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Zoology

Ants of the Genus *Cardiocondyla* from Georgia

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The ant genus *Cardiocondyla* is particularly interesting genus, with about 100 widely differed species in habitat preference, nesting sites, queen number and mating frequency, and also male reproductive tactics. They are tiny ants with a body size of only 1.5-3 mm and their small colonies live in the soil, rock crevices, or dead twigs. Typical *Cardiocondyla* colonies are polygynous, consisting of a few-dozen queens, some or hundreds of workers and several males. *Cardiocondyla* genus is characterised by the presence of wingless (ergatoid) males in almost all its known species except *C. zoserka.* The ant genus *Cardiocondyla* is characterised by a high variability of reproductive life histories and colony structures. Little is known about the *Cardiocondyla stambuloffii* group. We here present data of the colony structure of *Cardiocondyla* colonies from different parts of Georgia, which shows that they are monogynous. According to PCA, which was performed based on the results of morphomedrics done on the specimens from Georgia, Kazakhstan, Russia and Bulgaria, Georgian individuals did not clearly cluster neither with *C. koshewnikovi* from Kazakhstan, nor with *C. stambuloffii* from Russia and Bulgaria. They performed three different clusters, which gives us presumption that individuals of *Cardiocondyla* sp. from Georgia might be different, new species for Georgia, though it needs further investigations. *© 2022 Bull. Georg. Natl. Acad. Sci.*

Cardiocondyla, monogyny, ergatoid males

The Caucasus is one of the regions on the earth with the highest biodiversity. However, many endemic species are highly threatened by urbanization, habitat fragmentation and the conversion of land to agricultural use [1-4].

Ants are among the most abundant and most important invertebrates in terrestrial ecosystems. The ant genus *Cardiocondyla* is particularly interesting genus, with about 100 widely differed species in habitat preference, nesting sites, queen number and mating frequency, and also male reproductive tactics [5].

Cardiocondyla ants are tiny with a body size of only 1.5-3 mm. Their small colonies live in the soil, rock crevices, or hollow plant material, such as folded leaves, galls or dead twigs. Nests are not easy to discover and to excavate complete colonies requires special skills, as they sometimes reach up to 1.5 m down in the soil [6].

Typical *Cardiocondyla* colonies tend to be polygynous, consisting of a few-dozen short-lived queens, with some or hundred workers and several males.

Cardiocondyla genus is characterised by the presence of wingless (ergatoid) males in almost all its known species [7] except *C. zoserka* [8]. Besides the differences in morphology, winged males are peaceful, inseminate young queens from other colonies, have a limited sperm supply, whereas the testes of wingless long-lived males persist and produce sperm throughout their lives. Ergatoid males have sickle-shaped mandibles, usually stay and mate in the nest and try to monopolize the matings by killing other ergatoid males mostly in the pupal stage [7, 9, 10].

Previous research has focused mostly on tropical species from Southeast Asia, Australia, and Africa, and much less is known about *Cardiocondyla* from temperate areas, particularly from the Caucasus.

Presently 119 species are currently known from Armenia, 73 species from Azerbaijan and 148 species from Georgia [11-13]. Recent analyses of ant diversity record four *Cardiocondyla* species for the Caucasus countries (*C. elegans* Emery, 1869, *C. sahlbergi* Forel, 1913, *C. stambuloffii* Forel, 1892, *C. brachyceps* [12, 13]. A more careful study will certainly yield several additional taxa and revealing the social structure and life history of these species.

Aim of our study was to investigate *Cardiocondyla* colonies from Georgia. To study the colony structure and compare specimens from different parts of Georgia by morphometry, as many species of *C. stambuloffii* group are morphologically very similar and can only be determined by detailed morphometry [7, 14].

Material and Methods

Collecting site. Thirty three colonies of *Cardiocondyla* species were collected from nine localities in Georgia in summer 2020-2021. Colonies contained workers, occasionally alate and dealate female sexuals and wingless males. Some colonies – brood and eggs as well. Colony structure of collected colonies is shown in Table 2.

Morphometry. Morphometric analyses were done following [7, 15] with *Cardiocondyla stambuloffii* group. Analyze was performed with seven workers collected in June 2020 in Akhaltsikhe, three workers collected in June 2021 in Grakali, six workers of *C. koshewnikovi* from Kazakhstan, Zayan region, three workers of *C. stambuloffii* from Stepnoje, Stavropolij Kraj, Russia and two workers of *C. stambuloffii* from Slantshev Brjag, Bulgaria.

The dried specimens were mounted using a pin-holding stage and measured under OLYMPUS SZ61 stereo-microscope equipped with an apo-chromatic objective at a magnification of 200×. For each specimen 13 morphological characters and 2 indices were measured [7, 15]. The measurements are given in Table 1. The mean value, standard deviation (SD) for each morphological character and ratios were calculated. Patterns of morpho-metric variation were analysed by Principal Component Analysis (PCA) using the software packages Past v. 2.16.

Table 1. Definitions of characters used in morphometrics

Characters	Definitions of Characters
CL	maximum cephalic length in median line [μm]
CW	maximum cephalic width [μm]
CS	arithmetic mean of CL and CW [μm]
SL	maximum straight line scape length
PoOc	postocular distance [μm]
EYE L	large diameter of the elliptical compound eye [μm]
EYE W	small diameter of the elliptical compound eye [μm]
EYE	eye size index: arithmetic mean of large and small diameter of the elliptical compound eye is devided by CS
MW	maximum mesosoma width [μm]
SPTI	distance of spine tips in dorsal view [μm]
PEW	maximum petiole width [μm]
PPW	maximum post petiole width [μm]
PEH	maximum petiole height [μm]
MGr	Depth of metanotal groove or depression [μm]
ML	mesosoma length [μm]

Table 2. Colony structure of *Cardiocondyla* ants collected in eight localities of Georgia. The table shows: samples numbers, species names, quantities of queens, workers, pupae, eggs, males and sampling sites

Sample number	Species	Queen	Worker	Pupae	Egg	Male	Sampling sites
1	*C.sahlbergi*	-	4	-	-	-	Tbilisi botanical garden
2	*C.sahlbergi*	1	43	+	+	-	Tbilisi botanical garden
3	*C.sahlbergi*	-	11	-	-	-	Tbilisi botanical garden
4	*C.sahlbergi*	-	7	-	-	-	Tbilisi botanical garden
5	*C.sahlbergi*	-	13	-	-	-	Tezmis chala
6	*C.sahlbergi*	-	38	-	-	-	Tezmis chala
7	*C.sahlbergi*	-	12	+	-	-	Uflistsikhe
8	*C.sahlbergi*	3	10	-	-	-	Uflistsikhe
9	*C.sahlbergi*	1	5	-	-	-	Uflistsikhe
10	*C.sahlbergi*	3	4	-	-	-	Uflistsikhe
11	*C.sahlbergi*	-	21	-	-	-	Grakali
12	*C.* sp.	-	10	-	-	-	Grakali
13	*C.sahlbergi*	-	10	-	-	-	Grakali
14	*C.* sp.	-	20	+	-	-	Grakali
15	*C.sahlbergi*	1	45	+	+	-	Gareji monastery
16	*C.sahlbergi*	-	19	-	-	-	Gareji monastery
17	*C.sahlbergi*	-	28	-	-	-	Gareji monastery
18	*C.sahlbergi*	-	41	-	-	-	Gareji monastery
19	*C.sahlbergi*	-	2	-	-	-	Gareji monastery
20	*C.sahlbergi*	-	20	+	-	1 ergatoid	On the way of Udabno-Gareji
21	*C.sahlbergi*	-	14	-	-	-	On the way of Udabno-Gareji
22	*C.* sp.	1	30	+	+	-	Akhaltsikhe, farekha
23	*C.* sp.	-	4	-	-	-	Akhaltsikhe, farekha
24	*C.sahlbergi*	-	14	+	-	-	Akhaltsikhe, farekha
25	*C.* sp.	-	5	-	-	-	Akhaltsikhe, farekha
26	*C.* sp.	1	36	+	+	-	Akhaltsikhe, farekha
27	*C.sahlbergi*	-	8	-	-	-	Akhaltsikhe, farekha
28	*C.sahlbergi*	-	7	-	-	-	Akhaltsikhe, farekha
29	*C.sahlbergi*	-	20	-	-	-	akhaltsikhe, riv. fotskhovi
30	*C.sahlbergi*	-	9	-	-	1 ergatoid	akhaltsikhe, riv. fotskhovi
31	*C.*elegans dalmatica	-	6	-	-	-	akhaltsikhe, riv. fotskhovi
32	*C.* sp.	1	30	+	+	-	Akhaltsikhe, farekha
33	*C.*sahlbergi	-	2	-	-	-	Tezmis chala

Results

Colony structure. Among thirty three colonies, collected in eight localities of Georgia, eight contained queens. Three queens per nest occurred in two colonies, while others had only one queen. Nine colonies contained pupae and five colonies – eggs. Ergatoid males were fixed only in two colonies. Workers number differed from two to forty five.

Morphometry. According to Principal Component Analysis, which was performed with the specimens from Georgia, *C. koshewnikovi* from Kazakhstan, *C. stambuloffii* from Russia and Bulgaria, Georgian individuals did not clearly cluster neither with *C. koshewnikovi* nor with *C. stambuloffii* (Fig.). The main contributions to PC1 (68% of total variation) were CW, PEW, PoOc, against EYE W, those to PC2 (31% of total variation) were EYE L, against SL (Table 3).

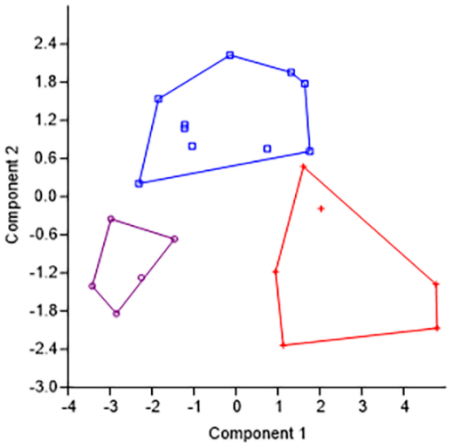

Fig. Principal component analysis of 21 workers of *Cardiocondyla* based on measurements of 13 morphological characters. Blue color indicates *Cardiocondyla* specimens from Georgia, red color – individuals of *C. koshewnikovi* from Kazakhstan and purple – *C. Stambuloffii* from Russia and Bulgaria.

Table 3. Proportion of contribution and variable coefficients of the first two eigenvectors PC1 and PC2 in workers of *Cardiocondyla koshewnikovi, C.* sp. and *C. stambuloffii*

Characters	PC1	PC2
CL	0.330	0.079
PoOc	0.334	0.007
CW	0.334	0.008
SL	0.128	-0.460
MW	0.313	-0.174
SPTI	0.172	0.427
PEW	0.334	0.003
PPW	0.209	0.389
PEH	0.325	0.100
EYE L	-0.033	0.495
EYE W	-0.332	0.056
ML	0.334	0.027
MGr	0.200	-0.399

Plot PC 1 against PC 2 reveals three different clusters, with PC1 separating *C. koshewnikovi* and *C. stambuloffii*, and PC2 separating the samples from Georgia from two other taxa (Fig.).

Morphometric measurements of *Cardiocondyla* workers are given in the Table 4.

Discussion

Our study gave us opportunity to study colony structure of *Cardiocondyla* ants from different places of Georgia. Thirty three colonies were excavated from their nests and only eight colonies contained queens. There were not winged female sexuals, just only queens. Two colonies from thirty three had wingless males. Only nine colonies were collected with brood (pupae or eggs). As most colonies were collected in June, it can be considered that sexuals (female and male) emerge in early spring or late summer and June was not proper time for collecting sexual individuals.

Our study is the first attempt to make morphometric analysis of the ants from the *Cardiocondyla stambuloffii* group as many species of this group are morphologically very similar and can only be determined by detailed morphometry [7,14]. According to our morphometric analysis specimens collected in Georgia, though similar, appeared to be different from *C. stambuloffii* and *C. koshewnikovi.* According to [7], specimens of

Table 4. Morphometric measurements of *Cardiocondyla koshewnikovi, C. stambuloffi* and *C.* sp. workers (mean±S.D., [range])

Characters	*C. koshewnikovi* (6 workers)	*C. stambuloffii* (5 workers)	*C.* sp (10 workers)
CS	561±12 [547; 583]	523±7 [517; 531]	546±13 [519; 562]
CL	591±8 [583; 602]	549±9 [541; 559]	577±15 [552; 597]
CW	530±27 [511; 582]	497±5 [494; 503]	515±15 [486; 537]
PoOc	271±7 [263; 280]	248±7 [239; 257]	261±8 [242; 269]
SL	439±20 [420; 470]	427±16 [409; 451]	410±18 [433; 374]
EYE L	121±9 [108; 134]	123±6 [119; 134]	133±6 [125; 147]
EYE W	103±9 [89; 112]	108±7 [97; 116]	106±5 [97; 116]
MW	330±6 [324; 336]	299±7 [292; 306]	305±13 [283; 327]
SPTI	127±6 [116; 134]	121±13 [104; 142]	134±10 [112; 145]
PEW	169±8 [160; 184]	151±8 [143; 161]	160±9 [149; 175]
PPW	319±9 [307; 330]	312±5 [307; 318]	323±16 [292; 341]
PEH	202±8 [190; 210]	189±6 [179; 197]	198±7 [190; 209]
ML	644±34 [586; 686]	602±3 [598; 606]	626±20 [597; 649]
MGr	29±4 [22; 36]	25±5 [21; 31]	23±3 [19; 30]

Georgian *C.* sp. are also different from *C. gibbosa*, as head size of *C. gibbosa* (CS, arithmetic mean of cephalic length CL and cephalic width CW) is lower (518±9, range 508–526) and the ratio between CL and CW (1.191±0.020, range 1.176–1.219) is larger than in the specimens from Georgia (CS 546±13, range 519–562, CL/CW 1.120±0.026, range 1.071–1.161, Table 4).

According to [12], only three species of *Cardiocondyla* are known from Georgia. The number of species reported from neighbouring countries, such as Turkey, Iran, Azerbaijan [13,16,17] is higher, and it is expected that future studies in Georgia will also reveal novel aspects and additional taxa of its highly variable genus.

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ზოოლოგია

გვარ *Cardiocondyla*-ს ჭიანჭველები საქართველოდან

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ჭიანჭველების გვარი *Cardiocondyla* წარმოადგენს მეტად საინტერესო გვარს 100-ზე მეტი სახეობით, რომლებიც განსხვავდებიან ჰაბიტატით, ბუდეების ადგილმდებარეობით, დედოფლების რაოდენობით და შეწყვილების სიხშირით, ასევე მამრების რეპროდუქციული ტაქტიკით. ისინი არიან პატარა ზომის, დაახლ. 1,5-3 მმ სიგრძის ჭიანჭველები და მათი კოლონიები ცხოვრობენ ნიადაგში, კლდის ნაპრალებსა და ხის კუნძებში. ტიპური *Cardiocondyla*-ს კოლონიები არიან მრავალდედოფლიანი, შეიცავენ მცირე რაოდენობით დედოფლებს, ზოგჯერ რამდენიმე ასეულ მუშას და რამდენიმე მამრს. *Cardiocondyla*-ს გვარი ხასიათდება უფრთო (ერგატოიდული) მამრების არსებობით თითქმის ყველა სახეობაში გარდა *C. zoserka*. *Cardiocondyla*-ს გვარს ახასიათებს რეპროდუქციული სასიცოცხლო ისტორიების და კოლონიის სტრუქტურის მრავალფეროვნება. ძალიან მცირეა მონაცემები *Cardiocondyla stambuloffii*-ის ჯგუფის შესახებ. აღნიშნულ სტატიაში მოცემულია *Cardiocondyla*-ს სახეობების კოლონიების სტრუქტურა საქართველოს სხვადასხვა ადგილიდან, რაც ადასტურებს მათ ერთდედოფლიანობას. PCA-ს თანახმად, რომელიც ჩატარდა მორფომეტრიის შედეგებზე დაყრდნობით, *Cardiocondyla*-ს ინდივიდები საქართველოდან, ყაზახეთიდან, რუსეთიდან და ბულგარე-

თიდან არ დაჯგუფდნენ არც *C. Koshewnikovi*-თან, არც *C. stambuloffii*-თან. მათ ჩამოაყალიბეს სამი სხვადასხვა კლასტერი, რამაც შეიძლება გვაფიქრებინოს, რომ *Cardiocondyla* sp. საქართველოდან შესაძლოა იყოს ახალი სახეობა საქართველოსთვის, თუმცა ამას დამატებითი კვლევები სჭირდება.

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