S5f$_4$)

Material examined: S13, *Juniperus oxycedrus*, 22/04/2017, 1 ♀♀.

Distribution: To date, this species has only been recorded from Algeria (García Morales et al., 2016). This represents the second report of the species worldwide.

Host: Cupressaceae: *Juniperus thurifera* L. (Vayssière, 1923). *J. oxycedrus* is a new record as a host plant of *P. peyerimhoffi* (Figs. S5f$_2$, S5f$_3$).

Remarks: The adult female was found on the needle leaf of *J. oxycedrus*, depositing its ovisac (Figs. S5f$_2$, S5f$_3$).

Distribution of species according to plant communities

The heatmap (Fig. 6) shows that each forest group is characterized by a distinct combination of scale insect species, indicating variation in species composition among sites. Certain species, including *Dynaspidiotus regnieri*, *Leucaspis pusilla*, *Kermes ilicis*, and *Kermes vermilio*, are mainly associated with forest plant communities A8 and A1, suggesting some level of association with these habitats. In contrast, species such as *Lineaspis striata*, *Gonaspidiotus minimus*, and *Quernaspis lepineyi* occur across several forest types, indicating broader ecological and host range tolerance. Other taxa show low occurrence, either reflecting rarity (*Planococcus vovae*) or more restricted distributions (*Gomezmenoraspis pinicola*). Overall, these patterns suggest variation in species distribution among forest communities.

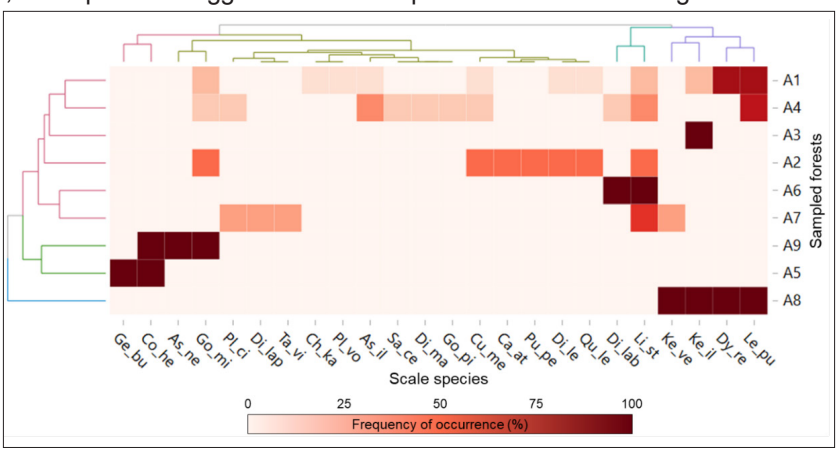

Figure 6. Heatmap with two-way clustering (complete linkage and Euclidean distances) showing the distribution of scale species along the studied forest types in BNP. See Table 1 for the explanation of codes of sampled forest A1-A9, including the forest tree species composition of each plant community.

However, the Pearson chi-square test revealed no significant association between species distribution and forest types (χ^2 = 95.27, *df* = 184, *p* = 0.99), indicating that observed differences are not statistically supported at the scale of analysis. This suggests that the observed variation may reflect sampling effects, low detection probability, or gradual ecological gradients rather than strict habitat specialization.

Field observations suggest that certain species may nevertheless show preferences for specific microhabitats. For example, *Kermes ilicis* and *Kermes vermilio* were frequently observed on large host trees in relatively humid and shaded conditions, particularly in northern exposures and higher elevation sites (S15, S31, S32, S33; Table 1), where holm oak and cedar forests predominate. In contrast, species such as *Diaspidiotus labiatarum* were more often recorded in drier conditions, while *Puto peyerimhoffi*, *Carulaspis atlantica*, and *Lineaspis striata* were mainly associated with more open and sun-exposed habitats. These observations suggest that microclimatic conditions and host plant structure may influence species occurrence, consistent with known ecological requirements of scale insects, particularly their sensitivity to host tissue and microenvironmental conditions (Gullan & Kosztarab, 1997; Miller & Davidson, 2006). However, these relationships remain observational and were not statistically tested in this study. A noteworthy example is provided by *Gonaspidiotus minimus*, whose occurrence on *Ilex aquifolium* is of particular interest, as this species is primarily reported from hosts within the Fagaceae, particularly *Quercus* spp. (García Morales et al., 2016; Ülgentürk & Dokuyucu, 2019; Stathas et al., 2013). Records on Aquifoliaceae are rare or absent in the available literature, suggesting that this observation may represent a rare or previously underreported host association. In the present study, this species was recorded on a large *I. aquifolium* tree located in a shaded and relatively humid microhabitat (S35), differing from the environmental conditions of other sites where the species was observed (e.g., S17). This finding may indicate a broader host range than previously documented and suggests some degree of ecological flexibility in host use under varying environmental conditions.

Table 1. Description of sampled forest sites in the National Park of Belezma (Algeria). Tree species marked in bold represents the dominant species per site.

Site*	Aspect	Slope (%)	Latitude (N)	Longitude (E)	Elevation (m)	Plant community	Composition of forest tree species of the plant community
S1. Col Telmet 1	SE	50	35.59745	6.07202	1594	A8	***Cedrus atlantica***, *Quercus ilex*
S2. Col Telmet 2	SE	50	35.59898	6.07380	1581	A8	***Cedrus atlantica***, *Quercus ilex*
S3. Col Telmet 3	SSE	30	35.60108	6.08998	1483	A8	***Cedrus atlantica***, *Quercus ilex*
S4. Thniet El Zaarour	S	10	35.59809	6.08890	1429	A1	***Cedrus atlantica***, *Quercus ilex*, *Juniperus oxycedrus*
S5. Djebel Bourdjem	SSE	40	35.57972	6.04602	1502	A1	***Cedrus atlantica***, *Quercus ilex*, *Juniperus oxycedrus*
S6. Djebel Tuggurt 1	S	10	35.57854	6.04627	1499	A1	***Cedrus atlantica***, *Quercus ilex*, *Juniperus oxycedrus*
S7. Djebel Tuggurt 2	S	60	35.57929	6.05066	1439	A1	***Cedrus atlantica***, *Quercus ilex*, *Juniperus oxycedrus*
S8. Djebel Tuggurt 3	S	50	35.57944	6.05849	1396	A1	***Cedrus atlantica***, *Quercus ilex*, *Juniperus oxycedrus*
S9. Djebel Tuggurt 4	S	50	35.57867	6.06549	1358	A1	***Cedrus atlantica***, *Quercus ilex*, *Juniperus oxycedrus*
S10#. Djebel Tuggurt 5	S	40	35.57885	6.07551	1290	A3	***Quercus ilex***, *Juniperus oxycedrus*
S11#. Djebel Tuggurt 6	S	50	35.57637	6.07762	1270	A3	***Quercus ilex***, *Juniperus oxycedrus*
S12. Djebel Tuggurt 7	S	40	35.56749	6.08023	1234	A2	***Quercus ilex***, *Juniperus phoenicea*, *Juniperus oxycedrus*
S13. Djebel Boumerzoug 1	NW	45	35.58076	6.07906	1284	A2	***Quercus ilex***, *Juniperus phoenicea*, *Juniperus oxycedrus*, *Phillyrea angustifolia*
S14. Djebel Boumerzoug 2	N	70	35.59497	6.09323	1419	A1	***Cedrus atlantica***, *Quercus ilex*, *Juniperus oxycedrus*, *Fraxinus xanthoxyloides*.
S15. Djebel Tichaou	N	85	35.55676	5.92396	1576	A3	***Quercus ilex***, *Juniperus oxycedrus*
S16. Djerma 1	N	4	35.68206	6.26374	988	A4	***Pinus halepensis***, *Quercus ilex*, *Juniperus phoenicea*, *Pistacia lentiscus*, *Phillyrea angustifolia*

Table continued

Site*	Aspect	Slope (%)	Latitude (N)	Longitude (E)	Elevation (m)	Plant community	Composition of forest tree species of the plant community
S17. Djerma 2	S	30	35.65120	6.26070	1042	A4	***Pinus halepensis***, *Quercus ilex*, *Juniperus phoenicea*, *Juniperus oxycedrus*, *Pistacia lentiscus*, *Olea europaea*, *Phillyrea angustifolia*
S18. Djerma 3	S	50	35.66806	6.28097	1073	A4	***Pinus halepensis***, *Quercus ilex*, *Juniperus phoenicea*
S19. Djerma 4	SE	10	35.68157	6.27753	1022	A6	***Pinus halepensis***, *Pistacia lentiscus*, *Phillyrea angustifolia*
S20. Djerma 5	SE	20	35.68136	6.27851	1025	A4	***Pinus halepensis***, *Quercus ilex*, *Juniperus phoenicea*, *Pistacia lentiscus*, *Phillyrea angustifolia*
S21. Djerma 6	NE	4	35.67329	6.27233	1045	A4	***Pinus halepensis***, *Quercus ilex*, *Juniperus phoenicea*, *Juniperus oxycedrus*, *Pistacia lentiscus*, *Phillyrea angustifolia*, *Cupressus sempervirens*
S22. Djerma 7	NE	5	35.66638	6.26558	1110	A4	***Pinus halepensis***, *Quercus ilex*, *Juniperus phoenicea*, *Juniperus oxycedrus*, *Pistacia lentiscus*, *Phillyrea angustifolia*, *Cupressus sempervirens*
S23. Djerma 8	SE	30	35.64660	6.26744	987	A5	***Olea europaea***, *Quercus ilex*, *Juniperus phoenicea*
S24. Djerma 9	SE	4	35.64698	6.26773	989	A5	***Olea europaea***, *Juniperus phoenicea*
S25. Bouielef 1	S	10	35.60081	6.20240	1025	A6	***Pinus halepensis***, *Pistacia lentiscus*, *Juniperus phoenicea*, *Juniperus oxycedrus*
S26. Bouielef 2	SE	40	35.59578	6.20094	1026	A6	***Pinus halepensis***, *Pistacia lentiscus*, *Juniperus phoenicea*
S27. Bouielef 3	NE	45	35.62528	6.23941	1041	A5	***Olea europaea***, *Juniperus phoenicea*, *Phillyrea angustifolia*
S28. Djebel Aourir 1	N	50	35.62436	6.01912	1203	A7	***Quercus ilex***, *Juniperus oxycedrus*, *Fraxinus xanthoxyloides*
S29. Djebel Aourir 2	NW	50	35.62408	6.01934	1213	A7	***Quercus ilex***, *Juniperus oxycedrus*, *Fraxinus xanthoxyloides*
S30. Djebel Aourir 3	N	45	35.62107	6.02606	1217	A7	***Quercus ilex***, *Juniperus oxycedrus*, *Olea europaea*, *Phillyrea angustifolia*
S31. Djebel Chlaalaa 1	NW	55	35.62075	6.02478	1252	A7	***Quercus ilex***, *Juniperus oxycedrus*, *Phillyrea angustifolia*, *Fraxinus xanthoxyloides*
S32. Djebel Chlaalaa 2	N	40	35.59846	6.03522	1465	A8	***Cedrus atlantica***, *Quercus ilex*
S33. Djebel Chlaalaa 3	N	55	35.59776	6.03711	1501	A8	***Cedrus atlantica***, *Quercus ilex*
S34. Djebel Chlaalaa 4	N	85	35.59651	6.04067	1525	A9	***Cedrus atlantica***, *Quercus ilex*, *Juniperus oxycedrus*, *Acer monspessulanum*
S35. Djebel Chlaalaa 5	N	60	35.59787	6.04070	1466	A9	***Cedrus atlantica***, *Quercus ilex*, *Ilex aquifolium*

* The same code is represented in Fig. 1.

[#] Sites 10 and 11 represent advanced stages of ecological succession in former cedar stands, where the massive die-off of *Cedrus atlantica* in 2010 led to their transformation into *Quercus ilex*-dominated oak forests.

More generally, vegetation structure and environmental conditions are known to influence insect assemblages, affecting their distribution and abundance (Symstad et al., 2000; Moreira et al., 2016). Additional factors, such as host density, plant neighborhood composition, and forest structure, may also contribute to shaping insect communities (Jeffries et al., 2006; Damien et al., 2016). These patterns highlight the potential role of host plant availability and local microhabitat conditions in shaping scale insect distribution. However, given the lack of statistically significant associations, these interpretations should be considered with caution.

The UpSet plot (Fig. 7) highlights both shared and exclusive species across the nine forest communities. Species richness varies among sites, with A1 showing the highest diversity, whereas A3 presents the lowest richness. Some species appear restricted to particular forest types, such as *Planococcus vovae* and *Chionaspis kabyliensis* in A1, and *Carulaspis atlantica* and *Puto peyerimhoffi* in A2. However, these exclusive records should be interpreted cautiously, as they may partly reflect sampling effort, host plant availability, or detection constraints rather than strict ecological restriction. In contrast, species such as *Lineaspis striata* occur across multiple forest types (A1, A2, A4, A6, A7), indicating broader ecological and host plant tolerance.

At the community level, forests A1, A2, and A4 share several species and show relatively higher similarity, whereas A3, A5, and A9 are more distinct due to lower species richness and fewer shared taxa. Intermediate forests (e.g., A6 and A7) show partial overlap with multiple groups. However, these patterns represent descriptive tendencies rather than statistically confirmed community structuring.

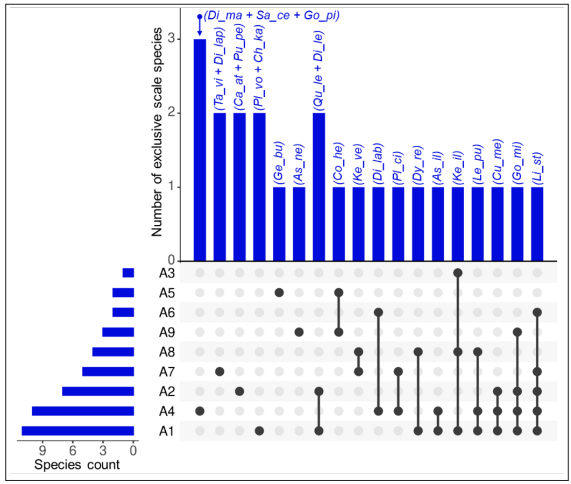

Figure 7. SetUp plot of shared scale insect species among the nine studied forest types. Codes of scale insect species included the two first letters of the genus and two letters of species. See Table 1 for the explanation of codes of sampled forest A1-A9, including the forest tree species composition of each plant community.

Similarity analyses and hierarchical clustering (Fig. 8) support these observations, grouping forests with comparable species composition. Forests A1, A4, and A8 show relatively higher similarity, while A3, A5, and A9 are more isolated. Although quantitative indices (Morisita-Horn and Bray-Curtis) incorporate abundance data, overall differences among forest types remain moderate, consistent with the absence of significant family- and species-level associations.

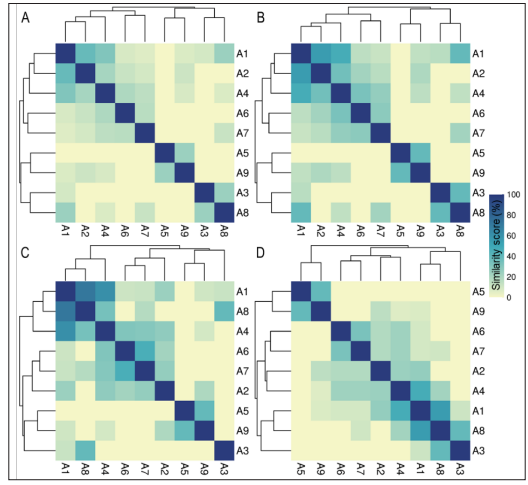

Figure 8. Heatmaps, with two-way clustering analysis (Complete linkage), displaying the matrices of similarity of scale insect species among the studied forests in the National Park of Belezma, Algeria. The similarity analysis used the qualitative indices of Jaccard (A) and Sorensen (B), and quantitative indices of Morisita-Horn (C) and Bray-Curtis (D). See Table 1 for the explanation of codes of sampled forest A1-A9, including the forest tree species composition of each plant community.

The Principal Component Analysis (PCA) (Fig. 9) illustrates variation in species composition across sites but does not indicate a clear or strong separation among forest types. A slight tendency for northern and eastern sites to be more dispersed, and southern and western sites to be more clustered, may reflect underlying environmental heterogeneity (e.g., humidity, exposure, and vegetation structure). However, this pattern should be interpreted cautiously, as overlap among sites remains high and no formal statistical grouping was detected.

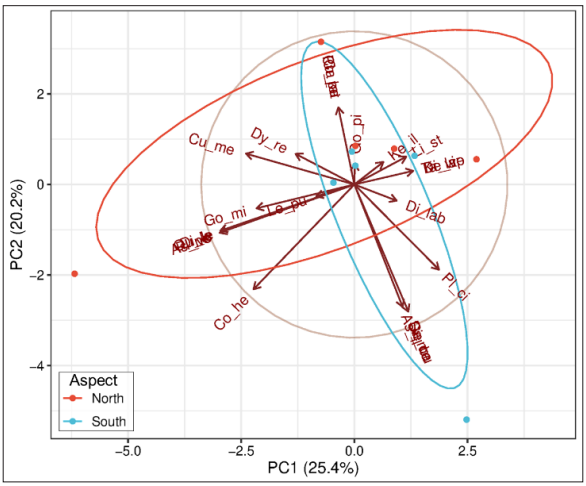

Figure 9. Principal Component Analysis (PCA) showing the distribution of scale insect species in relation to slope aspect. Ellipses represent groups of sampling sites by topographic orientation. Codes of scale insect species included the two first letters of the genus and two letters of species.

CONCLUSION

This study provides a comprehensive assessment of the diversity, composition, and spatial distribution of scale insects (Coccomorpha) across nine forest plant communities in Belezma National Park, eastern Algeria. A total of 35 species belonging to eight families were recorded, with the Diaspididae being the dominant group across nearly all forest types. Despite this predominance, statistical analyses revealed no significant association between forest type and family composition, indicating that habitat type alone does not explain the observed distribution patterns. Descriptive analyses nevertheless revealed variations in species and family occurrence among forests, including the presence of exclusive taxa in certain sites such as *Quercus ilex* stands. These patterns suggest localized differences in community composition, which may be related to variation in vegetation structure or local environmental conditions, although such relationships were not explicitly tested in the present study. In addition, field observations indicated that scale insect populations were generally well regulated, likely influenced by natural enemies, particularly endoparasitoid Hymenoptera, highlighting the importance of maintaining ecological balance within these forest systems.

Similarity and clustering analyses identified gradients of compositional overlap among forest types rather than clearly distinct ecological groupings. Forests dominated by broad-leaved species (e.g., *Quercus ilex*, *Ilex aquifolium*, *Olea europaea*) tended to share a higher number of taxa, whereas coniferous forests (e.g., *Cedrus atlantica* and *Pinus halepensis*) showed comparatively lower overlap, with the latter often associated with a xerophytic understory including species such as *Pistacia lentiscus*. However, these patterns remain descriptive and do not indicate strong habitat-driven structuring. Similarly, the PCA suggested variation in species composition in relation to slope aspect, with northern and eastern exposures showing greater dispersion of species compared to southern and western exposures, although this relationship was not formally tested. The results indicate that scale insect assemblages in the study area show moderate spatial variation but limited statistical differentiation at the scales and taxonomic resolution considered. Observed patterns are therefore more likely to reflect a combination of sampling effects, species-specific ecological tolerances, and gradual environmental gradients rather than strong habitat specificity.

Future research should focus on integrating additional ecological variables, such as canopy structure, and microclimatic gradients to better understand the mechanisms driving species distribution. Long term monitoring would also help assess the effects of climatic fluctuations and forest management on community dynamics. Moreover, incorporating molecular tools for species identification could help taxonomic resolution and reveal potential cryptic diversity. Expanding comparative studies to other Mediterranean forest systems would further contribute to understanding the broader biogeographical patterns of scale insect diversity.

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Competing interests

The authors declare that they have no competing interest.

Credit authors' contributions

Soumia Bouguenna (Conceptualization, Methodology, Resources, Investigation, Writing Original Draft, Writing Review & Editing), Nabil Bertella (Supervision), Jean-François Germain (Investigation, Visualization), Valérie Balmès (Investigation, Visualization), Haroun Chenchouni (Formal Analysis, Visualization, Writing Original Draft, WritingReview & Editing).

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Availability of data

The datasets used and/or analyzed during the current study are available from the first author on reasonable request.

Ethics statement

No studies involving vertebrates or human participants were conducted; therefore, ethical approval was not required.

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Supplementary materials

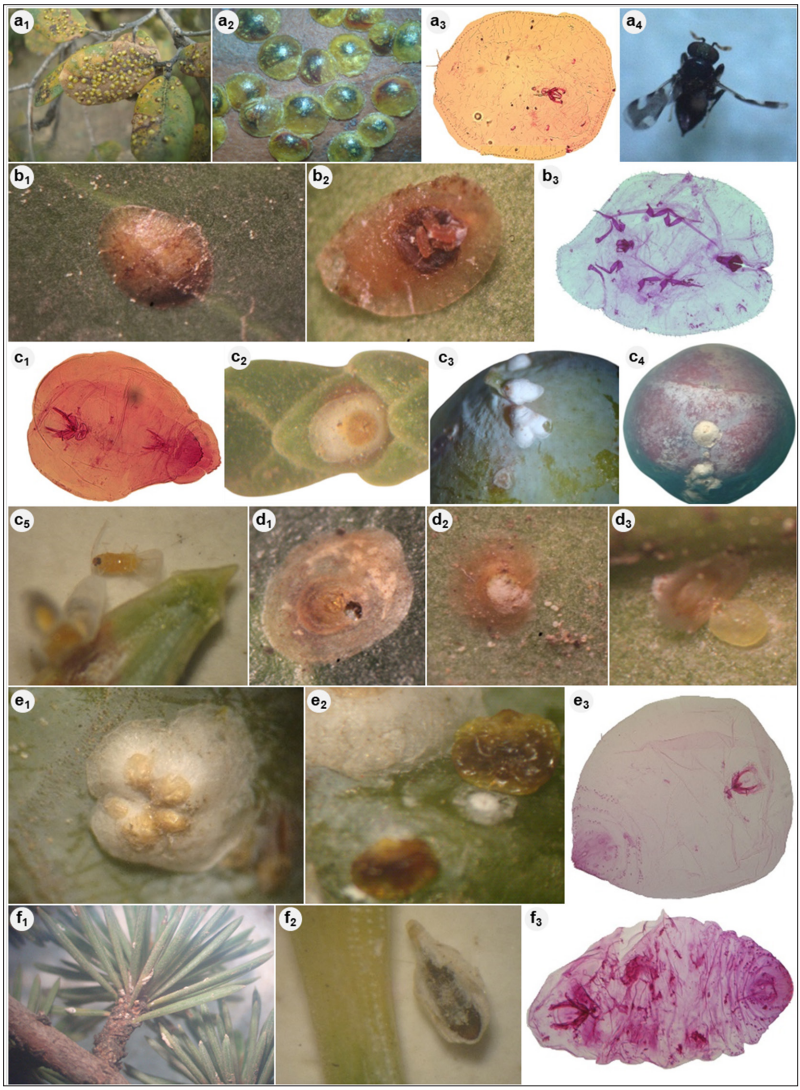

Figure S1. **a_1:** *Asterodiaspis ilicicola* on leaves of *Quercus ilex*, **a_2**: Parasitized ♀♀ of *A. ilicicola*, **a_3**: Microscopic view of *A. ilicicola,* **a_4**: *Marietta* sp. endoparasitoid of *A. ilicicola*; **b_1**: *Coccus hesperidum* on adaxial surface of *Ilex aquifolium* leaf, **b_2**: Ventral brood pouch of viviparous ♀ with larvae, **b_3**: Microscopic view of *C. hesperidum*; **c_1**: Microscopic view of *Cupressaspis mediterranea*, **c_2**: *C. mediterranea* on scale leaf of *Juniperus phoenicea*, **c_3**: *C. mediterranea* on galbulus of *J. phoenicea*, **c_4**: *C. mediterranea* on galbulus of *Juniperus oxycedrus*, **c_5**: Adult ♂ of *C. mediterranea* from leaf of *J. oxycedrus*; **d_1**: *Aspidiotus nerii* on adaxial surface of *I. aquifolium* leaf, with parasitoid emergence hole on shield, **d_2**: *A. nerii* on abaxial surface of *I. aquifolium* leaf, **d_3**: Adult ♀ of *A. nerii*; **e_1**: *Carulaspis atlantica* on galbulus of *J. oxycedrus*, **e_2**: Two adult ♀♀ of *C. atlantica*, **e_3**: Microscopic view of *C. atlantica*; **f_1**: *Chionaspis kabyliensis* infesting needles of *C. atlantica*, **f_2**: Adult ♀ of *C. kabyliensis*, **f_3**: Microscopic view of *C. kabyliensis*.

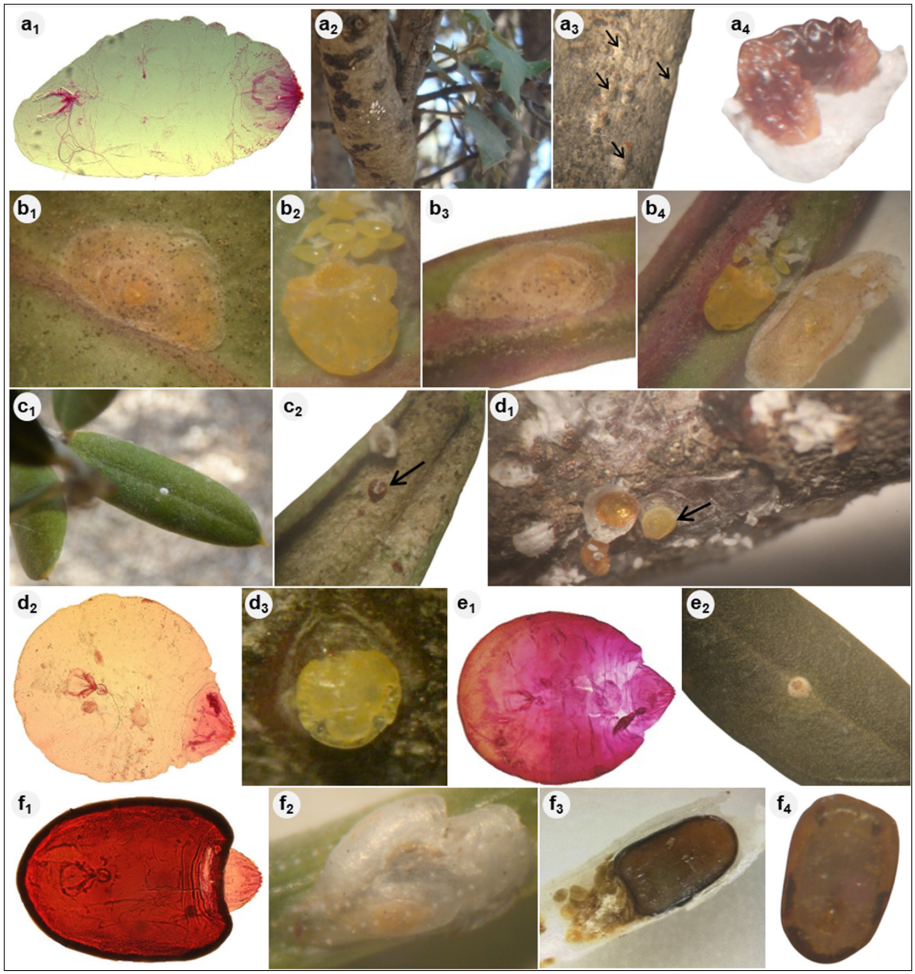

Figure S2. **a**$_1$: Microscopic view of *Quernaspis lepineyi*, **a**$_2$: ♂♂ of *Q. lepineyi* on trunk of *Quercus ilex*, **a**$_3$: Adults ♀♀ of *Q. lepineyi* camouflaged on the trunk (indicated by arrow), **a**$_4$: Two adults ♀♀ of *Q. lepineyi*; **b**$_1$, **b**$_2$: Adult ♀ of *Diaspidiotus labiatarum* on leaf of *Pistacia lentiscus* with eggs, **b**$_3$,**b**$_4$: Adult ♀ of *D. labiatarum* on twig of *P. lentiscus* with eggs; **c**$_1$: *Diaspidiotus laperrinei* on adaxial surface of *Olea europaea* leaf, **c**$_2$: *D. laperrinei* on abaxial surface of *O. europaea* leaf; **d**$_1$: Second-instar larva of *Diaspidiotus lenticularis* with shield on twig of *Q. ilex*, beside ♂♂ of *Q. lepineyi*, **d**$_2$: Microscopic view of *D. lenticularis*, **d**$_3$: Adult ♀ of *D. lenticularis*; **e**$_1$: Microscopic view of *Diaspidiotus maleti*, **e**$_2$: *D. maleti* on leaf of *O. europaea*; **f**$_1$: Microscopic view of *Dynaspidiotus regnieri*, **f**$_2$: *D. regnieri* on needle of *Cedrus atlantica*, cohabiting with *Leucaspis pusilla* beneath; shield mimics white stomatal bands of *C. atlantica* needles, extending onto insect, **f**$_3$: Viviparous adult ♀ of *D. regnieri*, **f**$_4$: Endoparasitoid of *D. regnieri*.

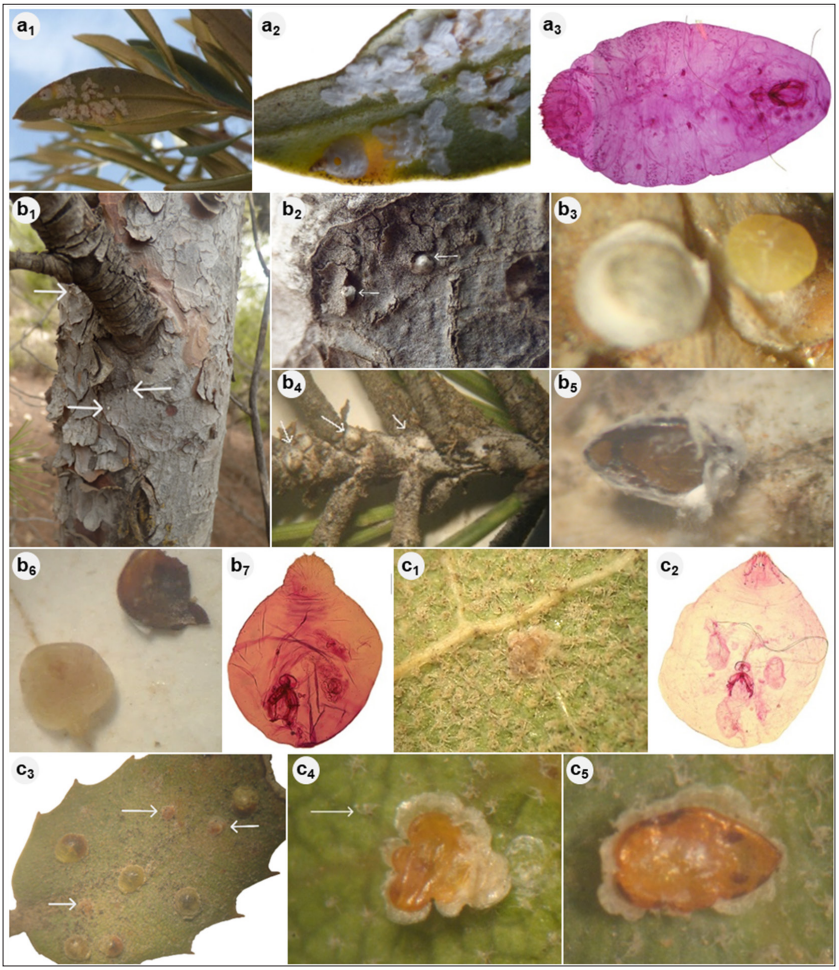

Figure S3. **a**$_1$: *Getulaspis bupleuri* on abaxial surface of *Olea europaea* leaf, **a**$_2$: Parasitized ♀ of *G. bupleuri* with dozens of ♂♂ aggregated around, **a**$_3$: Microscopic view of *G. bupleuri*; **b**$_1$: *Gomezmenoraspis pinicola* on trunk of *Pinus halepensis*, **b**$_2$: Adult ♀♀ of *G. pinicola* on trunk of *P. halepensis*, **b**$_3$: Adult ♀♀ of *G. pinicola* on twig of *P. halepensis*, **b**$_4$: Second-instar larva with shield on twig of *P. halepensis*, **b**$_5$: Adult ♀ of *G. pinicola* with ventral wax secretion on twig of *P. halepensis*, **b**$_6$: Adult ♀ of *G. pinicola* after removal of cuticle enveloping the body, **b**$_7$: Microscopic view of *G. pinicola*; **c**$_1$: *Gonaspidiotus minimus* on leaf of *Ilex aquifolium*, **c**$_2$: Microscopic view of *G. minimus*, **c**$_3$: *G. minimus* coexisting with *Asterodiaspis ilicicola* on *Quercus ilex*, **c**$_4$: Wavy shape of *G. minimus* on leaf of *Q. ilex* (trichome indicated by arrow), **c**$_5$: Endoparasitoid of *G. minimus*.

Figure S4. **a**$_1$: Microscopic view of *Lineaspis striata*, **a**$_2$: *L. striata* on *Juniperus phoenicea*, **a**$_3$: *L. striata* on scale leaf of *J. phoenicea*, **a**$_4$: *L. striata* on *Juniperus oxycedrus*, **a**$_5$: Adult ♀♀ and ♂♂ of *L. striata* on abaxial side of *J. oxycedrus* galbulus, **a**$_6$: Adult ♀♀ showing pygidium protruding from shield and ♂♂ on galbulus of *J. oxycedrus*, **a**$_7$: Large adult ♀ of *L. striata* carrying eggs, **a**$_8$: Eggs of *L. striata*, **a**$_9$: *L. striata* on leaves of *J. oxycedrus*; **b**$_1$: Microscopic view of *Leucaspis pusilla*, **b**$_2$: *L. pusilla* on needle of *Pinus halepensis*, **b**$_3$: *L. pusilla* on *Cedrus atlantica* cohabiting with *Dynaspidiotus regnieri*, **b**$_4$: Numerous second-instar larvae of *L. pusilla* beneath a *D. regnieri* individual, **b**$_5$: *L. pusilla* enclosed within cuticle of a *D. regnieri* individual, **b**$_6$: Parasitoid emergence hole showing probable escape of *L. pusilla* due to cover provided by *D. regnieri*; **c**$_1$: Microscopic view of *Saharaspis ceardi*, **c**$_2$: *S. ceardi* on twig of *Pistacia lentiscus*, **c**$_3$: *S. ceardi* on abaxial surface of *P. lentiscus* leaf, **c**$_4$: Adult ♂ of *S. ceardi*.

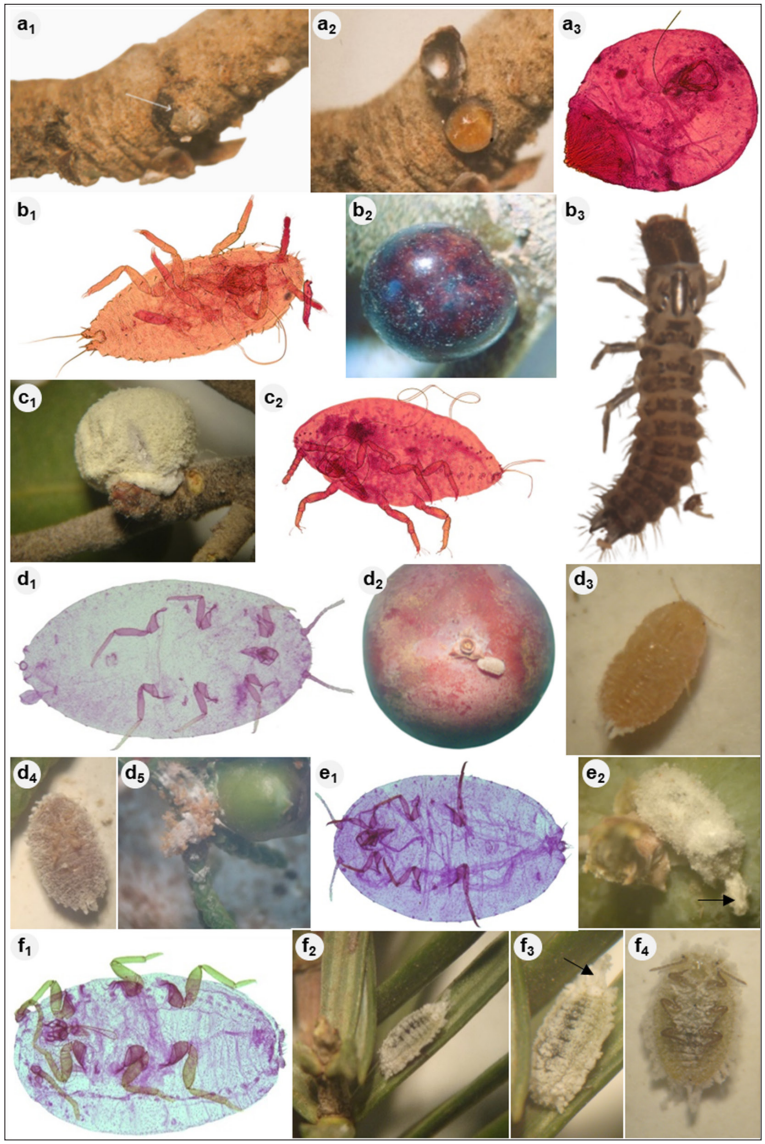

Figure S5. **a**$_1$: *Targionia vitis* on twig of *Quercus ilex*, **a**$_2$: Adult ♀ of *T. vitis* with its shield, **a**$_3$: Microscopic view of *T. vitis*; **b**$_1$: Microscopic view of 1st-instar nymph of *Kermes ilicis*, **b**$_2$: Globular ♀ of *K. ilicis* on twig of *Q. ilex*, **b**$_3$: Predatory larva (Coleoptera: Melyridae) found inside globular ♀ of *K. ilicis* feeding on crawlers; **c**$_1$: Adult ♀ of *Kermes vermilio* on twig of *Q. ilex*, **c**$_2$: Microscopic view of 1st-instar nymph of *K. vermilio*; **d**$_1$: Microscopic view of adult ♀ of *Planococcus citri*, **d**$_2$: *P. citri* on galbulus of *Juniperus oxycedrus*, **d**$_3$: Adult ♀ of *P. citri*, **d**$_4$: Adult ♀ of *P. citri* on *J. phoenicea*, **d**$_5$: White ovisac and young larvae of *P. citri* on *J. phoenicea*; **e**$_1$: Microscopic view of adult ♀ of *Planococcus vovae*, **e**$_2$: ♀ of *P. vovae* depositing ovisac (arrow) on galbulus of *J. oxycedrus*; **f**$_1$: Microscopic view of adult ♀ of *Puto peyerimhoffi*, **f**$_2$: ♀ of *P. peyerimhoffi* on leaf of *J. oxycedrus*, **f**$_3$: ♀ of *P. peyerimhoffi* depositing ovisac (arrow), **f**$_4$: Adult ♀ of *P. peyerimhoffi*.