

ALICE CASIRAGHI^{a,b} - VÍCTOR MORENO-GONZÁLEZ^c - NICOLÁS PÉREZ HIDALGO^{a,d}DESCRIPTION OF SEXUALES OF *BRACHYCOLUS CUCUBALI* (PASSERINI, 1863)
(HEMIPTERA APHIDIDAE)

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Casiraghi A., Moreno-González V., Pérez Hidalgo, N. – Description of sexuales of *Brachycolus cucubali* (Passerini 1863) [Hemiptera Aphididae].

The hitherto unknown oviparous females and apterous males of *Brachycolus cucubali* (Passerini, 1863), living in pseudogalls on *Silene vulgaris* (Moench) Garcke, (1869) (Caryophyllaceae), are described based on material from the North-West of Iberian Peninsula (Province of León). Sampling and morphometric data are given for every morph. Also, field data of monitored *Brachycolus cucubali* colonies are reported and information of polyphenism in males is discussed.

KEY WORDS: Aphids, morphology, sexual dimorphism, polyphenism

INTRODUCTION

The majority of the 5,500 known species of aphids (FAVRET, 2020; BLACKMAN and EASTOP, 2020) has been described from the most abundant or easier-to-localize morphs: apterous and winged viviparous females. On one side, they are the most frequent morphs within colonies during the year, and on the other aphidologists have always accomplished samplings in months with good weather, when other morphs are not so abundant (SMITH and MACKAY, 1989).

Therefore, in holocyclic species (with sexual morphs), monoecious as well as dioecious, fundatrices and sexuales appear in precise moments of the year (NIETO NAFRÍA and MIER DURANTE, 1998). The first normally hatch at the end of winter or at the beginning of spring, while the latter, with known exceptions (for example: many species of Fordini tribe, *Aphis farinosa farinosa* Gmelin, 1790 or *Mindarus abietinus* Koch, 1857, with sexuales in summer), appear in autumn when environmental conditions start to be adverse (HARDIE, 2017).

Aphid polyphenism is one of the most complicated types in nature (OGAWA and MIURA, 2014) and due to that, some morphs of many species have not been detected yet. Generally, it happens precisely with fundatrices and sexuales (e.g. WOOD-BAKER, 1958; CARTER and AUSTARÁ, 1994; WOOD-BAKER and HOPKINS, 2000; BUGA and STEKOLSHCHIKOV, 2006), even from common species, such as *Aphis verbasci* Schrank, 1801 (KANTURSKI *et al.*,

2014), or with the species of this work, *Brachycolus cucubali* (Passerini, 1863) (BLACKMAN and EASTOP, 2020). Knowing the sexuales is important to solve taxonomic problems, as in the case of *Shenahewum minutum* (Davis, 1910) (WIECZOREK *et al.*, 2013)

Brachycolus is an aphid genus from the Macrosiphini tribe (Hemiptera: Aphididae: Aphidinae) that includes only four ascertained species, and one doubtful (FAVRET, 2020; BLACKMAN and EASTOP, 2020). The genus is characterized by very short, asymmetrical, flangeless siphunculi and triangular cauda and body covered with wax (BLACKMAN, 2010). Representatives of this genus are for the malformations on its host plants (Caryophyllaceae) and shows a Holarctic distribution with four or five species, but some of them could belong to the *Semiaphis* van der Goot, 1913 genus (BLACKMAN and EASTOP, 2020). Six species are distributed in the Palearctic region and one species in the Nearctic area (Canada) (HEIE, 1992; BLACKMAN and EASTOP, 2020; FAVRET, 2020). Of the six Palearctic species, three are recorded in Europe: *Brachycolus cerastii* (Kaltenbach, 1846), *Brachycolus stellariae* (Hardy, 1850) and *B. cucubali* (HOLMAN, 2009; NIETO NAFRÍA *et al.*, 2011; BLACKMAN and EASTOP, 2020; FAVRET, 2020). The genus is considered monoecious and holocyclic, but only the oviparae and males of *B. stellariae* are known, being the sexual morphs of *B. cerastii* and *B. cucubali* apparently undescribed (BLACKMAN and EASTOP, 2020).

Brachycolus cucubali is a widespread species in Europe,

associated with *Silene* genus and mainly with *Silene vulgaris* (Moench) Garcke, (1869) (HOLMAN, 2009; BLACKMAN and EASTOP, 2020). Representatives of this species produce stems shortening and live inside the flowers, developing malformations and pseudogalls (Fig. I). In Kazakhstan, it has been recorded even on *Cerastium davuricum* Fisch. ex Spreng, 1815 and *C. tianschanicum* Schischk, 1936 by KADYRBEKOV (2017). It has also been recorded on *Saponaria officinalis* L., 1753, however, all these records need to be confirmed.

In this article, we describe the sexual morphs of *B. cucubali*, found in the North of the Iberian Peninsula on *S. vulgaris*.



Fig. I - Malformations produced by *Brachycolus cucubali* on *Silene vulgaris*.

MATERIALS AND METHODS

Several colonies of *B. cucubali* have been followed over *S. vulgaris* during the years 2017-2019. The colonies were located in a green area on the left bank of the Bernesga river, along its path in the city of León (coordinates 42°36'18.9"N 5°35'09.8"W). The colony with sexuales was collected on 22.X.2017 (sample reference 1302) and the aphids are deposited in the aphidological collec-

tion of the Institute for Integrative Systems Biology (University of Valencia-CSIC).

The individuals fixed in 70% ethanol have been used to mount microscope slides following the methodology exposed by NIETO NAFRÍA and MIER DURANTE (1998). Specific-level identification was carried out using quantitative and qualitative characters, following the identification keys of HEIE (1992) and BLACKMAN and EASTOP (2020). The microphotographs were taken with a Leica DC digital camera with IM 1000 version 1.10 software.

The following abbreviations of morphological characters are used in the table: ABD TERG, abdominal tergite; ANT, antenna; ANT I, ANT II, ANT III, ANT IV, ANT V, ANT VI, ANT VI b, antennal segments I, II, III, IV, V, VI, and the base of antennal segment VI, respectively; ANT III BD, basal diameter of antennal segment III; BL, length of body; C, cauda; D, basal diameter of antennal segment III; G PL, genital plate; HFEM, hind femur; HTIB, hind tibia; HT II, second segment of hind tarsus; L: length; n, number of specimens; PT, processus terminalis; R, rostrum; SEC RHIN, secondary rhinaria; SC PL, scent plaques; SIPH, siphunculus; THR, the ratio between the length of posterior seta on the hind trochanter and trochanteric-femoral suture; URS, ultimate rostral segments IV and V together; W, width.

RESULTS

HEIE (1992) and BLACKMAN (2010) give a good description of the apterae and alatae viviparous females of *B. cucubali*, which we have completed with the morphometric data of the specimens studied in this work. Nevertheless, they give no description of the fundatrix of this species and we never have found one in the colonies we have followed, probably because the percentage of fundatrices vs. apterous viviparous females is lower during spring.

APTEROUS VIVIPARAE - 50 specimens studied, 10 measured, Table 1, Fig. II, 1) have a yellowish to pale green colour in life and are covered with whitish powdery wax; head, legs, siphunculi and cauda dark; abdomen with a dark crossbars on tergites VII and VIII. They measure 1.30 to 2.20 mm and the hairs are short and pointed. The antennae are 0.40-0.52 times the body; the processus terminalis is 1.29-2.30 times the basal part of the last antennal segment and the longest hair on segment III about 0.38-0.83 times its articular diameter of the same article (*D*). The rostrum (0.27-0.31 mm) reaching to middle coxae and its apical segment have 2-4 accessory hairs and is 1.68-2.00 times its basal width and 0.68-0.79 times the second segment of the hind tarsus. Siphunculi are barrel-shaped, wrinkled, scaly and without a well-developed flange; they measure 0.03-0.04 times the body, 0.37-0.50 times the cauda, and 1.5-2.0 times as long as broad. The cauda is oblong triangular, obtuse, and it is 1.1-1.6 times as long as broad and has 6 to 8 hairs.

Table 1 - Morphological features of apterous and alatae viviparous females, oviparous females and males of *Brachycolus cucubali*. n = 10 in each morph.

	Apterous viviparous female	Oviparous female	Male	Alatae viviparous female
Metric characters (mm)				
BL	1.56 (1.30-1.70)	1.57 (1.40-1.83)	1.08 (1.00-1.20)	1.52 (1.43-1.68)
ANT	0.74 (0.63-0.89)	0.67 (0.61-0.75)	0.83 (0.78-0.86)	1.05 (1.00-1.20)
ANT I	0.06 (0.06-0.06)	0.05 (0.05-0.06)	0.05 (0.05-0.06)	0.06 (0.06-0.07)
ANT II	0.06 (0.06-0.06)	0.05 (0.05-0.06)	0.05 (0.05-0.06)	0.06 (0.06-0.07)
ANT III	0.32 (0.20-0.44)	0.22 (0.17-0.34)	0.36 (0.22-0.48)	0.35 (0.30-0.40)
ANT IV	0.12 (0.08-0.15)	0.09 (0.06-0.14)	0.17 (0.11-0.23)	0.15 (0.13-0.19)
ANT V	0.14 (0.10-0.20)	0.10 (0.08-0.17)	0.19 (0.11-0.25)	0.16 (0.12-0.20)
ANT V b	0.13 (0.09-0.18)	0.09 (0.06-0.16)	0.14 (0.09-0.18)	0.13 (0.11-0.18)
PT	0.25 (0.16-0.35)	0.17 (0.13-0.28)	0.32 (0.20-0.41)	0.30 (0.27-0.34)
D	0.02 (0.01-0.02)	0.02 (0.01-0.02)	0.02 (0.01-0.02)	0.02 (0.01-0.02)
HFEM	0.15 (0.12-0.19)	0.15 (0.13-0.25)	0.14 (0.13-0.15)	0.21 (0.18-0.25)
HTIB (length)	0.25 (0.20-0.30)	0.22 (0.21-0.24)	0.23 (0.22-0.25)	0.39 (0.33-0.48)
HTIB (diameter in the middle)	0.03 (0.03-0.04)	0.04 (0.03-0.05)	0.02 (0.02-0.03)	0.03 (0.03-0.04)
R	0.29 (0.27-0.31)	0.27 (0.22-0.30)	0.24 (0.22-0.26)	0.30 (0.29-0.32)
URS (length)	0.08 (0.08-0.09)	0.08 (0.08-0.09)	0.08 (0.07-0.08)	0.09 (0.08-0.09)
URS (basal width)	0.05 (0.04-0.05)	0.04 (0.04-0.05)	0.05 (0.04-0.05)	0.05 (0.04-0.05)
HT II	0.12 (0.11-0.13)	0.11 (0.10-0.12)	0.11 (0.10-0.11)	0.13 (0.12-0.14)
SIPH (length)	0.05 (0.05-0.07)	0.05 (0.05-0.06)	0.04 (0.03-0.04)	0.05 (0.04-0.05)
SIPH (basal width)	0.04 (0.04-0.05)	0.04 (0.03-0.05)	0.03 (0.03-0.04)	0.03 (0.03-0.04)
SIPH (apical width)	0.02 (0.02-0.03)	0.02 (0.02-0.03)	0.02 (0.02-0.02)	0.02 (0.02-0.02)
C (length)	0.13 (0.11-0.14)	0.11 (0.11-0.12)	0.09 (0.08-0.10)	0.12 (0.11-0.13)
C (basal width)	0.10 (0.08-0.12)	0.10 (0.08-0.11)	0.08 (0.08-0.09)	0.11 (0.10-0.12)
HAIRS on (length):				
FRONT	0.02 (0.02-0.02)	0.02 (0.01-0.03)	0.02 (0.01-0.02)	0.02 (0.01-0.02)
URS	0.69 (0.45-0.99)	0.69 (0.63-0.81)	0.66 (0.63-0.72)	0.81 (0.79-0.83)
ANT III	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.01 (0.01-0.01)
ABD TERG III (spinal)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.01 (0.01-0.01)
ABD TERG VIII	0.02 (0.02-0.03)	0.03 (0.02-0.04)	0.02 (0.02-0.03)	0.02 (0.02-0.03)
Meristic characters (number)				
SEC RHIN ANT III	-	-	15.06 (9-21)	9.75 (9-12)
SEC RHIN ANT IV	-	-	7.87 (6-10)	0.25 (0-1)
SEC RHIN on ANT V	-	-	10.25 (8-13)	-
SEC RHIN VI	-	-	2.75 (2-4)	-
SC PL	-	12.50 (6-24)	-	-
HAIRS on (number):				
URS	3.14 (2-4)	3.14 (2-4)	2.86 (2-4)	3.50 (3-4)
C	6.70 (6-8)	9.55 (7-11)	5.75 (5-7)	6.50 (6-7)
ABD TERG VIII	5.90 (5-7)	19.82 (13-24)	5.38 (4-8)	4.50 (4-5)
G PL (anterior)	9.30 (7-13)	16.55 (13-21)	-	9.50 (8-11)
G PL (posterior)	13.20 (11-15)	17.82 (13-20)	-	10 (12-14)
Ratios				
ANT / BL	0.47 (0.40-0.52)	0.43 (0.36-0.47)	0.78 (0.75-0.90)	0.71 (0.68-1.01)
HFEM / BL	0.10 (0.08-0.11)	0.10 (0.08-0.18)	0.13 (0.12-0.14)	0.14 (0.12-0.15)
HTIB / BL	0.16 (0.13-0.18)	0.14 (0.13-0.15)	0.23 (0.22-0.25)	0.26 (0.12-0.28)
ANT III / ANT IV	2.64 (2.36-3.11)	2.64 (2.19-3.36)	2.07 (1.96-2.14)	2.26 (2.16-2.36)
ANT III / ANT V	2.24 (1.9-2.64)	2.16 (1.88-2.76)	1.87 (1.69-2.14)	2.19 (2.12-2.46)
ANT III / PT	2.49 (1.90-3.22)	2.57 (2.00-4.00)	2.67 (2.44-2.88)	2.66 (2.22-2.96)
ANT III / PT	1.31 (1.12-1.98)	1.32 (1.11-1.62)	1.13 (1.08-1.23)	1.14 (1.09-1.19)
PT / ANT VI b	1.92 (1.41-2.21)	1.94 (1.65-2.91)	2.35 (2.23-2.53)	2.35 (1.86-2.61)
URS (L) / URS (W)	1.83 (1.68-2.00)	1.90 (1.68-2.21)	1.65 (1.47-1.82)	1.92 (1.84-2.07)
URS (L) / HT II	0.72 (0.68-0.79)	0.73 (0.69-0.76)	0.71 (0.64-0.74)	0.67 (0.62-0.71)
HAIR ANT III (l) / D	0.57 (0.38-0.83)	0.55 (0.43-0.67)	0.59 (0.50-0.67)	0.58 (0.50-0.67)
R / BL	0.19 (0.17-0.21)	0.17 (0.15-0.19)	0.23 (0.21-0.25)	0.20 (0.19-0.21)
HAIR FRONS / D	1.23 (1.00-1.50)	1.20 (0.77-1.80)	1.06 (0.67-1.33)	1.17 (1.17-1.17)
C (L) / C (W)	1.33 (1.17-1.56)	1.14 (1.00-1.38)	1.09 (0.94-1.18)	1.13 (1.00-1.26)
C (L) / SIPH (L)	0.43 (0.39-0.49)	0.45 (0.40-0.56)	0.42 (0.35-0.47)	0.39 (0.35-0.43)
SIPH (L) / C (L)	2.37 (2.04-2.59)	2.24 (1.79-2.50)	2.38 (2.12-2.85)	2.59 (2.30-2.88)
HTIB (L) / (diameter in the middle)	8.23 (6.4-10.90)	5.83 (4.55-6.85)	9.6 (8.6-11.00)	8.20 (7.8-10.00)



Fig. II - Apterous (1) and alate (2) viviparous females of *Brachycolus cucubali*.

ALATE VIVIPARAE - (25 specimens studied, 10 measured, Table 1, Fig. II, 2) are similar to the apterae but with the characters of the winged forms and marginal and dorsal sclerites, and with crossbars on posterior abdominal tergites. The antennae are longer (0.68-1.01 times the body length and the processus terminalis is 1.86-2.61 times the basal part of the antennal segment VI) and with secondary sensoria on antennal segments III and IV (9-16 and 0-2, respectively).

OVIPARAE - (25 specimens studied, 10 measured, Table 1, Fig. III, 1, 2) are similar to the apterae, but with the characteristics of this morph: thicker posterior tibia (length of the tibia from 4.55 to 6.85 times its diameter in the middle) and with 6 to 24 scent plaques, slightly shorter and wider cauda (1.00-1.38 times its basal width) and with more hairs (7-11), and with a greater number of hairs on the tergite VIII (13-24) and on the genital plate (13 to 21 in the anterior part and 13 to 20 in its posterior margin).

MALES - (25 specimens studied, 10 measured, Table 1, Fig. III, 3, 4) are apterous but with a pterothorax and are smaller and thinner than females. They have relatively long appendices (rostrum, antennae and legs) in relation to the body, and the cauda is smaller and triangular (0.94-1.18) than in viviparous and the oviparous. So, the rostrum is 0.21-0.25 times the body length, the posterior tibiae is 0.22-0.25 times the body, and antennae is relatively longer (0.75-0.90 times the body) and with many more secondary-sensory: 9 to 21, 6 to 10, 8 to 13 and 2 to 4, respectively in antennal segments III to VI.

FIELD OBSERVATIONS

Apterous viviparous females (fundatrices or apterous viviparae which survived the winter) of *B. cucubali* easily colonize the plant growth areas during spring and their sucking causes a shortening of the stems and malformations in the flowers, producing characteristic pseudo-galls (Fig. I).

Living inside the pseudo-galls grants protection against natural enemies and environmental conditions. It is not clear what causes winged forms to be produced: they are responsible for colonizing other plants of *S. vulgaris*, but it does seem that the presence of alatae is more marked in late autumn and very rare in spring and summer. As the cold season progresses, the oviparous females appear and a little later the males, which die after mating, leaving inside the pseudo-galls the resistant eggs and the living viviparous females (both adults and nymphs) that decrease their activity during the winter months.

DISCUSSION

The study of aphid sexual morphs has been carried on during all of XX century, but in the last few years, it has notably increased due to descriptions of new morphs (STEKOLSHCHIKOV and BUGA, 2017; BARJADZE *et al.*, 2018; DANILOV *et al.*, 2019) and the study of the internal and external morphology of males (WIECZOREK, 2008; WIECZOREK, *et al.*, 2011a; 2011b; 2019). However, it is common not to give much attention to those species that seem not to possess taxonomic problems, or which are not



Fig. III - *Brachycolus cucubali*. Ovipara: habitus (1) and details of the posterior part of the body (2) and male: habitus (3) and details of the posterior part (4).

pests (KANTURSKI *et al.*, 2017; KANTURSKI *et al.*, 2018).

This is the case of *B. cucubali*, that was described in 1863 and goes on being under cited in afidofaunistic studies, even though it is a quite widespread species which causes easy-to-notice malformations on its host plants (Fig. I). Until now *B. cucubali* was considered a holocyclic species because it only lived on one plant species and because the sexual forms of a nearby species, *B. stellariae*, were known (HEIE, 1992; BLACKMAN, 2010). To confirm it during the last years we monitored different populations of our species in the Northern part of the Iberian Peninsula (Province of León). There, the climate is temperate with autumn and winter night temperatures going down below zero degrees. We observed that the populations of *B. cu-*

cubali develop sexual morphs during the adverse season (from November to January), but they could maintain anholocyclic populations (mainly of viviparous apterae) inside pseudogalls in winter and in spring they developed colonies on their host plants.

Males are apterous, but they present a developed pterothorax like that shown by other monoecious holocyclic species, *Hayhurstia atriplicis* (L. 1761) in the same area and which lives inside pseudogalls on the former family Chenopodiaceae (Amaranthaceae). The males of the latter species can be apterous or winged, as it happens in 10% of European aphid species (SMITH and MACKAY, 1989; KRING and KRING, 1991; HEIE, 1992; BLACKMAN, 2010). The male dimorphism phenomenon is considered to have

evolved different times within Aphidinae (BRISSEON, 2010). This kind of dimorphism, called dispersal dimorphism (HARRISON, 1980) in aphid males has been understudied until now. Just a few species have been examined with attention and it seems that the cause of the variance could be genetic polymorphism (HILLE RIS LAMBERS, 1966; MÜLLER, 1969; SMITH and MACKAY, 1989; BRISSEON, 2010).

Among the examined species, *Acyrtosiphon pisum* (Harris, 1776) represented the most investigated. Thanks to the studies on the pea aphid, the locus responsible for wing determination *aphicarus* (*api*), present on the X-chromosome has been discovered (SMITH and MACKAY, 1989; CAILLAUD *et al.*, 2002; BRAENDLE *et al.*, 2005a; 2005b; OGAWA and MIURA, 2014). Therefore, wing morphology and presence seem to be determined by environmental triggers operating on the genome (BRISSEON, 2010).

This shows that wing absence in males of *B. cucubali* and *H. atriplicis* could be an adaptation to environmental changes, depending on their life inside protected pseudogalls. The possibility offered by reduced wing production favours putting more effort in reproduction (DEPA *et al.*, 2015). In fact, the development of flight apparatus and reproductive fitness are inverse correlated. At the same time, the reproductive trade-off implies a decrease in genetic exchange between populations as a result of decrease in migration (HARRISON, 1980; DENNO, 1994; LANGELLOTTO *et al.*, 2000).

So far, we do not know if males could develop wings depending on latitude, with winged males in temperate zones and wingless ones in cold areas, or if they are on their way to totally lose wings to increase their reproductive fitness. Because of this, *B. cucubali* could represent a good model for future studies dedicated to wing and sex evolution in aphids.

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