NEW CASES OF GYANANDROMORPHISM IN XYLOCOPA LATREILLE, 1802 (HYMENOPTERA: APIDAE)

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ABSTRACT

Gynandromorphism is the most common case of sexual anomaly reported in bees and is characterized by individuals that show male and female traits simultaneously in the body. Gynandromorphic cases have been reported for 140 species of bees, an underestimated number comparing to the twenty thousand bee species described nowadays. Here we describe and illustrate the first case of a gynandromorphic Xylocopa darwini Cockerell, 1926 and the fourth case of Xylocopa varipuncta Patton, 1879. The specimens show a mixed form of gynandromorphism with predominantly female features and with all its male traits concentrated in one side of the body, right side in X. darwini and left side in X. varipuncta. The gynanders of X. darwini and X. varipuncta were collected on Isabela Island (Galapagos – Ecuador) and Riverside (California – USA), and were deposited in Smithsonian Collection and California Academy of Sciences, respectively. Including this work, eighteen cases of gynandromorphism were reported to Xylocopa and twelve were recorded from Neoxylocopa subgenus.

Key-Words: Carpenter bee; Gynandromorphy; Neoxylocopa; New World; Xylocopini.

INTRODUCTION

Sexual anomalies were first reported for bees in 1857, when Sichel described a gynandromorphic form of Bombus lapidarius (Linnaeus, 1758) (Wcislo et al., 2004; Michez et al., 2009; Silveira et al., 2012). Gynandromorphs are individuals that have male and female traits simultaneously in the body, and the causes of this anomaly are discussed in relation to problems in fertilization, chromosome damages or loss, and association with symbionts and parasites (Wcislo et al., 2004; Michez et al., 2009; Narita et al., 2010; Camargo & Gonçalves, 2013; Ugajin et al., 2016).

Two types of classification are in use to distinguish the distribution of the gynandromorphic features in the body (Wcislo et al., 2004; Michez et al., 2009; Narita et al., 2010). The oldest classification was proposed by Dalla Torre & Friese (1899), who considered four types of gynandromorphs in nature: mixed, lateral, transverse and antero-posterior (Wcislo et al., 2004; Gonzalez, 2004; Lucia et al., 2009; Silveira et al., 2012; Camargo & Gonçalves, 2013; Lucia & Gonzalez, 2013; Alvarez et al., 2014; Coelho et al., 2010; Camargo & Gonçalves, 2013; Ugajin et al., 2016).

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More recently, only three categories started to be used by some mellitologists: bilateral, transverse and mosaic (Michez et al., 2009; Giangarelli & Sofia, 2011; Vivallo, 2015; Ugajin et al., 2016).

To date, gynandromorphism has been reported for approximately 140 species of bees in 35 genera (Wcislo et al., 2004; Michez et al., 2009; Fateryga et al., 2011; Hinojosa-Díaz et al., 2012; Lucia et al., 2012; Silveira et al., 2012; Camargo & Gonçalves, 2013; Lucia & Gonzalez, 2013; Alvarez et al., 2014; Lucia et al., 2015; Suzuki et al., 2015; Vivallo, 2015; Coelho et al., 2016). These are representatives of six families but especially Megachilidae (Wcislo et al., 2004; Michez et al., 2009; Hinojosa-Díaz et al., 2012; Lucia & Gonzalez, 2013; Alvarez et al., 2014; Coelho et al., 2016). In Apidae, most cases were recorded in Bombus Latreille, 1802 and Xylocopa Latreille, 1802, among the largest bees in the family (Michener, 2007; Michez et al., 2009). Lucia & Gonzalez (2013) provided a revision of gynandromorphism in the carpenter bees genus Xylocopa. They listed 14 records of gynandromorphs from 12 species in five subgenera of Xylocopa, three of them from the Old World and two from the New World. Recently, two new cases of gynanders were described, the second case for Xylocopa frontalis (Olivier, 1789) (Vivallo, 2015) and the first case for Xylocopa augusti Lepeletier, 1841 (Lucia et al., 2015). In short, ten of the 16 cases of Xylocopa gynandromorphs belong to species of Neoxylocopa, a neotropical subgenus that shows an evident sexual dimorphism in its representatives, males being yellowish to ferruginous and females blackish to dark brownish (Silveira et al., 2002; Michener, 2007).

Here we described and illustrated the first case of a gynandromorphic Xylocopa darwini Cockerell, 1926, an endemic bee and the most important pollinator species of the Galapagos Islands (Jaramillo et al., 2010; Chamorro et al., 2012; Ascher & Pickering, 2014; Vargas et al., 2015); and the fourth case of Xylocopa varipuncta Patton, 1879, one of the few number of large carpenter bees recorded from Mexico and United States (Moure, 2012; Ascher & Pickering, 2014).

**RESULTS**

**Xylocopa (Neoxylocopa) darwini**

*Cockerell, 1926 (Fig. 1)*

**Description** (Fig. 1A-D): Body length 22.1, head length 5.0, head width 7.0, mesosoma width 5.5, metasoma width 9.2; right forewing length 19.8; left forewing length 20.3. **Head** (Fig. 1B): entirely female-like. **Mesosoma** (Fig. 1A,C,D): female-like on the left side, with some male traits on right side. Integument predominantly black with black, plumose and long pubescence as in normal females; mesoscutum integument black with yellow hairs on right lateral margin; scutellum on right side brownish to ferruginous with yellow hairs; metanotum black as in females; propodeum vertical and black in females but propodeal triangle brownish red, smooth and shiny on right side, black, sculptured and dull on left side; right lateral of mesosoma, behind insertion of foreleg, dark, covered by yellow, plumose and long hairs as in normal males; in ventral view, right

**MATERIAL AND METHODS**

The bees were found in dry preservation in the entomological collections of Smithsonian and California Academy of Sciences. The external morphology of *X. darwini* was studied using a Zeiss Ste-mi SV8 stereomicroscope and the pictures were taken with a Canon EOS-60D camera attached to a Mi-
side behind foreleg, mostly male-like with black integument covered by yellow, plumose and very long hairs, but triangular area with sparse, simple, black hairs on middle of mesepisternum, before middle leg; legs on left side and foreleg on right side, female-like; middle right leg male-like; hind right leg with black trochanter and femur as in males, trochanter almost glabrous, shining on inner surface, with expanded apical margin; femur inner surface with tuft of yellow hairs on middle of very strong depression; hind right tibia and basitarsus female-like on outer surface, with black integument and black hairs, male-like on inner surface, with ferruginous integument and yellow hairs; inner surface of tibia with irregular margin as in normal male; remaining tarsomeres and claws on right hind leg missing; right tegula ferruginous, humeral plate almost white, as in males; right forewing male-like, remaining three wings female-like.

Metasoma (Fig. 1A,C,D): mostly female-like with male traits on right side. Six exposed terga and sternae as in female; terga asymmetric, left side longer than right side, left halves more round, right halves more straight; left side of tergites female-like, right side mixed but predominantly male-like: integument of T1 and T2 predominantly black with asymmetric ferruginous areas covered by dense, yellow hairs on right side; T1 fringes black as in females; T2 fringes yellow as in males; right side of T3 more related to males than T1 and T2, almost ferruginous covered by yellow, simple and long hairs; integument of T4 ferruginous covered by yellow hairs, except for its right lateral with black integument and small ferruginous area, hair fringe with mixture of long, yellow, simple hairs and very long, black, simple and branched hairs; integument of T5 dorsally ferruginous basally and darker apically, completely black on right lateral with dense fringe formed by long, simple and plumose, black hairs; left side of T6 female-like with half of pygidial plate and right side male-like with completely ferruginous integument covered by very long, yellow and ferruginous, simple and plumose hairs; right side of T6, with slightly emarginate apical margin medially; metasomal sterna female-like but very asymmetric in shape; integument black to dark-brown, reddish on apical margins, covered by black and simple hairs; all segments with conspicuous mid-longitudinal carina, typical of female X. (Neoxylocopa); male features of sterna only noticeable in S2, as irregular ferruginous areas and some yellow hairs on right lateral margin.

Terminalia: female sting apparatus; sting apparatus

FIGURE 1: Gynandromorph of Xylocopa (Neoxylocopa) darwini Cockerell, 1926: (A) Dorsal habitus; (B) Head in frontal view; (C) Right lateral habitus; (D) Left lateral habitus. Scale bars = 1 mm. (Photos: Hadel Go).
much similar to that of normal *X. darwini* female without recognizable male structure, just the plate corresponding to S7 on right side differs from that on left side.

**Examined material:** one gynandromorph, one male and three females collected in May 9th, 1964 by D.Q. Cavagnaro on North Coast of Isabella Island, Galapagos, Ecuador. The bees are deposited in the Smithsonian Collection – Washington DC, USA.

*Xylocopa (Neoxylocopa) varipuncta* Patton, 1879 (Fig. 2)

**Description** (Fig. 2A-D): Body length 23.1; head length 4.5; head width 6.6; mesosoma width 5.9; metasoma width 10; right forewing length 20.6; left forewing length 20.4. **Head** (Fig. 2B): mixed, female-like on right and male on left side, except for some mixed characters on left side of galea and mandible, one black area and hairs on left paraocular area and frons. **Mesosoma** (Fig. 2A,C,D): predominantly female with some male traits; one vertical line of ferruginous integument with yellow hairs on left middle of mesoscutum; sparse yellow hairs on left margin of mesoscutum; ferruginous integument and yellow hairs on left apical margin of scutellum, left middle part of metanotum, left basal half of pronotum; some yellow hairs on lateral and left ventral surface of mesepisternum; left anterior leg with mixed femur, male tibia and tarsal segments; left middle leg predominantly female-like with some yellow integument and hairs on ventral surface of femur, tibia and tarsal segments; left hind leg with tufts of short yellow hairs on ventral surface of tarsal segments 3-5 and claws; left tegula predominantly ferruginous with some black areas on lateral and posterior margins; some yellow hairs on basal outer margin of anterior left wing; forewings predominantly female-like but left slightly short than right. **Metasoma** (Fig. 2C-D): predominantly female-like with few features of male on left side; T1 left half male-like except for some black integument and hairs laterally; T2 and T3 female-like with some sparse ferruginous areas covered by yellow hairs; T6 with ferruginous integument and yellow hairs on middle half of left side, pygidial plate just on right side; left side of S2 with a big yellowish white area on middle part. **Terminalia:** female sting apparatus.

**FIGURE 2:** Gynandromorph of *Xylocopa (Neoxylocopa) varipuncta* Patton, 1879: (A) Dorsal habitus; (B) Head in frontal view; (C) Right lateral habitus; (D) Left lateral habitus. Scale bars = 1 mm. (Photos: Paula C. Zama).
Examin ed material: one gynandromorph, two males and two females collected in August, 1929 by L. Peirce Coy on Riverside, California, USA. The bees are deposited in the Entomological Collection of California Academy of Sciences – San Francisco, CA, USA.

DISCUSSION

New cases of gynandromorphism in bees have been reported since the beginning of the last century (Wcislo et al., 2004; Michez et al., 2009; Hinojosa-Díaz et al., 2012). In despite of this, the number of gynandromorphs for bees is still around 180 specimens (Wcislo et al., 2004; Michez et al., 2009; Fateryga et al., 2011; Hinojosa-Díaz et al., 2012; Lucia et al., 2012; Silveira et al., 2012; Camargo & Gonzàlves, 2013; Lucia & Gonzalez, 2013; Alvarez et al., 2014; Lucia et al., 2015; Suzuki et al., 2015; Vivallo, 2015; Coelho et al., 2016; Ugajin et al., 2016), an underestimated number comparing to total number of described bee species nowadays, something around 20.000 (Danforth et al., 2013). As the majority of the records, gynanders of X. darwini and X. varipuncta were found in the museums collections, in dry preservation, and the descriptions were based only in external morphology (Bonnet, 1952; Carcasson, 1965; Lucia et al., 2009; Lucia et al., 2012; Camargo & Gonzàlves, 2013; Lucia & Gonzalez, 2013; Alvarez et al., 2014; Lucia et al., 2015; Vivallo, 2015; Coelho et al., 2016). Just a few observations about biology and behavior of gynandromorphic forms have been made (Gordh & Gulmahamad, 1975; Wcislo et al., 2004; Michez et al., 2009; Giangarelli & Sofia, 2011; Hinojosa-Díaz et al., 2012; Silveira et al., 2012; Ugajin et al., 2016).

The majority of the bees show some level of sexual dimorphism and in some bees, like X. (Neoxylocopa), they show very evident dimorphic characteristics (Silveira et al., 2002; Michener 2007). The difference of color on integument and pilosity of males and females of X. (Neoxylocopa) is probably the more easily perceivable character to diagnose gynandromorphic cases. The specimens herein described increase the cases of gynandromorphism to 18 in the genus and to 12 in the subgenus, with 14 different species in Xylocopa and eight in X. (Neoxylocopa).

Both gynandromorphic bees described here are predominantly-female and have male traits concentrated in one side of their body. Taking this into consideration, they can be treated as partially bilateral, except for female head in X. darwini and for intermingled characteristics of both sexes in the right side in X. darwini and left side in X. varipuncta. As in many other gynandromorphic bees mentioned in the literature, the distribution of opposite sexual characters is not completely symmetrical (Wcislo et al., 2004; Michez et al., 2009; Hinojosa-Díaz et al., 2012; Lucia & Gonzalez, 2013).

The asymmetry of the features and the use of two classifications can take the definition of the categories of gynandromorphy controversial. According to Dalla Torre & Friese (1899), the cases described here can be classified as lateral gynanders, considering the fact that all male features are concentrated just in one side of the body. But, according to Michez et al. (2009), recognizing the asymmetrical features of males, the gynandromorphic forms of Xylocopa can be allocated in mosaic/mixed category. Comparing just Xylocopa records of gynandromorphy, controversial classifications can be found for three other cases: Xylocopa (Koptortosoma) nigrita (Fabricius, 1775) – gynander described by Carcasson (1965); Xylocopa (Neoxylocopa) mendozana Enderlein, 1913 – gynander by Enderlein (1913); and Xylocopa (Schonnerhria) micans Lepeltier, 1841 – described by Maidl (1912). Xylocopa nigrita and X. micans were classified as bilateral using the old classification of Dalla Torre & Friese (1899) (Maidl, 1912; Carcasson, 1965; Wcislo et al., 2004; Lucia & Gonzalez, 2013), and as transverse using Michez et al. (2009). Xylocopa mendozana is classified as mixed with the oldest classification and as bilateral with the newer (Wcislo et al., 2004; Michez et al., 2009; Lucia & Gonzalez, 2013). The case of X. micans seems more controversial, Maidl (1912) affirms that its head is female-like on the left and male-like on the right side, but inverted on the mesosoma and metasoma. Actually it seems to be a mixed/mosaic-kind of gynandromorph, since it has a heterogeneous distribution of traits in different parts of the body, and not bilateral or transverse as diagnosed in the previous works.

Besides the lack of consensus among the categories of gynandromorphs, other problems can bring some discussion. The high concentration of the gynandromorphic cases in the bees with Holartic distribution seem to be more related to the lack of information in other regions than with a genetic problem with these lineages (Wcislo et al., 2004; Michez et al., 2009; Hinojosa-Díaz et al., 2012; Lucia & Gonzalez, 2013; Suzuki et al., 2015). The same apparently to be happening with the great number of gynandromorphs occurring in some genera, as Megachile and Andrena. Probably, the cause is more related to a sampling artifact (Wcislo et al., 2004; Michez et al., 2009; Hinojo-sa-Díaz et al., 2012; Lucia & Gonzalez, 2013; Suzuki et al., 2015).
et al., 2015). Despite these misunderstandings and the fact the gynandromorphism is currently recorded in almost all bee families (Wcislo et al., 2004; Michez et al., 2009; Hinojosa-Díaz et al., 2012), further studies about gynandromorphy are needed. Works including morphology, behavior, ontogenetic or causes of gynandromorphy could be very important to increase the knowledge and the discussion about sexual anomalies, especially in insect.

RESUMO

Ginandromorfismo é o caso mais comum de anomalia sexual registrado para abelhas e destaca-se por indivíduos que apresentam características simultâneas de machos e de fêmeas no corpo. Casos de ginandromorfos foram registrados para aproximadamente 140 espécies de abelhas, um número subestimado comparado às vinte mil espécies de abelhas descritas atualmente. No presente trabalho, o primeiro registro de ginandromorfismo para Xylocopa darwini Cockerell, 1926 e o quarto caso para Xylocopa varipuncta Patton, 1879 são descritos e ilustrados. Os espécimes apresentam a forma mista de ginandromorfo com características de fêmeas predominantes e as de machos concentradas em uma lateral do corpo, lado direito em X. darwini e esquerdo em X. varipuncta. Os ginandromorfos de X. darwini and X. varipuncta foram coletados na Ilha Isabela (Galápagos – Ecuador) e em Riverside (California – USA), e estavam depositados nas coleções entomológicas do Smithsonian e da Academia de Ciências da Califórnia, respectivamente. Incluindo as abelhas do presente trabalho, dezoito casos de ginandromorfismo estão registrados para abelhas do gênero Xylocopa e doze para o subgênero Neoxylocopa.

PALAVRAS-CHAVE: Abelhas carpinteiras; Ginandromorfismo; Neoxylocopa; Novo Mundo; Xylocopini.

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