

The Inventory of Scale Insects (Hemiptera, Coccoidea) Associated With Olive Tree in North of Tunisia

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Abstract

Background: This study was realized for more than four years (from 2014 to 2018) in olive groves of northern Tunisian governorates. Scale insect samples were collected from leaves, stems and fruits.

Results: An annotated list of 22 scale insect species has been recorded. These species divided into 4 families. The family *Diaspididae* is the most species-rich, with 14 species in 9 genera; *Coccidae* contains 4 species in 3 genera; *Pseudococcidae* contains 3 species in 3 genera; and *Asterolecaniidae* contains 1 species in 1 genus.

Conclusions: This paper contains 3 species recorded for the first time in the Tunisian fauna: *Saissetia coffeae* (Walker), *Diaspidiotus ostreaeformis* (Curtis) and *Lepidosaphes conchiformis* (Gmelin).

Introduction

The olive tree, *Olea europaea* (L.) (*Oleaceae*: *Olea*) is a species belonging to the family *Oleaceae*, characterized by evergreen leaves, native to the coastal areas of the eastern Mediterranean region, Lebanon and the maritime parts of Asia Minor north of the Iran at the southern end of the Caspian Sea. Its fruit is of major agricultural importance as a source of olive oil and table olives (Cimato & Attilio 2011). In Tunisia, the olive tree is the most cultivated fruit species, there are about 88 million trees spread over 1,880 thousand hectares (Larbi et al 2020).

Scale insects, sap-sucking hemiptera, are found on various parts of their hosts such as leaves, twigs, branches and roots (Kondo et al 2008). Once fixed, Scale insects turn into a real automatic pump extracting the sap. Damage to plant tissue is often aggravated by toxic enzymes present in the saliva of some species. These enzymes are also responsible for the discoloration and premature fall of leaves as well as the deformation of plant tissues (Gullan & Martin 2003). Scale insects can also cause indirect damage by pathogens transmission or by accumulation of honeydew, which promotes the fungi establishment (Ross et al 2010).

With the increase in international plant trade, scale insects, due to their invasive nature, have become a serious threat to the agricultural economy (Smith et al 2007, Thomas 2006). In addition, new cultural techniques such as: high tree densities, ferti-irrigation, have created favorable conditions for their dissemination and prosperity (Coutinho 2011).

Sexual dimorphism is very pronounced in scale insects (Gullan & Kosztarab 1997). The morphological characteristics of adult females are used in identification (Pellizzari & Germain 2010). Adult females are often wingless and protected by waxy covers, they are sedentary or sessile. Unlike adult males, which are generally winged, inconspicuous and only live a few days (Pellizzari & Germain 2010).

Until now there has no specific and comprehensive study of scale-insect species on olive tree in northern Tunisia. This paper reports the survey and identification of scale insects on olive tree, with data on their

distribution. Therefore, it could be considered as a starting point for further investigation.

Material And Methods

This bio-systematic work was realized during period of 48 months (from September, 2014 till September, 2018) in the laboratory of Olive Tree Institut. During this work, several habitats belonging to different northern Tunisian governorates (Nabeul, Zaghouen, Beja, Seliana, Jendouba, El Kef, Bizerte, Ariana, Ben Arous, Manouba and Tunis) were prospected about once every one month for the duration of the study. These sites included olive trees in plantations of different ages, single or multiple trees, trees in coastal and interior areas. The most abundant olive cultivar is mainly Chetoui and other undetermined cultivars.

Insect scales associated with olives were collected from the tree canopy using two main methods, visual inspection and sampling. During visual inspection of the entire olive tree, including trunk, branches and leaves insects were observed. The second method is to take twigs 25 cm long per tree. These twigs are put in plastic bags bearing labels indicating the site and the date.

In the laboratory the scale insects collected were isolated and stored in vials containing 70% ethyl alcohol with the corresponding data. Permanent slide mounts of adult females were prepared using the methods given by Watson & Chandler (2000). Slide-mounted specimens were examined using a compound microscope with phase contrast illumination and magnifications of x 25- x 800.

Species identification was based on the morphological characteristics of adult females using various taxonomic keys, such as Evans et al (2009), Gill (1997), Guarino et al (2001), Hamon & Williams (1984), Hodgson (1994), Kosztarab & Kozar (1988), Miller & Davidson (2005) and Williams & Watson (1990). A large part of data of different collected species was obtained from the ScaleNet database (García et al 2020).

The genera and species are listed under their families and ordered alphabetically. Sites and collecting dates from northern Tunisia are mentioned.

Habitats of study

The surveys were carried out in these biotopes whose coordinates are as follows:

- **Beja:** Sidi Ismail 36°59'37.22"N 9°11'59.46"E, Tastour 36°54'93.92"N 9°42'89.14"E, Teboursouk 36°44'24.54"N 9°24'37.45"E, Tibar 36°51'58.06"N 9°11'51.35"E.
- **Bizerte:** Ghar el Melh 37°16'88.25"N 10°15'93.72"E, Mateur 37°03'88.95"N 9°78'54.74"E, Ras Jebel 37°22'26.16"N 10°09'46.03"E, Utique 37°04'26.62"N 10°04'50.33"E.
- **Cap Bon:** Grombalia 36°57'28.65"N 10°51'17.22"E, El Haouaria 37°04'45.55"N 11°02'11.78"E, Nabeul 36°52'68.52"N 10°63'91.01"E, Soliman 36°73'51.19"N 10°53'40.23"E, Takelsa 36°79'96.41"N 10°63'43.54"E.

- **ElKef:** Dahmani 35°94'96.51"N 8°81'30.44"E, Elles 35°95'06.97"N 9°09'48.84"E, Tajerouin 35°88'98.95"N 8°55'00.39"E.
- **Grand Tunis:** Mornag 36°66'99.53"N 10°28'02.66"E, Sabelet Ben Ammar 36°89'58.99"N 10°12'69.43"E, Tebourba 36°83'85.00"N 9°83'59.43"E.
- **Jendouba:** Bousalem 36°61'63.54"N 8°96'50.47"E, Bullaregia 36°55'74.82"N 8°75'93.25"E, Tabarka 36°90'86.19"N 8°78'51.37"E.
- **Seliana:** Al Krib 36°32'95.41"N 9°12'85.60"E, Bou Arada 36°35'41.37"N 9°63'84.54"E, Sidi Bourouis 36°17'18.66"N 9°12'56.58"E, Makthar 35°84'55.14"N 9°23'55.19"E.
- **Zaghoun:** El Fahs 36°39'11.78"N 9°93'21.98"E, Hammam Zriba 36°36'76.68"N 10°18'86.28"E, Sminja 36°46'59.03"N 10°01'17.21"E.

Results

Annotated list of scale insects associated with olives in North of Tunisia

Family Asterolecaniidae - pit scales

Pollinia pollini (Costa) 1857 - Globular mealy bug or *Pollinia* scale

Material studied. **Beja:** Sidi Ismail, 7.X.2017, 194 ♀♀; Tastour, 27.IV.2016, 181 ♀♀; Teboursouk, 15.X.2015, 167 ♀♀; Tibar, 7.X.2014, 123 ♀♀; **Bizerte:** Mateur, 19.X.2018, 111 ♀♀; Ras Jebel, 14.VIII.2018, 231 ♀♀; Utique, 20.IX.2017, 130 ♀♀; **Cap Bon:** Grombalia, 8.IX.2014, 111 ♀♀; Nabeul, 19.X.2017, 181 ♀♀; **ElKef:** Dahmani, 27.X.2016, 206 ♀♀; Elles, 18.IV.2014, 213 ♀♀; Tajerouin, 27.X.2016, 177 ♀♀; **Grand Tunis:** Mornag, 20.VII.2017, 163 ♀♀; Tebourba, 4.XII.2015, 323 ♀♀; Sabelet Ben Ammar, 14.X.2016, 243 ♀♀; **Jendouba:** Bousalem, 25.VI.2017, 123 ♀♀; Tabarka, 18.III.2015, 121 ♀♀; **Seliana:** Al Krib, 27.IV.2017, 115 ♀♀; Bou Arada, 14.IV.2018, 211 ♀♀; Makthar, 18.IV.2015, 142 ♀♀; Sidi Bourouis, 27.IV.2017, 218 ♀♀; **Zaghoun:** El Fahs, 10.X.2015, 98 ♀♀; Hammam Zriba, 27.X.2017, 144 ♀♀.

Geographic distribution. The scale is found in 19 countries on olive tree (García et al 2020). A serious pest of olive tree in Crete, Greece and Sicily (Liotta & Sammatrano 1981).

Biology. *Pollinia pollini* is found in most olive growing regions of the Mediterranean Region and in California. It is found on leaves, twigs and fruit of its exclusive host, the olive tree. Generally one (Liotta & Sammartano 1981) or two generations (Ahmed 2012, Gharbi 2020) or three generations (Shannag et al 2019) per year on olive tree. This species is specially frequent in North of Tunisia with significant economic damage was observed (Jarraya 2003).

Structure. Adult females are spherical, orange to red and covered with a grayish yellow waxy substance that protects entire colonies observed in the twigs and branches, or in crevices or cracks in the bark (Orecchia et al 2007). The males nymphs are lemon yellow in color, elongated, slightly flattened towards one of its ends, whose nymphs are found on the leaves. The males adults are winged (Jarraya 2003).

Family Coccidae - soft scales

Coccus hesperidum (Linnaeus) 1758 - soft brown scale

Material studied. **Beja:** Tastour, 22.IV.2017, 8 ♀♀; **Bizerte:** Ghar el Melh, 22.IX.2017, 5 ♀♀; Ras Jebel, 15.II.2017, 7 ♀♀; **Cap Bon:** Grombalia, 8.IX.2014, 3 ♀♀; Takelsa, 5.X.2016, 15 ♀♀; **Grand Tunis:** Mornag, 20.VII.2017, 13 ♀♀; Tebourba, 4.XII.2015, 7 ♀♀.

Geographic distribution. It originates from East Asia (Tereznikova 1981), widespread, is found in 140 countries (García et al 2020), including Tunisia on olive tree (Jarraya 1970).

Biology. *Coccus hesperidum* is a highly polyphagous species, feeding on plants belonging to 130 families, an important pest of various fruit trees and ornamental plants (Ebeling 1959, Hodgson & Henderson 2000). A tropicopolitan species commonly found on leaves and twigs (Hamon & Williams 1984). The females reproduce parthenogenetically in most areas. Males were observed in England (Newstead 1917) and in greenhouses in the USSR (Saakyan-Baranova 1964). Develops six annual generations in Israel (Bodenheimer 1951); 3–5 generations in the United States (Ebeling 1959).

Structure. The adult female of *C. hesperidum* is oval, flat or slightly convex, and asymmetrical. Young adult green-yellowish to yellowish-brown, spotted with brown spots, sometimes coalescing in marbled areas. It has been observed that the colour of females often resembles the colour of this part of the plant where they feed. The length of the mature female is 1.5 to 4.5 mm. The legs and the antennae persist during the antère life.

Lichtensia viburni (Signoret) 1873 – viburnum cushion scale

Material studied. **Beja:** Sidi Ismail, 7.X.2016, 14 ♀♀; Tastour, 27.X.2016, 8 ♀♀; **Bizerte:** Mateur, 19.X.2018, 4 ♀♀; Utique, 20.IX.2018, 3 ♀♀; **ElKef:** Elles, 18.IV.2015, 2 ♀♀; **Grand Tunis:** Mornag, 20.VII.2016, 16 ♀♀; **Jendouba:** Bousalem, 18.IV.2017, 12 ♀♀; **Seliana:** Al Krib, 27.X.2016, 5 ♀♀; Makthar, 18.IV.2015, 3 ♀♀; Sidi Bourouis, 2.X.2014, 5 ♀♀; **Zaghoun:** Hammam Zriba, 27.IX.2017, 5 ♀♀.

Geographic distribution. *Lichtensia viburni* is known from the Czech Republic, France, Germany, Russia, Italy, Yugoslavia, England, Wales, Spain, Portugal and USA. *Lichtensia viburni* was widely distributed in the north of Tunisia (Jarraya 2003).

Biology. *Lichtensia viburni* develops on the underside of leaves and shoots, particularly in the thickest parts of the foliage; the damage is caused by nutritional stings and the production of honeydew which, in addition to making the leaves asphyxiated, promotes the formation of sooty molds, further aggravating the damage. *Lichtensia viburni* overwinters as a nymph which completes development in the following spring. Females lay their eggs in their sacs between May and June. The emergence of the first generation nymphs requires about 2–3 weeks; the appearance of the second generation nymphs occurs between August and September (Quaglia 1986). In central and northern Italy, on olive trees, *L. viburni* is able to producing 1 or 2 generations per year (Kosztarab & Kozar 1988)

Structure. The adult female is about 5 mm in length, has a yellowish body, with darker, oval and slightly convex spots; in females, the body appears covered with an ovisac of white wax, produced by the ceriparous glands of the back. Nymphs are greenish-yellow and oval. The male is winged and flickers from an elongated follicle.

Saissetia coffeae (Walker) 1852 – hemispherical scale or brown scale

Material studied. **Nabeul:** ElHaouria, 15.VII. 2018, 3 ♀♀; Takelsa, 15.VII.2018, 5 ♀♀.

Geographic distribution. Cosmopolitan, it is found in 117 countries (García et al 2020).

Biology. *Saissetia coffeae* is polyphagous, feeding on plants belonging to 115 families. Females reproduce by parthenogenesis (García et al 2020). *Saissetia coffeae* develops up to 8 generations per year in Peru (Beingolea 1969), 1–2 generations in USA (Hamon & Williams 1984, Gill 1988).

Structure. Females are characterized by an oval body, strongly convex, smooth, shining body, from 2 to 5 mm in size (Tereznikova 1981). Young adult females turn yellow, with an H-shaped ridge that disappears at maturity. Older adult females are brown in color, becoming more convex and sclerotic. The eggs are light purple in color, stored under a concave sink (Choi & Lee 2017).

Saissetia oleae (Olivier) 1791 – olive black scale or mediterranean black scale

Material studied. **Bizerte:** Ghar el Melh, 13.V.2017, 33 ♀♀; Ras Jebel, 30.IV.2018, 28 ♀♀; Utique, 20.IX.2018, 13 ♀♀; **Cap Bon:** ElHaouaria, 18.VIII.2015, 117 ♀♀; Grombalia, 8.IX.2014, 7 ♀♀; Nabeul, 19.X.2017, 58 ♀♀; Soliman, 18.VIII.2015, 10 ♀♀; Takelsa, 5.X.2016, 46 ♀♀; **Grand Tunis:** Sabelet Ben Ammar, 29.VII.2017, 6 ♀♀; Tebourba, 4.XII.2015, 13 ♀♀; Mornag, 20.XII.2017, 11 ♀♀; **Jendouba:** Tabarka, 18.IV.2017, 7 ♀♀.

Geographic distribution. *Saissetia oleae*, which is thought to be native to South Africa (De Lotto 1965), is a cosmopolitan species, is found in most Mediterranean countries (Jarraya 1970). Recorded also from California and Australia.

Biology. *Saissetia oleae* is a polyphagous species, feeding on numerous cultivated and ornamental plants belonging to 80 botanical families (García et al 2020). In the Mediterranean basin, *S. oleae* is an economic pest of olive and citrus trees (Bodenheimer 1951). In the Tunisian coastal olive groves, *S. oleae* is considered to be the most important scale insect species (Jarraya 2003, Mansour et al 2011). In general, *S. oleae* shows only one generation per year (univoltine), but under mild climate in autumn, an incomplete second generation may occur (Gill 1988, Jarraya 2003).

Structure. The body of females is from 2.5 to 6 mm in size, convex, ranging in colour from light to dark brown. On the dorsal side there is visible a characteristic, protruding, H-shaped pattern, which allows to differentiate the species easily from another, similar species belonging to the same genus, i.e. *S. coffeae* (Tereznikova 1981).

Family Diaspididae - armored scales

Aonidiella aurantii (Maskell) 1879 - californian red scale

Material examined. **Bizerte:** Ras Jebel, 14.XI.2018, 7 ♀♀; **Cap Bon:** Nabeul, 3.II.2018, 32 ♀♀; Soliman, 14.II.2017, 8 ♀♀; Takelsa, 5.X.2016, 77 ♀♀; **Grand Tunis:** Mornag, 23.III.2016, 13 ♀♀.

Geographic Distribution. *Aonidiella aurantii* has a relatively cosmopolitan distribution, Encountered in 87 countries, mentioned in Tunisia by Balachowsky (1932).

Biology. *Aonidiella aurantii* is highly polyphagous species; it has been recorded on 263 plant host species (García et al 2020). It is an ovoviviparous, biparental species that can infest all aerial parts of host plants (Ferris 1938). Larvae exhibit positive phototropism and tend to move to the outer canopy, settling on fruits and young leaves (Campos-Rivela et al 2012). It seems to show a preference for young trees with a good vegetative state (Bodenheimer 1951).

Structure. The adult female is circular, rather flat, exuviae in the center, is rather thin and pale, is red-brown in color and severely sclerotized. The length of the body is 1.5 to 2 mm. The male is elongated oval, paler in color than in the female, exuvia slightly to one end (Ferris 1938, Longo et al 1994).

Aspidiotus nerii (Bouche) 1833 - oleander scale

Material examined. **Beja:** Tastour, 12.II.2016, 18 ♀♀; Tibar, 7.X.2014, 26 ♀♀; **Bizerte:** Mateur, 24.IV.2017, 13 ♀; Ras Jebel, 12.II.2017, 29 ♀♀; Utique, 12.III.2018, 37 ♀♀; **Cap Bon:** Nabeul, 8.IX.2016, 53 ♀♀; **ElKef:** Dahmani, 27.X.2016, 16 ♀♀; Elles, 18.IV.2014, 13 ♀♀; Tajerouin, 13.VII.2018, 36 ♀♀; **Grand Tunis:** Mornag, 20.VI.2017, 44 ♀♀; Tebourba, 4.XII.2015, 9 ♀♀; **Jendouba:** Bullaregia, 18.VII.2014, 4 ♀♀; **Seliana:** Makthar, 15.III.2016, 10 ♀♀; Al Krib, 27.X.2016, 9 ♀♀; **Zaghoun:** Hammam Zriba, 27.X.2015, 8 ♀♀.

Geographic distribution. *Aspidiotus nerii* is a cosmopolitan; It has a worldwide distribution, especially in the tropical and subtropical zones (Zahradnik 1990). Encountered in 73 countries (García et al 2020), including Tunisia on olive tree (Mansour et al 2011).

Biology. *Aspidiotus nerii* has been recorded on 546 plant species belonging to more than 100 families (García et al 2020). It is one of the most polyphagous scale insects (Ammar 1986), is a serious pest of olive in the Mediterranean basin (Argyriou 1990). Magsig-Castillo et al (2010) showed the existence of larvae phoretic dispersion. *A. nerii* produces 3 generations per year: unisexual and bisexual populations have been reported (DeBach & Fisher 1956).

Structure. Female is white or pale gray scale, the body length is about 2 mm, circular, flat, subcentral exuviae. Male with similar color, slightly oval, exuvia subcentral (Ferris 1938).

Chrysomphalus aonidum (Linnaeus) 1758 - Circular black scale

Material studied. **Cap Bon:** Soliman, 18.VIII.2015, 11 ♀♀; Takelsa, 5.X.2017, 6 ♀♀.

Geographic distribution. *Chrysomphalus aonidum* is found in 84 countries (García et al 2020), cited in Tunisia by Jendoubi (2012). Today, it is present in five continents.

Biology. *Chrysomphalus aonidum* is a very polyphagous species, grows on the leaves and fruits of many host plants. Reproduction is sexual, each female lays between 50 to 150 eggs over a period of 1–8 weeks (Watson 2005). We record 3–4 generations per year in China (Miller & Davidson 2005) and 5–6 generations per year in California (Gill 1997).

Structure. The female scale is circular, flat to moderately convex, 1.5–2.5 mm in diameter, of little variable color but tending to be rather dark brown or bluish-black with reddish brown central exuviae (Watson 2005). The exuvies placed in the center being slightly paler than the other parts; the male is oval a little elongated, exuvia near one end (Ferris 1938).

Chrysomphalus dictyospermi (Morgan) 1889 - Dictyosperm scale

Material studied. **Beja:** Tastour, 26.V.2016, 2 ♀♀; **Bizerte:** Ras Jebel: 30.IX.2018, 8 ♀♀; **Cap Bon:** Grombalia, 8.IX.2014, 5 ♀♀; Takelsa, 5.X.2016, 16 ♀♀; **Grand Tunis:** Mornag, 20.VII.2017, 14 ♀♀; **Jendouba:** Tabarka, 18.IV.2017, 2 ♀♀.

Geographic distribution. *Chrysomphalus dictyospermi* is cosmopolitan (García et al 2020), mentioned in Tunisia by Balachowsky (1932). It is widespread in tropical and subtropical regions (Davidson & Miller 1990, Gill 1997). It is distributed predominantly in Mediterranean countries and in Middle Eastern countries (Lodos 1982).

Biology. *Chrysomphalus dictyospermi* is a highly polyphagous species (Borchsenius 1966). It is a serious pest of citrus and other trees such as olives and palms (Miller & Davidson 2005).

In most *C. dictyospermi* populations, the reproduction is sexual. However, uniparental (parthenogenetic) and biparental (sexual) populations of this species have been recorded in the USA (Brown 1965). The female lays between 80 and 200 eggs over a period of one to several months (Chkhaidze & Yasnosh 2001). In the USA, *C. dictyospermi* has 3 to 6 generations per year (Gill 1997), in Egypt, only 2 (Salama 1970). Mortality due to abiotic factors is high reach to 78% (Chkhaidze & Yasnosh 2001).

Structure. The female scale is greyish or brown in color with a coppery tinge; the shape is almost circular (1.5 to 2.0 mm in diameter), flat and thin (Salama 1970, Watson 2005). Male scale covers are yellowish in color and elongated oval in shape with subterminal exuviae (Gill 1997).

Diaspidiotus ostreaeformis (Curtis) 1843 - yellow apple scale

Material studied. **Beja:** Tastour, 27.III.2016, 5 ♀♀; **Bizerte:** Ras Jebel, 20.IX.2018, 2 ♀♀; Utique, 20.IX.2018, 2 ♀♀; **Cap Bon:** Grombalia, 8.IX.2015, 6 ♀♀; **Grand Tunis:** Tebourba, 4.V.2017, 6 ♀♀; Mornag, 20.VII.2018, 9 ♀♀.

Geographic distribution. Large distribution, it is found in 49 countries (García et al 2020).

Biology. *Diaspidiotus ostreaeformis* is a very polyphagous species, most often living on deciduous trees, mainly rosaceae (Balachowsky 1950, Argyriou 1990). It mainly inhabits the lignified parts of the plant. In Central Europe, it has an annual generation and overwinters as a second stage nymph under a shield (Podsiadlo 2017).

Structure. The female scale is circular, moderately convex, exuviae subcentral. It is gray-brown in color, dark in the central part and margin sometimes with a white border (Ferris 1938). The diameter is about 1.5 mm. The male is oval to elongate, gray-green in color, almost white on the margins. The length is about 0.6–0.8 mm (Borchsenius 1935).

Diaspidiotus pyri (Lichtenstein) 1881 - pear oystershell scale

Material studied. Cap Bon: Grombalia, 8.IX.2014, 5 ♀♀; **Grand Tunis:** Mornag, 20.VII.2017, 6 ♀♀.

Geographical distribution. It is found in 26 countries (García et al 2020).

Biology. This species is a pest of deciduous fruit trees, mainly pears and plums (Balachowsky 1950, Schmutterer 1957), as well to forest trees (Zahradnik 1990).

Structure. The adult female scale is almost circular (diameter 1.5-2 mm), convex and dark grayish-brown in colour; dark orange exuviae (Hall 1925).

Epidiaspis leperii (Signoret) 1869 - grey pear scale

Material examined. Grand Tunis: Mornag, 20.VII.2017, 4 ♀♀; Tebourba, 4.XII.2015, 2 ♀♀.

Geographic distribution. This cochineal is found in 42 countries (García et al 2020), mentioned in Tunisia by Miller & Davidson (2005).

Biology. *Epidiaspis leperii* is a polyphagous species recorded on 48 species from 13 plant families (García et al 2020). It can cause serious problems on olives in the Mediterranean (Argyriou 1990). It hibernates as immature females. Spawning occurs in April-May, with about 50 eggs per female. A single annual generation (Bodenheimer 1953).

Structure. Female scale cover circular, flat or slightly convex, 0.75–1.6 mm diameter, usually white or light grey or whitish yellow, with yellow or brown central or subcentral exuviae. Male scale cover elongate, white or light grey, with terminal yellow exuviae and body of living female light pink to orange-yellow, becoming dark red-brown with age. The insects are often found sheltering under lichens on the bark. Adult male wingless, with orange-yellow body (Gill 1997, Kosztarab 1996).

Hemiberlesia lataniae (Signoret) 1869 - latania scale

Material studied. Beja: Tastour, 27.X.2016, 24 ♀♀; **Cap Bon:** ElHaouaria, 21.IX.2017, 5 ♀; Grombalia, 8.IX.2014, 12 ♀♀; Soliman, 18.VIII.2015, 4 ♀♀; Takelsa, 5.X.2016, 3 ♀♀; **Grand Tunis:** Tebourba, 4.XII.2015, 9

☒☒; Mornag, 20.VII.2017, 3 ☒☒.

Geographic distribution. Cosmopolitan, widely distributed, it is found in 111 countries (Claps & Wolff 2003, García et al 2020), considered as a serious pest in many areas of the world (Miller & Davidson 1990). Mentioned by Mansour et al (2011) in Tunisia on vine.

Biology. *Hemiberlesia lataniae* is highly polyphagous. It is a pest of several crops and ornamentals (Blank et al 1992, Argyriou 1990). *Hemiberlesia lataniae* eggs are laid under the female shell and take a few hours to hatch. The first larval instar settles near the female mother and moults after 14 days. The larval development takes 56 to 65 days. Active dispersal is provided by the first stage and passive dispersal is achieved by wind and animal agents. Magsig-Castillo et al (2010) observed a larvae phoretic dispersal. Each year, *H. lataniae* completes 2 generations in USA (Stoetzel & Davidson 1974), 3 generations in Egypt (El-Minshway et al 1972) and 4 generations in Israel (Gerson & Zor 1973).

Structure. The adult female cochineal is 1.5-2.0 mm diameter, convex slightly elongated, yellow, transparent in the center and white in the circumference or around the exuviae; large exuvia, oval elongated (Davidson & Miller 1990). If present, male scale cover elongate oval with yellow subterminal exuviae, smaller and sometimes paler than that of female. Body of adult female bright yellow (Gill 1997). Eggs yellow, elongate, each 0.15 mm long.

Hemiberlesia rapax (Comstock) 1881 - greedy scale

Material studied. Cap Bon: El Haouaria, 21.IX.2017, 8 ☒☒; Takelsa, 5.X.2016, 12 ☒☒.

Geographic distribution. *Hemiberlesia rapax* is native to Europe (Gill 1997), is a cosmopolitan (Davidson & Miller 1990), mentioned in Tunisia by Balachowsky (1932).

Biology. *Hemiberlesia rapax* is a polyphagous pest, was observed affecting the stem, leaves, and fruit (Moghaddam 2004). This species is primarily found on over 117 genera in 60 plant families (Davidson & Miller 1990, Borchsenius 1966) and is considered as one of the 43 most damaging diaspidid species to agriculture (Beardsley & González 1975).

Structure. The female is 1.0–2.0 mm long, circular to somewhat elongate, convex, grey to white with yellow-brown central or subcentral exuviae. Ventral scale often well developed (Ferris 1938, Gill 1997). The male scale cover as similar to that of female but smaller and more oval, with yellow subterminal exuviae (Davidson & Miller 1990).

Lepidosaphes conchiformis (Gmelin) 1790 - mediterranean fig scale

Material studied. Beja: Tastour, 18.III.2017, 4 ☒☒; **Bizerte:** Ras Jebel, 22.IX.2016, 6 ☒☒; **Cap Bon:** Grombalia, 8.IX.2014, 3 ☒☒; **ElKef:** Dahmani, 18.III.2017, 4 ☒☒; **Grand Tunis:** Mornag, 20.VII.2017, 7 ☒☒; Tebourba, 4.XII.2015, 14 ☒☒; **Jendouba:** Bousalem, 27.X.2016, 1☒; **Zaghoun:** El Fahs, 18.IV.2015, 3 ☒☒.

Geographic distribution. Large distribution, it is found in 45 countries (García et al 2020).

Biology. *Lepidosaphes conchiformis* has 2 generations per year, overwintering as fertilized females. The female lays about 60 eggs. Eggs hatch from May to June (first generation) and from August to September (second generation) (Murakami 1970).

Structure. The female scale is light brown, small, wide posterior, 1.2–2.7 mm long, curved or straight, after completion of oviposition. The male is thin, membranous, white to purplish white, 0.7-1.0 mm long (Borchsenius 1958). The eggs are white (Kuwana 1925).

Lepidosaphes flava (Signoret) 1870

Material studied. **Bizerte:** Utique, 20.IX.2018, 5 ♀; **Cap Bon:** Nabeul, 19.X.2017, 2 ♀♀; **Grand Tunis:** Mornag, 20.VII.2017, 5 ♀♀; Tebourba, 4.XII.2015, 4 ♀♀.

Geographic distribution. It is found in 23 countries (García et al 2020), mentioned in Tunisia by Balachowsky (1954).

Biology. Bibolini (1958) considers *L. flava* a serious pest of olive trees. Each female produces 25–30 eggs and winters as a fertilized female. In Italy, there is only one generation per year.

Structure. The female scale is brown, elongated, mytiliform, 2.4-3.0 mm long. Male puparium is light brown, 1.8 mm long (Balachowsky 1954).

Lepidosaphes ulmi (Linnaeus) 1758 - apple mussel scale

Material studied. **Beja:** Tastour, 27.X.2016, 42 ♀♀, Tibar, 7.X.2014, 26 ♀♀; **Bizerte:** Mateur, 15.X.2015, 31 ♀♀; Ras Jebel, 30.V.2016, 8 ♀♀; Utique, 20.IX.2018, 18 ♀♀; **Cap Bon:** Soliman, 18.VIII.2015, 17 ♀♀; **ElKef:** Tajerouin, 27.X.2016, 18.IV.2017, 3 ♀♀; **Grand Tunis:** Mornag, 20.VII.2017, 41 ♀♀; Tebourba, 4.VI.2016, 441 ♀♀; **Jendouba:** Bullaregia, 18.VIII.2017, 16 ♀♀; **Zaghoun:** Hammam Zriba, 18.IV.2015, 24 ♀♀.

Geographic distribution. Large distribution, it is found in 64 countries (García et al 2020).

Biology. Encountered on several cultivated and wild woody plants. Develop 3 generations a year. The first generation is in march-april, the second is in june-july and the third is at the end of august (Ammar 1986).

Structure. The adult female is 1.0-3.5 mm long, convex, mussel-shaped, strongly tapered towards the exuvial end. The female body is white to yellowish, with yellowish-brown pygidium (Zahradník 1990). Scale cover of male is light brown, smaller, slenderer, with yellow terminal exuviae. Adult male is winged (Ghauri 1962).

Leucaspis riccae (Targioni Tozzetti) 1881 - white olive scale

Material studied. **Bizerte:** Utique, 22.IX.2017, 3 ♀♀.

Geographic Distribution. Occurs in 20 countries (García et al 2020). Mentioned in Tunisia by Trabut (1910), and seems to be rare.

Biology. In Greece, *L. riccae* undergoes 2 generations per year. It is observed on ripe olive fruit. The infested fruit was severely deformed (Argyriou & Kourmadas 1981).

Structure. the body of the female remaining within the whitish exuvium of the 2nd stage nymph. The bodies of all stages, including the male, are purple, except before molting, when they are brownish. The shield is elongated, white-grey, about 2.1 mm long, with the darker dorsal exuvium of the 1st stage nymph embedded at one end. The shield of the male is white, slightly curved, about 1.8 mm in length.

Parlatoria oleae (Colvée) 1880 - olive scale

Material studied. **Beja:** Sidi Ismail, 27.IV.2017, 2 ♀♀; Tastour, 27.IV.2017, 37 ♀♀; Teboursouk, 15.X.2015, 4 ♀♀; **Bizerte:** Mateur, 19.X.2018, 8 ♀♀; Ras Jebel, 20.X.2016, 14 ♀♀; **ElKef:** Dahmani, 27.X.2016, 3 ♀♀; Elles, 18.IV.2014, 13 ♀♀; Tajerouin, 27.X.2016, 12 ♀♀; **Cap Bon:** Grombalia, 8.IX.2014, 26 ♀♀; Nabeul, 8.X.2017, 54 ♀♀; **Grand Tunis:** Mornag, 20.VII.2017, 10 ♀♀; **Jendouba:** Bousalem, 18.IV.2017, 2 ♀♀; Bullaregia, 18.VIII.2014, 9 ♀♀; **Seliana:** Al Krib, 27.X.2016, 6 ♀♀; Bou Arada, 18.V.2018, 2 ♀♀; Makthar, 18.III.2015, 4 ♀♀; Sidi Bourouis, 18.IV.2017, 4 ♀♀; **Zaghoun:** El Fahs, 27.X.2017, 6 ♀♀; Hammam Zriba, 18.IV.2016, 14 ♀♀.

Geographic distribution. This scale is found in 57 countries, Mentioned by Mansour et al (2011) in Tunisia on olive tree.

Biology. Miller & Davidson (1990) considers this species as a pest in most areas where it occurs. The species is regarded as a polyphagous pest on more than 200 plant species belonging to 56 families (García et al 2020). It particularly attacks the olive tree (Huffaker et al 1962, Argyriou 1990). The larvae that settle at the beginning of the development cause anomalies and deformations on the fruits, which makes them unpleasant. On olives, the spots are black. According to Stafford (1948), the oil content of heavily infested olives can be reduced by 20%.

Each year, the olive scale develops from 1 (Imamkuliev 1966) to 4 (Grandi 1951) generations. Overwintering occurs as fertilized adult females, although a small portion of the population can overwinter at the second stage (Huffaker et al 1962). Adult males are required for breeding (Stafford 1947). Adult female lay a maximum of 100 eggs, the laying lasts 2–3 weeks (Huffaker et al 1962).

Structure. The eggs and immature stages are pink to violet. The adult female is 1.0–2.0 mm diameter, convex, circular to elliptical, white to very light grey with darker, subcentral to terminal exuviae. Pygidium with 4 pairs of lobes (Rahman & Ansari 1941).

Male scale cover white, oblong, about 1.0 mm long, with a brownish-yellow terminal exuviae often marked with dark green. Adult male is winged (Ghauri 1962).

Family Pseudococcidae - Mealybugs

Pelionella cycliger (Leonard) 1908

Material studied. **Beja:** Tastour, 27.X.2016, 6 ♀♀; **Grand Tunis:** Mornag, 20.VII.2017, 8 ♀♀; **Zaghoun:** Sminja, 18.IV.2016, 13 ♀♀.

Geographic distribution. The scale is found in 9 countries on olive tree (García et al 2020), Porcelli & Pizza (1995) noted that no damage was observed on the olive. Mentioned in Tunisia on pomegranate tree by Halima-Kamel et al (2014).

Biology. This species is observed in association with the ants *Crematogaster scutellaris* Olivier (1792) and *Tapinoma nigerimum* Nylander (1856) (Longo et al 1989). Three generations a year are observed on the olive in Puglia in Italy. The first stages of the third generation overwinter under the wax cocoon (Porcelli & Pizza 1995).

Structure. Body of elongated oval adult female, 1.2–2.5 mm long, 0.7–0.9 mm wide. Has antennae of 9 segments (Kaydan 2015).

Planococcus ficus (Signoret) 1875 - grape vine mealybug

Material studied. **Grand Tunis:** Mornag, 20.V.2017, 26 ♀♀; **Cap Bon:** Soliman, 18.VII.2015, 41 ♀♀; Takelsa, 5.X.2016, 5 ♀♀.

Geographic distribution. The scale is found in 44 countries (García et al 2020), mentioned in Tunisia by Mahfoudhi & Dhouibi (2009) and Mansour et al (2011, 2016) on vine.

Biology. Scale insects overwinter as adult females, in cracks and old wounds under the bark of the trunk and at the base of branches. In the spring, the females begin to lay, then the young larvae colonizing the bark and young stems, the bases of the leaves, the flowers and the new shoots. A female is able to lay up to 500 eggs. Often, the emergence of males coincides with the appearance of young females. In warm regions this species develops up to 7 generations, while in colder regions only 4 generations are recorded per year (Mendel et al 2012).

Structure. The adult female is 2–4 mm long, mobile with elongated legs. The female has 18 pairs of short wax filaments around the edge of the body; the anal pair measures up to a quarter of the body. The body is covered with grayish-white wax. The female larvae and the first two male instars are similar but the latter are smaller. The male is dark brown, having a single pair of wings and a length of 1.5 mm (Mahfoudhi & Dhouibi 2009).

Pseudococcus longispinus (Targioni Tozzetti) 1867 - longtailed mealbug

Material studied. **Beja:** Tastour, 18.V.2017, 5 ♀♀; **Bizerte:** Mateur, 14.X.2018, 3 ♀♀; **Cap Bon:** Grombalia, 8.IX.2014, 11 ♀♀; Nabeul, 8.IX.2016, 5 ♀♀; **Grand Tunis:** Mornag, 20.VII.2017, 13 ♀♀; **Zaghoun:** Sminja, 27.X.2017, 6 ♀♀.

Geographic distribution. The longtailed mealybug is found in 113 countries (García et al 2020), mentioned in Tunisia by Ben-Dov (1994). It is a common greenhouse pest around the world, but can also be found

outdoors in warm climates (Tenbrink & Hara 2007).

Biology. Females lay between 20 and 240 eggs. Eggs can hatch very quickly after laying. Female larvae go through 3 complete larval instars before giving birth to adult females. At 20–22 °C the life cycle is around one month. Females live about 2–3 months and males only a few days. The reproduction is sexual. Smith et al (1997) reported on citrus fruit in Australia that it grows between 3 and 6 generations per year.

Structure. Adult females with an oval body measuring 4.5 mm long, a pinkish-gray color and covered with a powdery whitish wax. These females have a long tail as long as the body (Goolsby 1994). Males are smaller, slender, darker in color, and winged.

Discussion

With the advent of national and international commercial exchanges. Several species of scale insects have been introduced to Tunisia due to the free trade of live plants and fresh produce. Most of these species would pose an economic or environmental.

In Tunisia, about 75 scale insect species have been recorded by Mansour et al. (2016). The great majority of these species are of no or minor economic importance.

On olive tree, Jarraya (2003) started to listing scale insect species. This work have been followed by Mansour et al (2011). The survey performed in 2009 in Tunisian olive groves, revealed the occurrence of six scale insects. The identified species were: the armoured scales *A. nerii*, *L. ulmi*, and *P. oleae*, *S. oleae* and *F. follicularis* and the mealybug species *P. cycliger*.

Our recent study carried out only in the north of Tunisia revealed more species of scale insects on olive tree than those described by Mansour et al. (2011); those are, 22 species including 3 species encountered for the first time in Tunisia on olive trees.

According to Mansour et al. (2011), only one scale insect specie was found in olive groves, namely either *S. oleae* or *P. cycliger*. The mealybug *P. cycliger* was the most common species reported within olives groves of the Northwest region of Tunisia. While, in the Northeast regions, *S. oleae* was proven to be occurring throughout olive groves of the Northeast region of Tunisia.

However, in our study the most widespread species in the olive groves of the north are *P. pollini*, *P. oleae*, *A. nerii* and *S. oleae*. This goes hand in hand with the study of Longo & Suma (2008), in italien olive groves, stated that the most common scale insect species are *P. pollini*, *S. oleae*, *P. oleae* and in restricted areas *L. ulmi*.

Finally, our manuscript presents a geographic distribution, generalized description of their biology, and damage of collected species. This checklist is therefore to be considered as a starting point for further

investigation. Further investigations may reveal the presence of other species of scale insects on olive tree in some localities of Tunisia.

Conclusion

This present inventory on olive tree in North of Tunisia, allowed us to identify 22 species of scale insect belonging to 4 families and to 16 genera. Most of these species were found in very low numbers or were rare. Moreover, the olive producers generally did not consider scale insects as economic pests.

This list of species should be considered preliminary. Future investigations may probably reveal the presence of other scale insect species in many hard-to-reach locations. Additional studies are also needed to identify the exhaustive list of predators and parasitoids associated to these phytophages.

Some species of scale insects have been encountered for the first time on olive trees in Tunisia. Only four species could be considered as potential pests: *P. pollini*, *P. oleae*, *A. nerii* and *S. oleae*. A control program could be especially considered against these species.

Most cochineal species found in olive groves have a wide geographical distribution. The coastal regions characterized by a mild climate: Grand Tunis, Bizerte, and Cap Bon seem to be the most favorable areas for extensive biodiversity.

Declarations

- Ethics approval and consent to participate

'Not applicable'

- Consent for publication

'Not applicable'

- Availability of data and materials

'Not applicable'

- Competing interests

The authors declare that they have no competing interests

- Funding

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- Authors' contributions

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- Conflicts of Interest

The authors declare no conflict of interest.

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