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Taxonomy and Biology of *Pauropsylla buxtoni* comb. nov. (Hemiptera: Psylloidea) on *Ficus carica* (Moraceae)

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ABSTRACT

A detailed morphological study of adult and immature *Trioza buxtoni* Laing, 1924 (Hemiptera: Psylloidea: Triozidae) shows that the species belongs to the tropical and subtropical genus *Pauropsylla* Rübsaamen, 1899 to which it is transferred. The adult of *Pauropsylla buxtoni* (Laing, 1924) comb. nov. is redescribed and the previously unknown immatures are described. Illustrations are provided for both adults and immatures. Immatures of *P. buxtoni* infest leaves of *Ficus carica* and induce conspicuous galls. The species is a pest on cultivated figs in the Palestinian Territories. Four successive phases in the formation and development of the galls can be recognised in which the five immature instars of *P. buxtoni* develop. The gall size increased significantly when the instar length increased and there were significant differences in the susceptibility of fig cultivars to psyllid infestation. The life cycle of *P. buxtoni* is univoltine with no significant differences between cultivars.

Key words: Triozidae, description, immatures, life cycle, cultivar, susceptibility, gall development.

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INTRODUCTION

Psyllids or jumping plant-lice are small phloem-feeding insects that are usually host specific, i.e., they complete their development on one or few related plant species (Burckhardt *et al.*, 2014). Often closely related psyllid species are restricted to one plant taxon such as the species of Homotomidae which all develop on Moraceae (Hollis and Broomfield, 1989). Moraceae, and *Ficus* species in particular, are utilised as hosts also by psyllids from other groups such as *Pauropsylla* (Triozidae) (Hollis, 1984) or some species of *Paurocephala* (Liviidae) (Mifsud and Burckhardt, 2002) and *Trioza* (Triozidae) (Ouvrard, 2017).

Two species, viz. *Homotoma ficus* (Linnaeus) (Homotomidae) and *Pauropsylla buxtoni* (Laing) (Triozidae) are associated with cultivated fig, *Ficus carica* L., in the west Palaearctic realm. The former is widely distributed throughout the Mediterranean region, West and Central Europe, the Black Sea region, the Caucasus, the Middle East to Iran and, introduced, in North America (Ouvrard, 2017). It is monophagous on its host with free living immatures, usually on the underside of the leaves, which do not induce galls (Prodanovic, 2011). *Pauropsylla buxtoni*, the second species, in contrast, develops on *F. carica*, *F. palmata* Forssk. and *F. cf. exasperata* Vahl on which their immatures induce very conspicuous leaf galls (Figs. 1-4). *Pauropsylla buxtoni* was originally described by Laing (1924) as *Trioza* and reported by Buxton (1924) as a serious pest on *Ficus carica* trees in Jericho (Palestinian Territories) and Lod (as Lydda) (Israel). The species was listed later from Israel on *F. carica* and *F. palmata* (Bodenheimer, 1937; Halperin *et al.*, 1982; Spodek *et al.*, 2017), from Egypt on *F. palmata* (Halperin *et al.*, 1982), from Saudi Arabia on *F. cf. exasperata* and *F. palmata* (Burckhardt, 1986) and from Jordan on *F. carica* (Al-Khawaldeh *et al*., 1997). The last authors list the species also from Syria but do not provide a source for this record. Apart from the original description of the adult and the few distributional records not much is known about *P. buxtoni*. In particular, several taxonomically important characters were not mentioned in the original description, the immatures have not been described nor have the phylogenetic relationships of the species been previously studied. Laing (1924) stated that *P. buxtoni* resembles *Colopelma thomasii* (Löw) (cited as *Trioza thomasi* (sic)) in the shape of the genal processes and the rounded apex of the forewing but differs in coloration. He did not mention if the characters shared between the two species indicate close phylogenetic relationship.

Common fig, *F. carica*, is an important fruit tree in the Palestinian Territories where many local cultivars are grown. These are characterised by having large fruits with a sweet taste, in addition to their adaptation to Mediterranean climate (Shtayeh *et al.*, 1991). Basheer-Salimia *et al.* (2013) characterised the genetic diversity in relation to the genotypes of 12 local Palestinian varieties of *F. carica* defined by pomological and morphological descriptors. Their results indicated that there were four clusters: the first cluster consisted of one genotype (cultivar Khidari), the second of four (Ghzali, Biadi, Shami and Himari), the third of three (Mowazi, Moozi and Ruzzi) and the fourth of four genotypes (Aswad, Sewadi, Khurtmani and Smari), respectively. Similar results on genetic diversity of Palestinian fig cultivars were reported by Ali-Shtayeh *et al.* (2014).

In recent years, heavy infestations of fig trees by *P. buxtoni* were observed in the northern part of the Palestinian Territories. The psyllids induce large, elongate, pocket-shaped galls, often clustered in large groups on the upper leaf surface (Figs. 1-6).

The objectives of the present paper are to redescribe the adults and describe the immatures of *P. buxtoni*, to examine the phylogenetic relationships and the life cycle of the species, to describe the gall development, to quantify growth and development of immatures relative to gall development and to study the susceptibility of fig cultivars to psyllid infestation.

MATERIAL AND METHODS

Material

For each of the fig varieties Biadi, Himari, Khidari, Khurtmani and Mowazi 100 leaves of the infested with galls of *P. buxtoni* were collected in *F. carica* orchards at different locations in the Tulkarm district in the northern part of the Palestinian Territories (N32.3125° E35.021111°). The mean annual temperature in the sampled area is 17.6 °C (5-38 °C) and the average annual relative humidity is 60.8 % (45-98 %) (PMA, 2015). Samples were taken from different fig cultivars. The collected galls were used either for describing the growth and development of galls or for dissecting them to extract the immatures living inside. Immatures were extracted from dissected galls and preserved in 70 % ethanol and adults were reared from the galls and preserved dry or in 70 % ethanol. Voucher specimens are preserved in the collections of the Naturhistorisches Museum Basel (NHMB). Additional material was examined from the collections of the NHMB, the Natural History Museum, London, UK (BMNH), the Muséum d'histoire naturelle, Geneva (MHNG) and the Naturhistorisches Museum, Vienna, Austria (NHMV).

Morphological terminology follows White and Hodkinson (1982), Hollis (1984, 2004), Ossiannilsson (1992) and Yang *et al.* (2009). The nomenclature of psyllid names accords with Ouvrard (2017) and the psyllid classification with Burckhardt and Ouvrard (2012).

Development of galls and immatures

For studying the development of galls and immatures, the galls were cut open under a dissecting microscope and the enclosed immatures extracted. Then the instar was determined and the length of the specimens measured using an eyepiece reticule mounted on the microscope. The gall size was quantified by cutting the gall longitudinally into two halves and then measuring the gall length, the distance between the base and apex of the gall (Figs. 5, 6) using a ruler. For each instar, 100 galls and the enclosed immature were measured, each gall containing one immature.

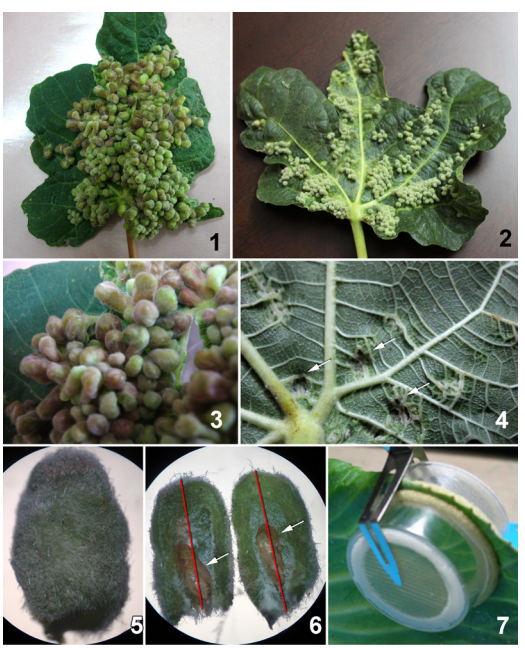
Susceptibility of local fig cultivars

Samples of fig leaves infested with galls of *P. buxtoni* were randomly chosen from trees of the five local cultivars (Biadi, Himari, Khidari, Khurtmani and Mowazi) for testing their susceptibility to psyllid infestation. The sampled trees were located in

neighbouring orchards in the Tulkarm district with similar meteorological conditions. For each cultivar, 50 galled leaves were randomly chosen and the number of galls on each leaf, singly or in clusters (Figs. 1-3), was counted.

Life cycle duration and number of generations per year

The duration of life cycle of *P. buxtoni* was studied on the five local fig cultivars (Biadi Himari, Khidari, Khurtmani and Sewadi) from 1 March 2015 to 30 April 2016. The life cycle duration, which represents the time from egg laying to adult emergence, was measured as follows: a pair of newly emerged male and female of *P. buxtoni* was put into a small cage (3.5 cm diameter x 3.0 cm height) fixed onto non infested young fig leaves on trees of the tested cultivars. Each cage consisted of two identical top and bottom parts made of transparent fiberglass with spongy margins to ensure a perfect fit when assembled. Each part had a dish shape with a circular diameter of 3.5 cm and a height of 1.5 cm. The bottom of each part consisted of a tightly fixed fine muslin mesh to allow aeration of the chamber. The cages were fixed onto the leaves using a clamp so that the insects could access a circular part of the leaf (Fig. 7). For each cultivar, 50 young leaves with 50 pairs of *P. buxtoni* were studied. After egg laying by the confined females, the leaves were labelled and the time to adult emergence was recorded.



Figs. 1-7. Galls induced by *Pauropsylla buxtoni* on leaves of *Ficus carica*, 1. Galls densely clustered on dorsal leaf surface, 2. Galls spread over the leaf surface, 3. Detail of clustered galls, 4. Lower leaf surface with slit-like openings of galls (arrows), 5. Gall enlarged, outer, hairy surface, 6. Gall enlarged, inner surface with one immature (arrows) per chamber; red lines indicate gall length, 7. Lateral view of the small cage used for confining one pair of *P. buxtoni* on young leaves of *F. carica* for the study of life cycle duration.

Statistics

The mean and range values of the length of galls and enclosed immatures, the number of galls per leaf and cultivar, as well as the life cycle duration on different cultivars were calculated. Analysis of Variance (ANOVA) and means separation by Tukey's HSD test were used to compare the gall size during the gall development as well as length of the enclosed immatures and for testing differences in the number of galls of *P. buxtoni* as well as life cycle duration of the psyllid between cultivars.

RESULTS

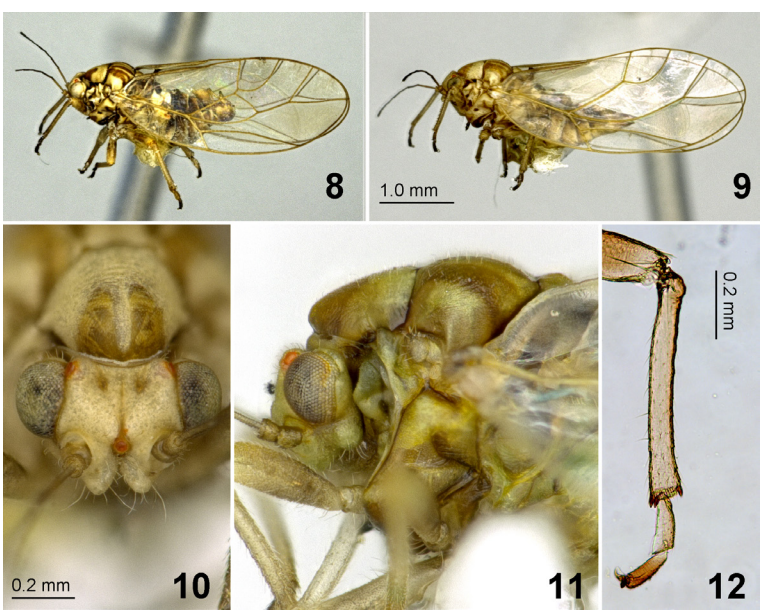
Pauropsylla buxtoni (Laing, 1924), comb. nov. (Figs. 8-25)

Trioza buxtoni Laing, 1924: 247; lectotype ♂: 'Type, *Trioza buxtoni*', 'Making thickenings on fig leaves', 'Palestine, Ludd (Lydda = Lod), ix.1921, P.A. Buxton', 'Pres. by, Imperial Bureau of Entomology, British Museum 1923-289', *Trioza buxtoni* Lg., Det. F. Laing.', 'BMNH(E)_1266347' (BMNH, examined), here designated.

Description. Adult (Figs. 8, 9). Colour. Body greenish, yellow or ochreous. Median suture, lateral margins of vertex and foveae brown; ocelli red; clypeus brown; antenna dark brown to black, segments 1-3 ochreous to brown. Mesopraescutum with two submedian patches anteriorly; mesoscutum with four submedian longitudinal brown stripes; mesothorax brown ventrally. Forewings transparent with light brown veins; hindwings transparent. Legs with dark brown tarsi, except for basimetatarsus which is ochreous. Abdomen with dark brown sclerites and yellowish membranes; terminalia partly ochreous. Younger specimens with less expanded dark pattern.

Structure. With generic characters as given by Hollis (1984). Integument granular, sparsely covered with short setae. Median suture of vertex weak near occiput, becoming stronger towards median ocellus; area around lateral ocelli hardly raised; frons triangular, small, about as long as diameter of median ocellus; vertex anteriorly rounded down to genae which are produced into conical processes, subacute apically, about half as long as vertex along mid-line (Fig. 10); with big suborbital lobe (Fig. 11). Clypeus slightly tubular, with a pair of setae; ultimate rostral segment with or without a pair of long basal setae. Antenna 10-segmented, 1.71-2.00 times as long as head width; with a simple subapical rhinarium on each of segments 4, 6, 8 and 9; terminal setae about three quarters and half as long as antennal segment 10. Forewing (Fig. 9) oval, widest in the middle, narrowly rounded apically; 2.07-2.33 times as long as wide, 4.43-5.67 as long as head width; sparsely clothed in setae which are about as long as diameter of veins; vein R+M+Cu trifurcating into veins R, M and Cu; m_1 cell value 1.35-1.44. Hind wing with costal margin bearing 1-2 setae proximal to costal break, setae distal to costal break divided into two distinct groups of 2-3 setae each; vein R+M+Cu indistinctly splitting into veins R and M+Cu. Procoxa lacking ventro-apical spur; basal and apical tarsal segments subequal; metacoxa with large, conical, subacute meracanthus; metafemur with a transverse row of 4-6 subapical bristles; metatibia 1.00-1.33 times as long as head width, with 1+2 apical metatibial spurs

(Fig. 12). Abdomen with lateral setae on tergite 2♂♂ and 3♀♀. Male proctiger (Figs. 13, 18) flask-shaped; outer surface covered with long setae in apical half; in profile, with weak posterior expansions which bear moderately long, simple setae on their inner surface (Fig. 14). Subgenital plate (Figs. 13, 18) subglobular, sparsely covered with moderately long setae posteriorly and ventrally. Paramere (Figs. 13, 18, 19) narrowly lamellar, in profile, weakly tapering towards apex and hardly curved to the rear; outer surface with long setae mostly along apical half of foremargin and along entire hind margin; inner surface (Fig. 19) covered with moderately long setae, in basal portion longer and thicker than near apex; apex strongly sclerotised, somewhat blunt in profile, sharply truncate and with each a small anterior and posterior point in dorsal view. Distal portion of aedeagus (Fig. 20) simple, weakly expanded and rounded apically; sclerotised end tube of ductus ejaculatorius short, weakly sinuous. Female terminalia (Fig. 15) cuneate. Female proctiger 1.08-1.33 times as long as head width, dorsal margin, in profile, almost straight, apex subacute; covered in moderately long setae, in apical third with two submedian longitudinal rows of long setae, and some sparse peg setae in apical fifth, laterally; circumanal ring oval, very short, consisting of two unequal rows of oval pores (Fig. 16). Dorsal valvulae cuneate, lacking teeth; ventral valvulae styliform, straight, apically narrowly rounded, lacking teeth (Fig. 17).



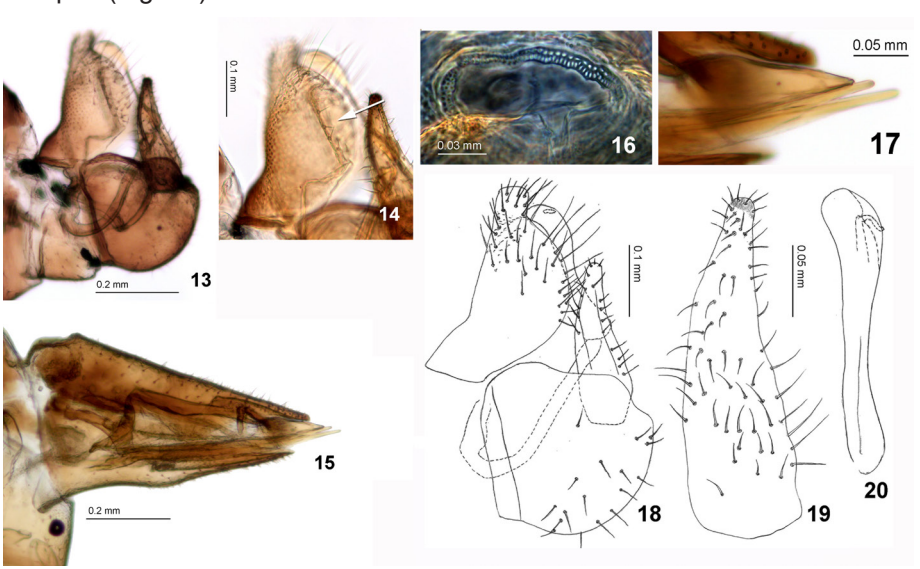
Figs. 8-12. Adult *Pauropsylla buxtoni*, 8. Male, 9. Female, 10. Head, dorsal view, 11. Head and thorax, lateral view, 12. Metatibia and metatarsus. Scale 1.0 mm (Figs. 8, 9), 0.2 mm (Figs. 10, 11), 0.2 mm (Fig. 12).

Measurements (in mm, range, mean±SD taken from 6♂♂, 6♀♀, dry mounted specimens). Body length ♂ 3.5-3.8 (3.65±0.11), ♀ 3.7-4.2 (3.92±0.17); head width ♂ 0.6-0.7 (0.62±0.04), ♀ 0.6-0.7 (0.62±0.05); antenna length ♂ 1.1-1.1 (1.15±0.06), ♀ 1.1-1.3 (1.18±0.08); forewing length ♂ 2.9-3.1 (2.95±0.08), ♀ 3.1-3.5 (3.30±0.17);

metatibia length ♂ 0.7-0.8 (0.77±0.05), ♀ 0.7-0.9 (0.78±0.06); proctiger length ♀ 0.7-0.8 (0.75±0.06).

Immature. The five instars differ in body size (Table 1). Fifth instar (Figs. 21-25). Colour. Whitish, yellowish. Antennae and legs brown. Thorax and abdomen with a longitudinal row of submedian brown dots (Fig. 25).

Structure. Body (Fig. 21) elongate, oval, 1.83-1.92 times as long as wide. Antenna (Fig. 22) 7-segmented, segment 7 sometimes indistinctly subdivided. Forewing pads with humeral lobes weakly developed, rounded, not reaching posterior eye margin anteriorly. Caudal plate (Figs. 24, 25) 0.73-0.82 times as long as wide; circumanal ring ventral; distance between hind margins of circumanal ring and caudal plate as distance between fore and hind margin of circumanal ring; transversely elongate, small, consisting of a single row of pores. Head anteriorly with densely spaced very slender sectasetae and short normal setae, distance between setae shorter than length of setae; forewing pad with irregularly spaced very slender pointed marginal and submarginal sectasetae and normal setae, distance between setae usually larger than length of setae; hindwing pad with a few slender pointed marginal and submarginal secatsetae, distance between setae about as long as setae; postocular seta absent, dorsal sectasetae absent from head, thorax and wing pads; caudal plate marginally, submarginally and dorsally with relatively thick pointed sectasetae, distance between setae shorter than setae (Fig. 24). Tarsal arolium sessile, slightly shorter than claws, fan-shaped (Fig. 23).



Figs. 13-20. Terminalia of *Pauropsylla buxtoni*, 13, 18. Male terminalia, lateral view, 14. Male proctiger showing setae on inner surface (arrow), 15. Female terminalia, lateral view, 16. Female circumanal ring, dorsal view, 17. Valvulae, lateral view. 19. Paramere, inner surface, 20. Distal portion of aedeagus. Scale 0.2 mm (Figs. 13, 15), 0.1 mm (Fig. 14), 0.03 mm (Fig. 16), 0.05 mm (Fig. 17) 0.1 mm (Fig. 18), 0.05 mm (Figs. 19, 20).

Table 1. Length of galls and instars of *Pauropsylla buxtoni* on fig leaves in the Palestinian Territories. Mean and range values of gall length and length of associated instar (in mm) (n=100 galls/instar) on cultivar Khidari.

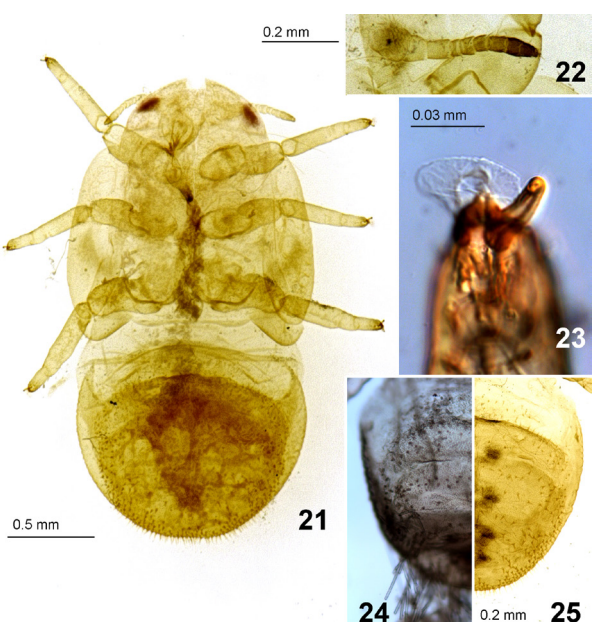
Instar	Gall length		Instar length	
	mean±SEM [1]	range	mean ± SEM [1]	range
First	1.05±0.14 a	0.7-1.3	0.21±0.05 a	0.18-0.33
Second	2.97±0.66 b	2.3-3.6	0.41±0.07 b	0.35-0.53
Third	4.98±1.27 c	4.0-6.1	0.65±0.12 c	0.61-0.85
Fourth	6.60±0.36 d	6.2-7.3	0.98±0.09 d	0.89-1.08
Fifth	8.75±1.90 e	8.0-9.8	1.52±0.28 e	1.21-1.68

[1]Means of gall length and instar length within the same column followed by different letters are significantly different at $p < 0.05$ according to ANOVA and Tukey's HSD test for means separation.

Measurements (in mm, taken from 4 slide mounted specimens). Body length 2.2-2.3 (2.25±0.06); forewing pad length 0.7-1.0 (0.85±0.01); caudal plate length 0.8-0.9 (0.85±0.06).

Egg. Yellowish. Oval, 0.15 mm long, with short pedicel which is inserted into leaf tissue.

Material examined: Israel: Bet Dagan; Kfar Yedidya; Lod; Tel Aviv (BMNH, MHNG, NHMB). Jordan: Al-Hammah (NHMB). Palestinian Territories: Tulkarm (BMNH, NHMB). Saudi Arabia: Abha/Jawsan; Bisha (MHNG, NHMB).



Figs. 21-25. Fifth instar immature of *Pauropsylla buxtoni*, 21. Habitus, dorsal view, 22. Antenna, 23. Apex of tarsus with tarsal arolium and claws, 24. Caudal plate showing setal pattern and wax strands, dorsal view, 25. Caudal plate showing setal pattern and brown submedian dots, dorsal view. Scale 0.5 mm (Fig. 21), 0.2 mm (Fig. 22), 0.03 mm (Fig. 23), 0.2 mm (Figs. 24, 25).

Phylogenetic relationships

Adult *P. buxtoni* fit the description of *Pauropsylla* Rübsaamen provided by Hollis (1984), e. g., the basally weak median suture of the vertex, the broad apically rounded forewings, the 1+2 apical metatibial spurs and its host association with *Ficus* spp. It differs from other *Pauropsylla* species in the presence of short conical genal processes and the absence of lateral setae on abdominal tergite 3 in males and on tergite 4 in females. Presence or absence, size and shape of genal processes can vary within triozid genera such as *Bactericera* Puton (Burckhardt and Lauterer, 1997) or *Leuronota* Crawford (Burckhardt and Couturier, 1994) and the distribution of lateral setae on the abdominal tergites may vary between closely related species, e.g. in the *Trioza berberidis*-group (Burckhardt, 1988). These characters are hence not of generic importance and we transfer *Trioza buxtoni* to *Pauropsylla* as *Pauropsylla buxtoni* (Laing, 1924), comb. nov. The immatures of *P. buxtoni* resemble those of other *Pauropsylla* spp. (e.g. Hollis, 2004) but we could not find any putative synapomorphies defining *Pauropsylla*.

Pauropsylla is a tropical and subtropical genus with 25 described species from the Old World (Hollis, 1984; Ouvrard, 2017) and two undescribed species from the New World (Brown and Hodkinson, 1988). Most species develop, as far as known, on *Ficus* species. Within *Pauropsylla*, Hollis (1984) defined three species groups, in addition to several ungrouped species. *Pauropsylla buxtoni* does not fit any of them. It resembles two Afrotropical species: *P. trigemma* Hollis in the relatively narrow forewings and the simple apical segment of the aedeagus, and *P. longipes* Hollis in the lamellar paramere and the long, apically pointed female terminalia. However, these are probably superficial similarities, not indicating close phylogenetic relationships.

When describing *P. buxtoni*, Laing (1924) suggested that it is 'near to *T. thomasi*, Lw. [=*Colopelma thomasii*], in the genal cones and the rounded apex of the tegmen, but differing in the coloration.' *C. thomasii*, of which we have examined syntypes from Ratzes, Alto Adige, Italy (NHMW), has similar forewings and relatively long female terminalia. It differs, however, in the absence of genal processes and 1+3 apical metatibial spurs. The resemblance between the two species is superficial and they are probably not closely related.

Gall development

The galls induced by *P. buxtoni* are on the upper leaf surface of fig leaves either solitary or in clusters (Figs. 1-3). The galls are unilocular and contain only one immature each. The development of the gall passes through four successive phases.

Folding phase. The gall formation starts after the first instar hatches from the egg which is inserted with the pedicel into leaf tissue and begins to suck plant sap. The area around the immature on the upper leaf epidermis starts folding upwards.

Swelling phase. With the growth of the first instar the surrounding tissue swells and forms a small nipple-shaped gall containing the insect. Within the gall, the insect grows, passing through five instars. The gall grows simultaneously and increases in size by a factor of 100, becoming more pocket-shaped.

Dehiscence phase. It starts when the third instar immature completes its development and the fourth instar is ready to hatch. This phase is characterised by the development of a small slit-like opening at the bottom of the gall on the lower leaf surface (Fig. 4). This opening is used by the full-grown fifth instar immature for leaving the gall. Once outside, the adult will hatch.

Senescence phase. It begins after the fully developed fifth instar leaves the gall. The gall turns greyish and black apically, followed by the blackening and desiccation of the rest of the gall. While uninfested leaves are usually shed in autumn, the ones bearing mature galls with insects persist on the tree throughout winter until new flush appears in spring coinciding with the hatching of adults which will re-infest the new leaves.

Development of galls and immatures

Our study of gall size in relation to that of the enclosed immature shows that the size increase of the two is correlated. The most significant increase in gall size was observed during the swelling phase. On the cultivar Khidari, e.g., the body length of the immature from the first to the fifth instar increased significantly (at $p < 0.05$) from 0.21 to 1.52 mm during the development (Table 1). At the same time, the mean values of gall length (as an indicator of gall size) increased significantly (at $p < 0.05$) from 1.05 to 8.75 mm (Table 1). This implies that there was a significant relationship between the gall size and the body length of the instars developing inside the galls.

Susceptibility of local fig cultivars to psyllid infestation

The results indicate that there are significant differences (at $p < 0.05$) between the means of gall number per leaf of the cultivars Khurtmani, Himari and Biadi but not of Khidari, Mowasi and Biadi (Table 2). Himari is the most susceptible to *P. buxtoni* infestation with the highest mean number of galls per leaf (150.3), whereas Khurtmani is the least susceptible with the lowest mean number of galls per leaf (96.3). The other tested cultivars (Biadi, Khidari and Mowasi) are intermediate.

Table 2. Number of galls induced by *Pauropsylla buxtoni* on fig leaves of local cultivars grown in the Palestinian Territories. Mean and range values of gall numbers per randomly chosen leaf were used as indicator of varietal susceptibility to psyllid infestation (n=50 leaves/variety).

Fig cultivars	Mean±SEM [1]	Range
Biadi	125.8±8.89 b	98-142
Himari	150.3±7.12 c	135-206
Khidari	142.3±8.49 bc	103-194
Khurtmani	96.3±3.71 a	81-120
Mowazi	110.5±9.39 ab	90-151

[1]Means of gall number followed by different letters are significantly different at $p < 0.05$ according to ANOVA and Tukey's HSD test for means separation.

Life cycle duration and number of yearly generations

The life cycle of *P. buxtoni* lasted from 298 to 324 days. The comparison of the means of life cycle duration revealed no significant differences between the five tested fig cultivars with the means ranging from 305.3 to 320.6 days (Table 3). *P. buxtoni* is hence univoltine, independent on which cultivar it develops.

Table 3. Mean of life cycle duration (in days) of *Pauropsylla buxtoni* on fig leaves of five cultivars grown in the Palestinian Territories (n=50 leaves/variety).

Fig cultivars	Mean±SEM [1]	Range
Biadi	315.4±0.39 a	312-320
Himari	320.6±0.35 a	315-324
Khidari	305.3±0.15 a	298-310
Khurtmani	310.5±0.71 a	302-315
Sewadi	318.1±0.89 a	314-322

[1] Means of the life cycle duration followed by the same letter are not significantly different at $p < 0.05$ according to ANOVA and Tukey's HSD test for means separation.

The newly hatched adults become active after bud break and the appearance of young leaves of the fig trees from early March to late April. After mating the females lay eggs inserting the egg pedicel into the leaf tissue with the ovipositor. The first instar immatures hatch in late spring and the following instars develop during summer and autumn. The fifth instar immatures hibernate inside the gall and leave it in early spring when the adult emerges. Contrary to uninfested leaves, which are shed in autumn, those bearing galls persist on the plants during winter until next spring. Then, the last instar leaves the gall and the adult hatches.

DISCUSSION

Gall induction is widespread amongst psyllids and Triozidae in particular (Hodkinson, 1984; Burckhardt, 2005). *Pauropsylla* species are gall inducing on *Ficus* spp. as far as hosts are confirmed (Hollis and Broomfield, 1989; Percy *et al*., 2016). Our results indicate that the increase in gall size of *P. buxtoni* is correlated with the increase of size of the immature living inside. Similar observations were reported from other gall-inducing psyllids such as *Pachypsylla venusta* (Osten-Sacken) on *Celtis occidentalis* (Cannabaceae) (Yang and Mitter, 1994) or *Glycaspis* (*Synglycaspis*) *cameloides* Moore, *Schedotrioza marginata* Taylor and *S. multitudinea* (Maskell) on *Eucalyptus obliqua* (Myrtaceae) (Taylor, 1987). The galls induced by *P. buxtoni* can cover most of the leaves leading to serious distortion. In the Palestinian Territories high gall density reduces the yield of cultivated figs up to 5 % (Batta, unpublished data) leading to economic losses.

Our observations regarding the prolonged attachment to the tree of leaves bearing *P. buxtoni* galls through autumn and winter until spring and the synchronisation between the adult emergence and fig phenology are in agreement with reports on other gall-inducing psyllids such as *Trioza simplifica* Mathur on *Terminalia travancorensis* (Combretaceae), *T. gigantea* Crawford on *Vaccinium neilgherrense* (Ericaceae) or *Trioza tabebuiae* Burckhardt and Santana on *Handroanthus* spp. (Bignoniaceae) (Hodkinson, 1984, 2009; Santana and Burckhardt, 2001; Burckhardt, 2005). *Pauropsylla* species are variable with respect to voltinism. *P. buxtoni* and *P. longispiculata* Mathur are univoltine, *P. depressa* Crawford and *P. purpurescens* Mathur have 1-2 and 3 generations per year, respectively, and *P. trichaeta* Petty and *P. udei* Rübsaamen are polyvoltine (Hodkinson, 2009).

It is known that different cultivars can influence psyllid populations (Asadi *et al*., 2011; Camargo *et al*., 2014) which was also observed on fig. Himari and Khidari were the most susceptible to *P. buxtoni* infestation among the tested cultivars with the highest number of galls per leaf (mean = 150.3 and 140.3, respectively) compared to Khurtmani and Mowazi with the lowest number (mean = 96.3 and 110.5, respectively). As the climatic conditions within the study area are similar, the higher susceptibility of certain local fig cultivars can be attributed to genetic differences between the tested cultivars. Himari, the most susceptible to *P. buxtoni* infestation, belongs to a different genotype cluster than Khurtmani, the most resistent cultivar (Basheer-Salimia *et al*., 2013). According to these authors, the genetic distances (UPGMA=Unweighted Pair Group Method with Arithmetic Mean) between these genotype clusters ranged from 0.517-0.863 (mean=0.690) implying that Himari and Khurtmani cultivars are genetically distant and thus may respond differently to the infestation of *P. buxtoni*. Probably the same is true for Khidari and Mowazi.

CONCLUSION

The detailed morphological study of adult and immature *Trioza buxtoni* suggests that the species is congeneric with *Pauropsylla udei*, the type species of *Pauropsylla*, rather than similar to *Colopelma thomasii* as was suggested by Laing (1924). For this reason the species is transferred here to *Pauropsylla*. *P. buxtoni* differs from other *Pauropsylla* species in the presence of short, though distinct genal processes.

For a successful management of *P. buxtoni* on fig trees in the Palestinian Territories, information on its life history is crucial. In view of sustainable fig production, the most resistant cultivar should be planted and in autumn the gall bearing leaves which persist on the trees should be removed and burned for reducing the psyllid population. Future research should investigate the role of natural enemies, such as predators and in particular parasitoids, about which nothing is known to date and which may be useful in the management of this psyllid pest.

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