

The first cases of gynandromorphism in oil-collecting bees (Hymenoptera, Apidae: Centridini, Tapinotaspidini)

Leopoldo Jesús Alvarez^{1,3}; Wagner Pereira Silva^{2,4}; Mariano Lucia^{1,5} & Antonio J.C. Aguiar^{2,6}

¹ Universidad Nacional de La Plata (UNLP), Facultad de Ciencias Naturales y Museo (FCNyM), División Entomología. La Plata, Buenos Aires, Argentina. Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET).

² Universidade de Brasília (UNB), Instituto de Ciências Biológicas (IB), Departamento de Zoologia. Brasília, DF, Brasil.

³ ORCID: <http://orcid.org/0000-0003-4330-9617>. E-mail: lalvarez@fcnym.unlp.edu.ar

⁴ ORCID: <http://orcid.org/0000-0002-5199-3124>. E-mail: wagner.silva@yahoo.com.br

⁵ ORCID: <http://orcid.org/0000-0001-8019-6768>. E-mail: mlucia@fcnym.unlp.edu.ar (corresponding author)

⁶ ORCID: <http://orcid.org/0000-0002-1319-6431>. E-mail: ajcaguiar@unb.br

Abstract. Here we provide descriptions of gynandromorphs of two species oil-collecting bees: *Lophopedia nigrispinis* and *Epicharis iheringii*, both with partial bilateral phenotypic asymmetry. The bees have a female phenotype predominantly on mesosoma and metasoma. The specimen of *L. nigrispinis* has distinct characteristics on legs, suggesting a mosaic pattern of gynandromorphism. The pollen and oil loads on legs suggest that the bee was foraging normally. The gynander specimen of *E. iheringii* has mostly a female phenotype, except for head, with right half female type and left half male type. The specimen of *L. nigrispinis* was collected foraging on flowers of *Bidens* sp. at Parque Nacional Iguazú, Argentina with loads of pollen on legs suggesting it was reproductive and was provisioning a nest. The specimen of *Epicharis iheringii* has no evidence of any oil or pollen collection, despite its mostly female phenotype.

Key-Words. Gynander; *Epicharis*; *Lophopedia*; Intersex; Pollinators; Mosaic gynandromorphy.

INTRODUCTION

Gynandromorphs are sexually abnormal individuals that display secondary sex characters of both sexes simultaneously (Lucia & González, 2013). The occurrence of gynandromorphy is widespread in arthropods, with numerous records reported in Hymenoptera, especially in bees (Engel, 2007; Hinojosa-Díaz *et al.*, 2012). Gynandromorphs are characterized in three main types according to Michez *et al.* (2009): mosaic, transverse and bilateral. Despite its common occurrence in insects, very little is known on about potential behavioural changes, with scarce data on lycaenid butterflies (Dantchenko *et al.*, 1995), driprionid sawflies (Mertins & Coppel, 1971), drosophilids (Nissani, 1977), locusts (Maeno & Tanaka, 2007), bumblebees (Ugajin *et al.*, 2016; Matsuo *et al.*, 2018) and mason bees (Sampson *et al.*, 2010). Most of these reports about the behaviour of gynandromorphy suggest a predominance of female characteristics, with the persistence of the reproductive capacity in some gynandromorphs (Wcislo *et al.*, 2004).

The oil-collecting bees occur in at least six lineages distributed in Neotropical and Palearctic re-

gions. In Neotropical region there are three of the main tribes of oil-collecting bees, with more than two hundred species. Among them, Centridini and Tapinotaspidini are the most diverse groups in terms of abundance and richness (Roig-Alsina, 1997; Michener, 2007). These bees have specialized structures to collect oils, mainly combs or pads of setae, typically in forelegs and middle legs (Neff & Simpson, 1981; Cocucci *et al.*, 2000). This oil is used presumably to provision larval cells or cell lining (Michener, 2007).

Herein, we document for the first time two specimens of oil-collecting bees with mixed gynandromorphy: *Lophopedia nigrispinis* (Vachal, 1909) (Tapinotaspidini) and *Epicharis (Epicharitides) iheringii* Friese, 1899 (Centridini).

MATERIAL AND METHODS

External morphological features were studied using a Nikon SMZ 745T and Leica M125 stereomicroscope. Photographs were taken with a Canon T3i and AmScope MU 500 digital cameras attached to a stereomicroscope, and imag-

Pap. Avulsos Zool., 2019; v.59: e20195936

<http://doi.org/10.11606/1807-0205/2019.59.36>

<http://www.revistas.usp.br/paz>

<http://www.scielo.br/paz>

Edited by: Kelli dos Santos Ramos

Received: 12/04/2019

Accepted: 01/07/2019

Published: 15/08/2019

ISSN On-Line: 1807-0205

ISSN Printed: 0031-1049

ISNI: 0000-0004-0384-1825



es were assembled using CombineZM open software. Morphological terminology follows Michener (2007). The abbreviations T and S for metasomal terga and sterna, respectively. Measurements were taken with an ocular micrometer and mean values and ranges are given in millimeters. Total body length was measured from the head to the apex of metasoma in lateral view; mesosoma width was measured between the outer borders of the tegulae; metasoma width was measured across the second tergum. Series of other specimens of the same species were studied to compare the morphological variation between the gynandromorphs and the male and female normal phenotypes.

The specimen of *L. nigrispinis* was collected at Parque Nacional Iguazú (Argentina) and is deposited in the entomological collection of the Museo de La Plata, Argentina (MLP). The specimen of *E. iheringii* was collected on a cerrado habitat, at Parque Nacional de Brasília (Brazil, DF, Brasília) and is deposited on entomological collection of the Universidade de Brasília (collection voucher UNB008980). The first species occurs only in forested areas in Southern America (Brazil, Paraguay, Argentina) (Aguiar, 2009; Torretta & Roig-Alsina, 2017) and the second is mainly related to cerrado areas in Brazil (Moure *et al.*, 2007).

RESULTS

Lophopedia nigrispinis – gynandromorphy

Description: Body length 7.5, head length 1.9, head width 2.5, mesosoma width 2.8, metasoma width 2.6. **Head:** mixed. Partial bilateral gynandromorph, right side mostly male and left side female; integument mostly black except mandible pale yellow with apex and posterior basal angle black; right side of labrum pale yellow like male and left side black as female; clypeus with lower margin yellow on right side and black on left side; left half of supraclypeal area without lower margin surpassing the upper margin of clypeus as female; paraocular area with a narrow yellow stripe occupying less than the lower part. Both antennae have 11 flagellomeres as is typical for male. Pubescence on mandibles, labrum, clypeus, frons, paraocular area and gena, mostly white and not distinct between sides, vertex with sparse erect simple setae light brown; left half of labrum with long light brown setae as female, distinct longer than male right side (Fig. 1B). **Mesosoma:** general appearance male-like, except for the legs with a mix of male and female features. Integument black and pubescence brown to black; mesoscutum and scutellum with sparse punctures and lamella of pronotal collar with lateral portions high, characteristic of males. Legs with mixed secondary sex characteristics, with integumental color black and most distitarsi yellow as in normal male. Forelegs male-like modified to collect oil, however basitarsi narrower than female basitarsi (Fig. 1C, D). Middle legs female-like with ventral surface of tibiae with spatulate setae, except for left distitarsi yellow as male and the right mixed with yellow and brown coloration (Fig. 1E, H). Hind right leg male-like; the left hind scopa blackish composed of dense

plumose pubescence with integument mostly black except the distal part of tibia, basitarsus and mediotarsus light brown, distitarsus yellow; tibial spurs light brown; pubescence mostly black except by pale yellow on tibial postero distal margin and basitarsus (Fig. 1G). Right hind leg female-like, with plumose pubescence not so dense as left scopa, with numerous simple setae; mediotarsus and distitarsus brown; tibial spurs dark brown (Fig. 1H). Wing membrane dark brown infumated. **Metasoma:** symmetric female-like, with six exposed terga and sterna. Genital structure developed as a normal sting (Fig. 1A).

Material Examined: One gynandromorph, Argentina, Misiones, Parque Nacional Iguazú, 28-IX-2016, Coll. L. Alvarez-M. Lucia-P. Ramello.

Epicharis (Epicharitides) iheringii – gynandromorphy

Description: Body length 16.2, head length 4.0, head width 4.3, mesosoma width 4.9, metasoma width 6.7. **Head:** Bilateral gynandromorph, left side male-like and right side female; integument mostly black; labrum and clypeus yellow on left side as male, and black on right side as female; right paraocular area with a yellow stripe occupying half area like female. Both antennae have 10 flagellomeres as is typical for females. Pubescence on mandibles, frons, paraocular area, gena and clypeus not distinct between sides; right half of labrum with light brown setae as female, distinct longer than on male left side; left side of vertex with yellowish setae as male and right side with blackish setae as female (Fig. 2B). **Mesosoma:** general appearance female-like. Integument black and pubescence brown to black; mesoscutum and scutellum with sparse punctures. Legs female-like (Fig. 2A), with integument color black as in normal female. Fore and mid legs female-like, modified to collect oil on ventral surface. Hind legs female-like; the scopa yellowish composed of dense plumose pubescence with integument yellowish except the distitarsus and mediotarsus light brown; tibial spurs light brown; pubescence mostly yellowish. **Metasoma:** symmetric female-like, with six exposed terga and sterna, and symmetric yellow marks on terga as female (Fig. 2C).

Material Examined: One gynandromorph, Brazil, Brasília, Parque Nacional de Brasília, 23-XI-2012, Coll. J.C.S. Oliveira.

DISCUSSION

Gynandromorphism in bees are known from more than 140 species and 36 genera belonging to all families, though most of these records belong to the long-tongued bee families (Almeida *et al.*, 2018; Prashantha *et al.*, 2018). Within the family Megachilidae, the records of gynandromorphs are in three tribes (Anthidini, Megachilini and Osmiini), but mainly are present in the genus *Megachile* Latreille (Hinojosa-Díaz *et al.*, 2012;

Coelho *et al.*, 2016). In the family Apidae, the records of gynandromorphs were recorded from numerous genera and tribes as Anthophorini, Apini, Bombini, Epeolini, Eucerini, Euglossini, Melictini, Meliponini, Nomadini and, Xylocopini (Urban, 1999; Wcislo *et al.*, 2004; Michez

et al., 2009; Hinojosa-Díaz *et al.*, 2012; Lucia & González, 2013; Alvarez *et al.*, 2014; Le Féon *et al.*, 2016; Onuferko, 2018). Despite the great diversity and abundance in the Neotropical region, this is the first reported case of gynandromorphism in oil-collecting bees. The gynandro-

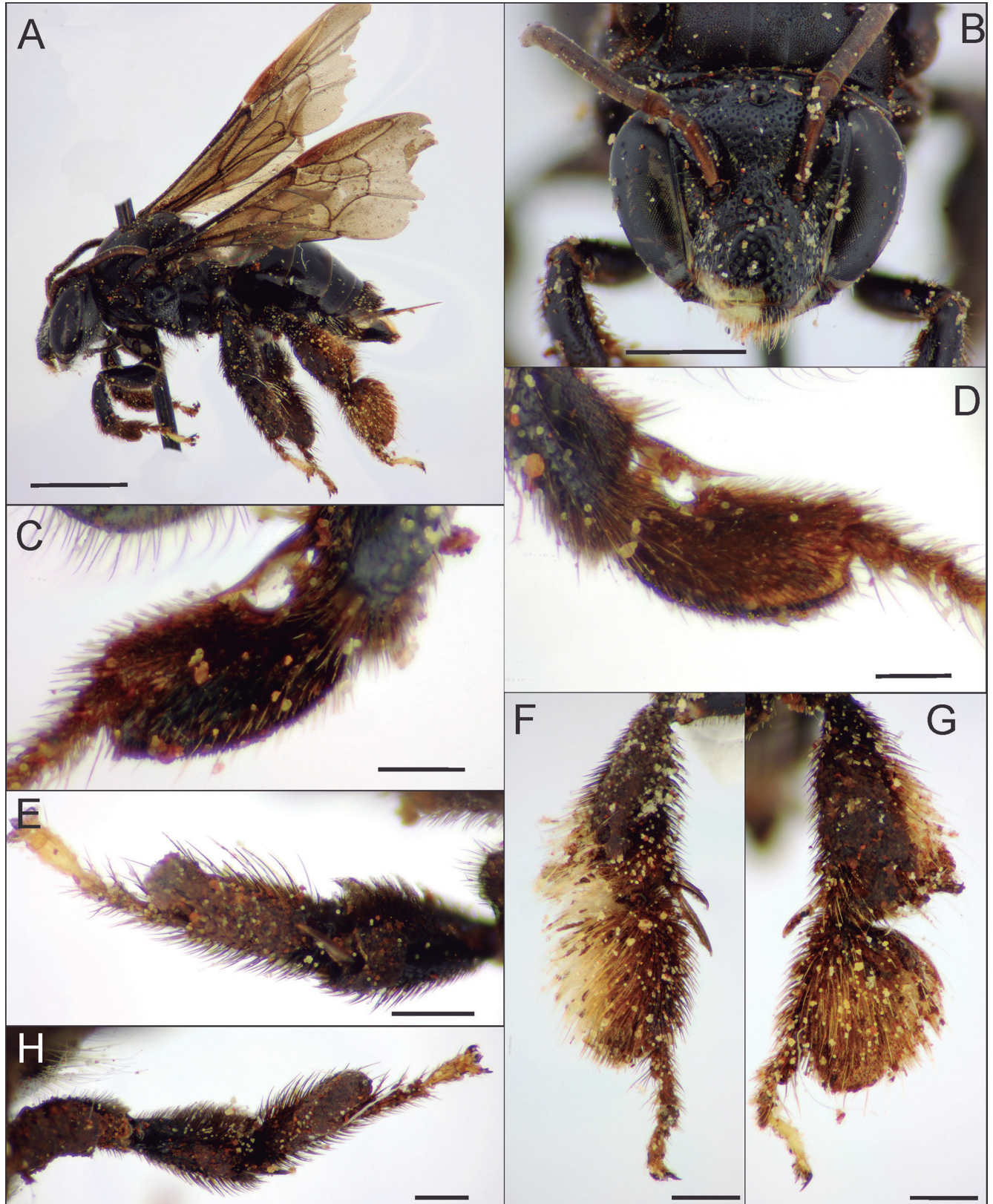


Figure 1. Gynandromorph of *Lophopedia nigripinis* (Vachal): (A) Habitus in lateral view. (B) Head in frontal view. (C) Foreleg right basitarsus in inner view. (D) Foreleg left basitarsus in inner view. (E) Left middle leg in inner view. (F) Right hind leg in external view. (G) Left hind leg in external view. (H) Right middle leg in inner view. Scale bars: (A) 2 mm. (B) 1 mm. (C) 0.25 mm. (D-H) 0.5 mm.

morphs described here have a mix of male and female features in head and mesosoma, and the metasoma is female like in both species, and thus it can be assigned to the mosaic category (see Michez *et al.*, 2009). The morphological differences of the legs on *L. nigrispinis* of the two sexes are not very clear because the males can also collect oil on flowers, however the males have a scopa on the hind leg not developed as females.

The specimen of *L. nigrispinis* was captured, along with numerous normal females and males, foraging on flowers of *Bidens* sp. at Parque Nacional Iguazú, Argentina in October 2016. Their foraging behaviour was normal and indistinguishable from the other females. The gynander carries pollen mixed with oil in all middle and hind legs. The gynander of *E. iheringii* has mostly a female phe-

notype, except the head, with structures for collecting and transport floral oils and pollen on legs. Despite the male phenotypes, it is suggested that both specimens are reproductively functional, due their well developed metasoma and oil and pollen collecting apparatus.

The causes of gynandromorphism in bees are unknown, but some hypotheses suggest that they may be result of problems in fertilization or related to genetic factors (Michez *et al.*, 2009; Narita *et al.*, 2010). Polyspermy in an egg is suggested as one of the causes of gynandromorphism, when a secondary spermatozoa do not degenerated and persist as a male tissue in an original female embryo (Aamidor *et al.*, 2018). However, it was reported also two spermatozoa fusing to form a diploid female ginandromorphy (Woyke, 1986). Studies

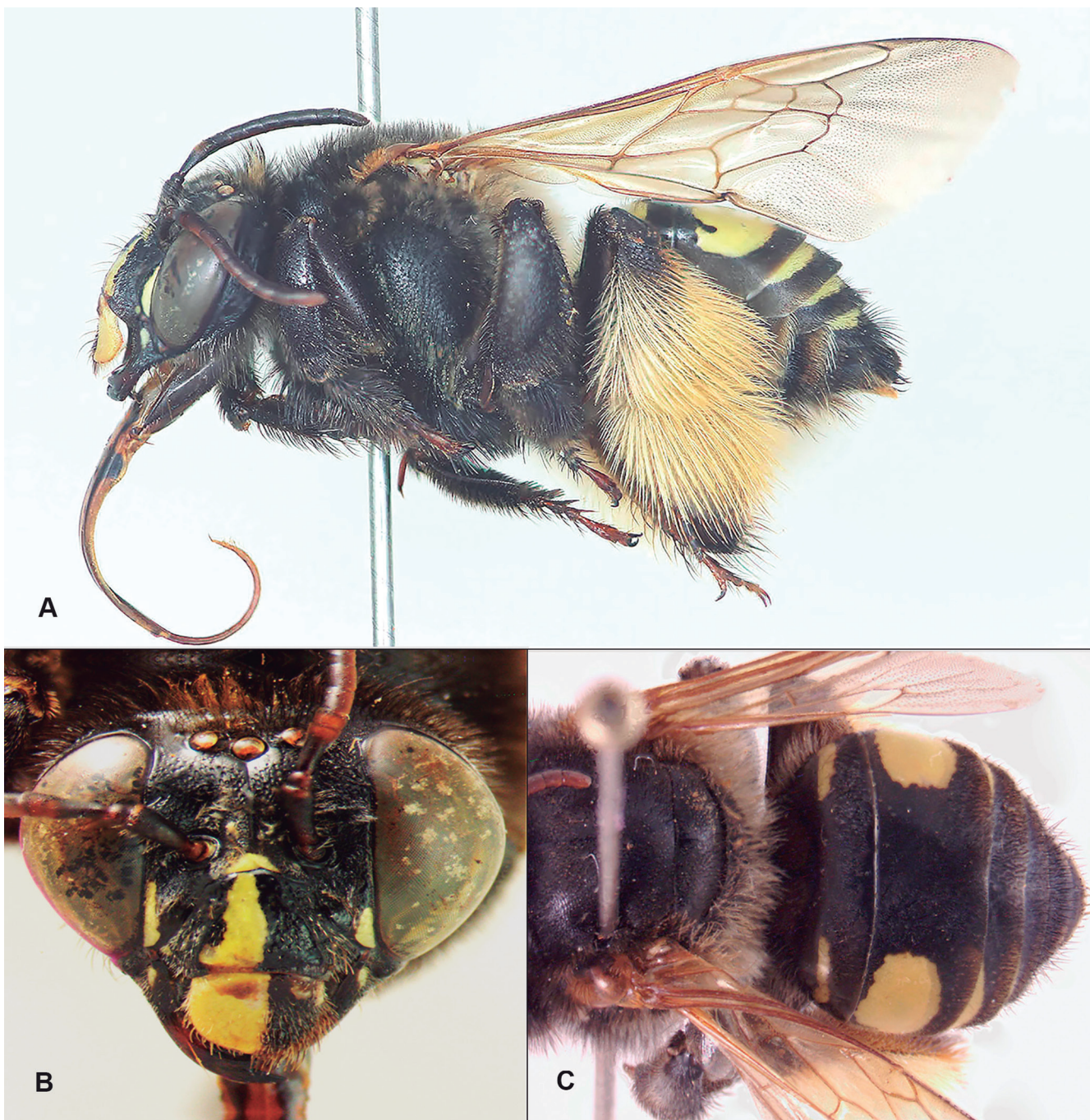


Figure 2. Gynandromorph of *Epicharis* (*Epicharitides*) *iheringii* Friese: (A) Habitus in lateral view. (B) Head in frontal view. (C) Metasoma in dorsal view.

with the objective of understanding the causes of gynandromorphism in bees are necessary for the greater understanding of this anomaly.

ACKNOWLEDGEMENTS

We would like to thank to Administración de Parques Nacionales (APN) for awarded permit (NEA344 project) and two anonymous reviewers for their helpful comments on the manuscript. Financial support to L.J.A. and M.L. was provided by the Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina (CONICET), and to A.J.C.A. provided by FAPDF, and W.P. Silva by CAPES.

REFERENCES

- Aamidor, S.E.; Yagound, B.; Ronai, I. & Oldroyd, B.P. 2018. Sex mosaics in the honeybee: how haplodiploidy makes possible the evolution of novel forms of reproduction in social Hymenoptera. *Biology Letters*, 14: 20180670.
- Aguar, A.J.C. 2009. Taxonomic revision of the bee genus *Lophopedia* Michener and Moure (Hymenoptera, Apidae, Tapinotaspidini). *Zootaxa*, 2193: 1-52.
- Almeida, R.P.S.; Leite, L.A.R. & Ramos, K.S. 2018. Two new records of Gynandromorphs in *Xylocopa* (Hymenoptera, Apidae s.l.). *Papéis Avulsos de Zoologia*, 58: e20185817. <http://www.revistas.usp.br/paz/article/view/137920>.
- Alvarez, L.J.; Lucia, M.; Ramello, P.J. & Abrahamovich, A.H. 2014. Description of two new cases of gynandromorphism in *Paratrigona* Schwarz and *Augochlora* Smith (Hymenoptera: Apidae and Halictidae). *Zootaxa*, 3889(3): 447-450.
- Cocucci, A.A.; Sérsic, A. & Roig-Alsina, A. 2000. Oil-collecting structures in Tapinotaspidini: their diversity, function and probable origin (Hymenoptera: Apidae). *Mitteilungen der Münchner Entomologischen Gesellschaft*, 90: 51-74.
- Coelho, I.R.; Zama, P.C. & Ferrari, R.R. 2016. First record of gynandromorphism in *Megachile* (*Pseudocentron*) *rubricata* Smith, 1853 (Hymenoptera: Megachilidae). *Pan-Pacific Entomologist*, 92(2): 104-107.
- Dantchenko, A.; Emmel, T.C. & Sourakov, A. 1995. Nuclear pollution and gynandromorphic butterflies in southern Russia. *Holarctic Lepidoptera*, 2: 77-79.
- Engel, M.S. 2007. A Lateral Gynandromorph in the Bee Genus *Thyreus* and the Sting Mechanism in the Melectini (Hymenoptera: Apidae). *American Museum Novitates*, 3553(1): 1-11.
- Friese, H. 1899. Neue arten der Bienengattungen *Epicharis* Klug und *Centris* Fabr. *Természetráji Füzetek*, 23: 39-48.
- Hinojosa-Díaz, I.A.; González, V.H.; Ayala, R.; Mérida, J.; Sagot, P. & Engel, M.S. 2012. New orchid and leaf-cutter bee gynandromorphs, with an updated review (Hymenoptera, Apoidea). *Zoosystematics and Evolution*, 88(2): 205-214.
- Le Féon, V.; Le Névé, A. & Dufrière, É. 2016. Premières mentions d'un cas de gynandromorphie chez *Nomada flava* Panzer, 1798 et *Nomada lathburiana* (Kirby, 1802) (Hymenoptera, Apoidea, Apidae). *Invertébrés Armoricains*, 14: 15-21.
- Lucia, M. & González, V.H. 2013. A new gynandromorph of *Xylocopa frontalis* with a review of gynandromorphism in *Xylocopa* (Hymenoptera: Apidae: Xylocopini). *Annals of the Entomological Society of America*, 106(6): 853-856.
- Maeno, K. & Tanaka, S. 2007. Morphological and behavioural characteristics of a gynandromorph of the desert locust, *Schistocerca gregaria*. *Physiological Entomology*, 32: 294-299.
- Matsuo, K.; Kubo, R.; Sasaki, T.; Ono, M.; Ugajin, A. 2018. Scientific note on interrupted sexual behavior to virgin queens and expression of male courtship-related gene *fruitless* in a gynandromorph of bumblebee, *Bombus ignitus*. *Apidologie*, 49: 411-414.
- Mertins, J.W. & Coppel, H.C. 1971. Sexual behavior in gynandromorphs of *Diprion similis* (Hymenoptera: Diprionidae). *Annals of the Entomological Society of America*, 64: 1191-1192.
- Michener, C.D. 2007. *The Bees of the world*. Baltimore, The John Hopkins University Press. 992p.
- Michez, D.; Rasmont, P.; Terzo, M. & Vereecken, N.J. 2009. A synthesis of gynandromorphism among wild bees (Hymenoptera: Apoidea), with an annotated description of several new cases. *Annales de la Société Entomologique de France*, 45(3): 365-375.
- Moure, J.S.; Melo, G.A.R. & Vivallo, F. 2007. Centridini. In: Moure, J.S.; Urban, D.; Melo, G.A.R. (Eds.). *Catalogue of Bees (Hymenoptera, Apoidea) in the Neotropical Region*. Curitiba, Sociedade Brasileira de Entomologia. p. 632-637.
- Narita, S.; Pereira, R.A.S.; Kjellberg, F. & Kageyama, D. 2010. Gynandromorphs and intersexes: potential to understand the mechanism of sex determination in arthropods. *Terrestrial Arthropod Reviews*, 3(1): 63-96.
- Neff, J.L. & Simpson, B.B. 1981. Oil-collecting structures in the Anthophoridae: Morphology, function and use in systematics. *Journal of the Kansas Entomological Society*, 54: 95-123.
- Nissani, M. 1977. Gynandromorph analysis of some aspects of sexual behaviour of *Drosophila melanogaster*. *Animal Behaviour*, 25(3): 555-566.
- Onuferko, T.M. 2018. A record of bilateral gynandromorphism in *Epeolus* (Hymenoptera: Apidae: Nomadinae). *Journal of Melittology*, 76: 1-6.
- Prashantha, C.; Lucia, M. & Belavadi, V.V. 2018. Two new cases of gynandromorphism in Xylocopinae bees (Hymenoptera: Apidae) from India. *Oriental Insects*, 53: 291-297, 2019. <https://www.tandfonline.com/doi/pdf/10.1080/00305316.2018.1508522>.
- Roig-Alsina, A. 1997. A generic study of the bees of the tribe Tapinotaspidini, with notes on the evolution of their oil-collecting structures (Hymenoptera, Apidae). *Mitteilungen der Münchner Entomologischen Gesellschaft*, 302: 3-21.
- Sampson, B.J.; Kirker, G.T.; Werle, C.T. 2010. Morphology, courtship and mating of a mixed bilateral gynander of *Osmia ribifloris biedermannii* Michener (Hymenoptera: Megachilidae). *Journal of the Kansas Entomological Society*, 83(4): 347-351.
- Torretta, J.P. & Roig-Alsina, A.H. 2017. Las abejas colectoras de aceite del género *Paratetrapedia* (Hymenoptera, Apidae, Tapinotaspidini) en la Argentina. *Revista del Museo Argentino de Ciencias Naturales, Nueva serie*, 19(2): 131-140.
- Ugajin, A.; Matsuo, K.; Kubo, R.; Sasaki, T. & Ono, M. 2016. Expression profile of the sex determination gene double sex in a gynandromorph of bumblebee, *Bombus ignitus*. *The Science of Nature*, 103: 17.
- Urban, D. 1999. Ginandromorfia em *Alloscirtetica brethesi* (Joergensen) (Hymenoptera, Anthophoridae). *Revista Brasileira de Zoologia*, 16: 171-173.
- Vachal, J. 1909. Espèces nouvelles ou litigieuses d'Apidae du haut bassin du Parana et des régions contiguës et délimitation d' une nouvelle sous-famille Diphaglossinae (Hym.). *Revue d'Entomologie Caen*, 28: 221-244.
- Wcislo, W.T.; González, V.H. & Arneson, L. 2004. A review of deviant phenotypes in bees in relation to brood parasitism, and a gynandromorph of *Megalopta genalis* (Hymenoptera: Halictidae). *Journal of Natural History*, 38(11): 1443-1457.
- Woyke, J. 1986. Sex determination. In: Rinderer, T.E. (Ed.). *Bee genetics and breeding*. Orlando, San Diego, Academic Press. p. 91-119.