

The tiny *Solenopsis* ants in greenhouses are two species: *S. canariensis* Forel and *S. carolinensis* Forel (Hymenoptera: Formicidae)

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<https://zoobank.org/9CE8E817-A4F9-4411-8BAA-4042C776A7FE>

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Abstract

Tiny ants of the genus *Solenopsis* Westwood, 1840 are increasingly found in greenhouses of Europe and were identified as *Solenopsis canariensis* Forel, 1893 and *S. carolinensis* Forel, 1901 by type investigation and Numeric Morphology-Based Alpha-Taxonomy (NUMOBAT). The 29 workers of the two species, including the type specimens, are clearly separable by principal component analysis and linear discriminant analysis, with $p > 0.999$ for each individual. The type specimen of *Solenopsis texana* r. *truncorum* Forel, 1901 was clearly allocated to the *S. carolinensis* cluster and was considered a junior synonym of the latter. The type specimens of *Solenopsis pollux* var. *texana* Emery, 1895 and *Solenopsis saudiensis* Sharaf & Aldawood, 2011 were clearly allocated to the *S. canariensis* cluster and recognized as junior synonyms. The identity of *Solenopsis abdita* Thompson, 1989 could not be clarified with certainty due to the absence of type specimens from any of the published depositories and an insufficient original description. It is supposed to be a synonym of *Solenopsis canariensis* based on an image of the petiole shape in Thompson's description. The zoogeographic origins of the two focal species are apparently the New World tropics and subtropics. The current picture of distribution shows that both species have the potential for wider global spread as tramp species. To date, no reports are known that these apparently soil- and litter-foraging species can occur as pests in greenhouses or outdoor habitats. This paper offers criticism of the frequent use of inapplicable investigation methods for the study of very small ants and emphasizes the imperative of adapting the methodology to the small size of the specimens.

Key Words

Invasive species, morphometry, Numeric Morphology-Based Alpha-Taxonomy

Introduction

As a new development after the turn of the millennium, tiny ants of the genus *Solenopsis* Westwood, 1840 were observed in heated greenhouses of England, Norway, Germany, and France. The identity and naming of these ants have been controversial. The name *Solenopsis saudiensis* Sharaf & Aldawood, 2011 was allocated by mitochondrial DNA (mtDNA) barcoding to ants from the greenhouse of Kristiansand Dyrepark, Norway (Odegaard et al. 2016). Sharaf et al. (2020) also used molecular

data to test whether ants from Saudi Arabia, which they had formerly described as *Solenopsis saudiensis*, represent a distinct species or are an introduced population of *Solenopsis abdita* Thompson, 1989. They concluded that *Solenopsis saudiensis* is a junior synonym of *Solenopsis abdita* based on mtDNA barcoding. The name *abdita* was then used by Hamer and Turner (2024) for ants found in a tropical greenhouse near St Austell, Cornwall. Simultaneously, ants from two tropical greenhouses in Potsdam and Berlin, Germany, were considered to be *Solenopsis texana* Emery, 1895 (Freyhof and Janke 2024).

The main problem with this story is that the identity of *Solenopsis abdita* Thompson is unresolved. Thompson (1989) reported 26 April 1984 as the collecting date of the types taken at Fort Lauderdale, Florida, but according to Pacheco and Mackay (2013), no type specimens could be identified in any of the three depositories stated by Thompson. Furthermore, the original description of Thompson (1989) does not allow identification to the species level. The verbal redescription of Pacheco and Mackay (2013) lacks indicative statements, and the applied morphometric methods were inadequate for the minute size of workers. They presented no individual data of measurements but only mean, maximum, and minimum values of six workers with an accuracy of 0.01 mm. A neotype of *Solenopsis abdita* was not fixed by Pacheco and Mackay. This paper shows that there are two well-separable species in which strongly separating characters, such as frontal lobe distance or scape length, show interspecific differences of only 0.013 or 0.025 mm.

The objective of the present work is to determine the valid names of these species by investigating the types of the oldest available names by Numeric Morphology-Based Alpha-Taxonomy (NUMOBAT, see Seifert 2009). This study uses the investigation system of Csősz et al. (2023b), which considers the conditions required for investigating very small ants. Fortunately, this is a favorable case because the interspecific differences are strong enough to allow credible extraction of data even from images, and the small sample size of only 26 directly investigated specimens does not pose a problem.

Material

NUMOBAT data were stereomicroscopically taken in six samples with 13 worker individuals of *Solenopsis canariensis* and in four samples with 13 worker individuals of *Solenopsis carolinensis*. Data of type specimens of *Solenopsis texana*, *S. truncorum* Forel, 1901, and *S. saudienensis* were taken from the images available on <https://www.antweb.org>. For details of measurements and collecting sites, see Suppl. material 1.

Methods

Equipment and measurement procedures

A pin-holding stage, permitting full rotations around *X*, *Y*, and *Z* axes, and a Leica M165C high-performance stereomicroscope equipped with a 2.0× planapochromatic objective (resolution 1050 lines/mm) were used at magnifications of 120–360×. To avoid parallax error (see section 2.2.1 in Seifert 2002), its measuring line was constantly kept vertical within the visual field. Further details of the illumination system and mode of measuring are provided in Seifert (2025). Z-stack images of

mounted specimens were produced with a KEYENCE VHX-7000 digital microscope.

Digital images of type specimens presented on <https://www.antweb.org> provide the standard viewing head in dorsal view, the whole ant in dorsal view, and the whole ant in lateral view. This allowed a selection of images for the condition that measurements under the two-dimensional representation of body parts did not deviate substantially from measurements expected under stereomicroscopic measuring of the real specimen in three-dimensional space. When a small tilt of a measuring line at an angle α was indicated by an image from another, orthogonal viewing position, a correction to the real value was performed using the tangent and cosine functions: real value = apparent value / $\cos \alpha$. This correction procedure can be explained by an example: if the dorsal view of the head provided an apparent scape length of 215 μm and if the lateral view indicated that the distal scape end was lowered relative to the proximal end by 58 μm , the tilt angle α is $\arctan(58/215)$, or 15°. The corrected scape length is then $215 / \cos 15^\circ = 223 \mu\text{m}$. For measuring, the images were zoomed on the computer screen to a sufficiently large size, and measurements were read directly using a transparent ruler.

The morphometric characters and terminology

Seventeen phenotypic characters were investigated in worker ants and numerically recorded. In bilaterally developed characters, arithmetic means of both body sides were calculated. All measurements were made on mounted and fully dried specimens.

CL	Maximum cephalic length in the median line; the head must be carefully tilted to the position yielding the true maximum, i.e., avoiding foreshortening due to tilt; excavations of the hind vertex or clypeus reduce CL.
CISpD	Distance between the tips of the large paramedian clypeal dents.
CISpLM	Mean protrusion of the tips of paramedian clypeal dents from the clypeus, measured perpendicular from the tangent running through the bottoms of the menisci left and right of the spines.
CISpLL	Mean protrusion of the tips of lateral clypeal dents from the clypeus, measured perpendicular from the tangent running through the bottoms of the menisci left and right of the spines.
CW	Maximum cephalic width. This is either across and including the eyes or posterior of the eyes, depending on whether the eyes protrude past the lateral head margins.

CS Cephalic size. The arithmetic mean of CL and CW, used as a less variable indicator of body size.

EL Eye length. The maximum diameter of the compound eye over all structurally visible ommatidia.

FL Maximum distance of frontal carinae; if no maximum is defined by a posterior constriction of frontal carinae, set FL equal to FRS.

FR Minimum distance of the frontal carinae posterior of the FL level; if no minimum is defined by a constriction, set FR equal to FRS.

FRS Distance of the frontal carinae immediately caudal to the posterior intersection points between the frontal carinae and the lamellae dorsal to the torulus (Fig. 1). If these dorsal lamellae do not laterally surpass the frontal carinae, the deepest point of the scape corner pits may be taken as the reference line. These pits take up the inner corner of the scape base when the scape is fully switched caudad and produce a dark triangular shadow in the lateral frontal lobes immediately posterior to the dorsal lamellae of the scape joint capsule.

Full face view Dorsal aspect of the head with both maximum head width and maximum median head length in the visual plane.

ML Mesosoma length. Anterior measuring point: the transition point of the anterior pronotal slope to the anterior pronotal shield; posterior measuring point: caudal-most margin of the propodeal lobe.

MGr Depth of metanotal groove or depression, measured from the tangent connecting the dorsalmost points of pronotum and propodeum.

MW Mesosoma width; this is in workers maximum pronotal width.

PeH Petiole height (Fig. 2). A straight imagination of the ventral petiolar profile at the node level is the reference line perpendicular to which the maximum height of the petiole node is measured. PeH is the maximum height of a section line.

PeW Maximum width of petiole.

PnHL The length of the longest member of pronotal setae.

PpH Postpetiole height (Fig. 2); the straight section of the margin line between the tergum and sternum is the reference line perpendicular to which the maximum height of the postpetiole is measured.

PpW Maximum width of postpetiole.

PrOc Preocular distance (Fig. 3). The shortest distance between the anterior eye margin and the sharp frontal margin of the gena. Caution: do not confuse this with the beaded rim of the mandible that is often very closely appressed to the genal margin.

SL Maximum straight-line scape length excluding the articular condyle, i.e., the bulbus neck and bulbus.

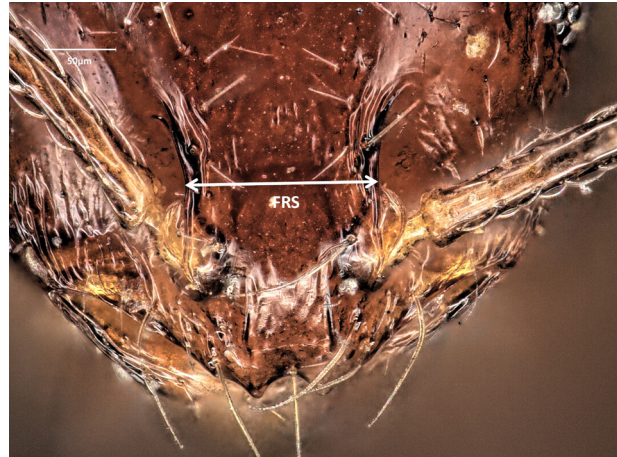


Figure 1. Measuring frontal carinae distance FRS.



Figure 2. Measuring petiole and postpetiole heights, PeH and PpH.

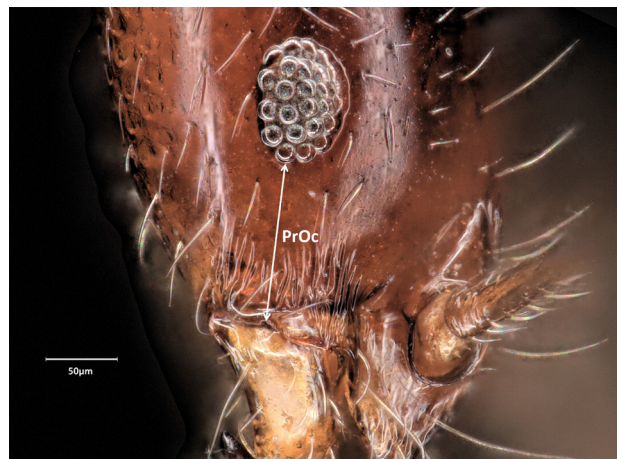


Figure 3. Measuring preocular distance PrOc.

NUMOBAT: Explorative and supervised data analyses, classification, and statistical testing

Formation of species hypotheses was performed by principal component analysis (PCA) considering the 17 morphological standard characters specified above. The low sample size, with only 13 specimens in each species available, did not allow discriminant analyses with more than four characters. To reflect the whole character combination in a linear discriminant analysis (LDA) without overfitting, the first three principal components were used as characters. After defining the species clusters in this way, a character-reduced LDA was run using raw data of three morphometric characters. PCA, LDA, and ANOVA tests were run with the SPSS 15.0 software package.

Results

Cluster analyses and species separation

The cluster analyses included data sets for 26 worker ants obtained by direct stereomicroscopic evaluation and three data sets of type workers extracted from image evaluation. Since the measurements ClSpM, CLSpL, PrOc, EL, PeH, PnHL, PpH, and MGr could not be taken from images without large error, PCA was run with the remaining 10 characters CS, CL/CW, SL/CS, FL/CS, FR/CS, ClSpD/CS, ML/CS, MW/CS, PeW/CS, and PpW/CS. The PCA showed two main clusters largely separated by the first principal component (Fig. 4). The type specimens of *Solenopsis texana* Emery, 1895 and *S. saudiensis* Sharaf & Aldawood, 2011 were placed in the same cluster with the types of *S. canariensis* Forel, 1893, while the type of *S. truncorum* Forel, 1901 was in the cluster with the *S. carolinensis* types. The two-species hypothesis and the probability of cluster allocation of the individuals were

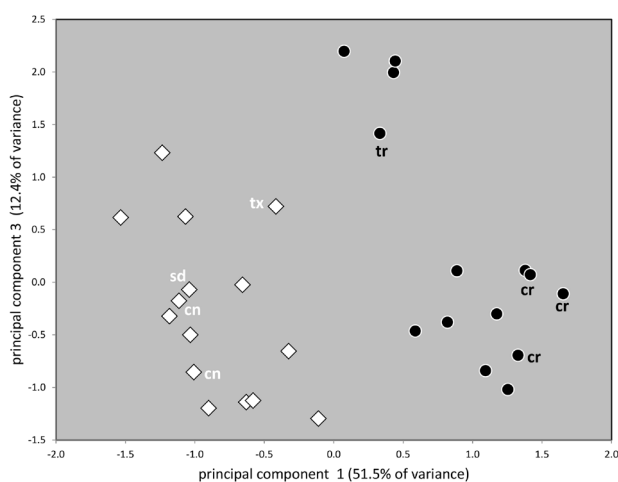


Figure 4. Principal component analysis of workers of *Solenopsis canariensis* (white rhombs) and *S. carolinensis* (black dots) extracted from 10 morphometric characters; designation of type specimens: cn – *S. canariensis*, cr – *S. carolinensis*, sd – *S. saudiensis*, tr – *S. truncorum*, tx – *S. texana*.

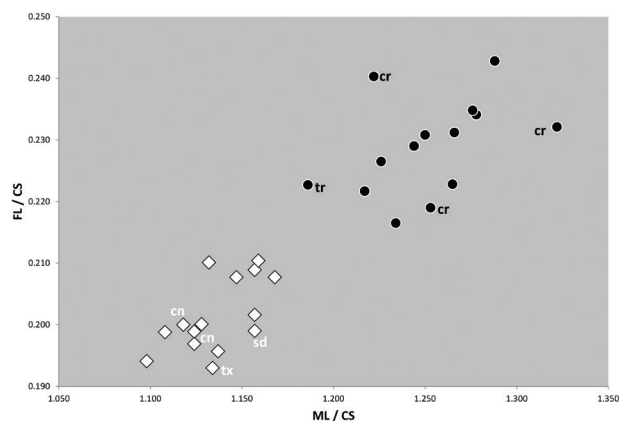


Figure 5. Mesosoma length index ML/CS of workers of *Solenopsis canariensis* (white rhombs) and *S. carolinensis* (black dots) plotted against the frontal lobe width index FL/CS; designation of type specimens: cn – *S. canariensis*, cr – *S. carolinensis*, sd – *S. saudiensis*, tr – *S. truncorum*, tx – *S. texana*.

then checked by a linear discriminant function, which used the first three principal components as characters. This resulted in posterior probabilities of $p > 0.999$ in all 29 specimens in a leave-one-out LDA. A plot of the most discriminative shape variables, ML/CS and FL/CS, shows very strong separation of the clusters—again, with clear allocation of the type specimens (Fig. 5). The most parsimonious means for separation of the two species is a discriminant function using three raw measurements in mm: $284.56 \times FL + 67.19 \times ML - 126.02 \times CW - 9.776$. The discriminant score is $-2.085 \pm 0.705 [-3.572, -1.143]$ in 15 *Solenopsis canariensis* workers and $3.405 \pm 1.241 [1.143, 6.002]$ in 14 *S. carolinensis* workers.

Taxonomic treatment

Solenopsis canariensis Forel, 1893

Solenopsis orbuloides r. *canariensis* Forel, 1893 [direct type investigation]

This taxon was described from La Punta, Tenerife. Investigated were two syntype workers on the same pin labeled “*S. orbuloides* r. *canariensis* Forel La Punta Teneriffe,” “r. *S. canariensis* Forel,” “Typus,” “ANTWEB CASENT 0908861”; depository: Muséum d’histoire naturelle de Genève. The second specimen, which had been drowned in glue, was washed off and remounted. The posterior probabilities of cluster allocation for both specimens were $p > 0.999$ (see also Figs 4, 5).

Solenopsis pollux var. *texana* Emery, 1895 [image evaluation, new synonym of *S. canariensis*]

This taxon was described based on workers collected by Pergande in Texas. The original description is poor in usable statements, but Emery wrote “sehr blasse Farbe” (very pale color) and “Länge nicht ganz 1.25 mm”

(= length a little below 1.25 mm). From these statements, it is clear that the published lectotype designation performed by Pacheco and Mackay (2013) in the worker specimen CASENT0908855 (image available on <https://www.antweb.org>) is definitely wrong. The specimen is stored in the Forel collection in MHN Genève, has a total length of 2.98 mm, is not very pale, and shows a blackish brown gaster. It is labeled “ANTWEB CASENT 0908855,” “*S. pollux* v. *texana* Em” [poorly legible, handwritten] and “Tex.” [handwritten], “Cotyplus” [printed label of the form as it was used by Forel], and “LECTOTYPE *Solenopsis pollux* var. *texana* Forel Desg. Moreno and Mackay 2001” [the names Moreno and Pacheco should refer to the same person]. Note also that Moreno and Mackay wrongly gave Forel as the author and that the cotype label was attached by Forel. As a true type specimen that is in agreement with the original description, the worker specimen CASENT0904625 (image available on <https://www.antweb.org>), which is stored in the Emery collection at MCSN Genova, can instead be considered. It is labeled “*Solenopsis pollux* Forel var. *texana* Em.” [Emery’s handwriting, well legible], “Tex.” [printed label], “TYPUS” [red printed label of the form used by Emery], and “PARALECTOTYPE *Solenopsis pollux* var. *texana* Forel Desg. Moreno & Mackay 2001” [yellow printed label, again with the wrong author]. The evaluation of the image placed this specimen with $p > 0.999$ in the cluster with the *Solenopsis canariensis* types (Figs 4, 5). Assessing which specimens should belong to the type series, paragraph 72.4.1.1 of the ICZN states the following: “For a nominal species or subspecies established before 2000, any evidence, published or unpublished, may be taken into account to determine what specimens constitute the type series.” As for the specimen in the Forel collection, it is clear that the published evidence in the original description very strongly speaks against considering it as part of the type series that Emery had in mind. Furthermore, the later attachment of the “Cotype” label by Forel has no meaning. Hence, the lectotype designation by Pacheco and Mackay (2013) is considered invalid according to the rules of the ICZN. In contrast, the morphology of the specimen in the Emery collection is in agreement with the published evidence in the original description, and its labeling makes clear that it represents the primary type Emery had in mind.

***Solenopsis abdita* Thompson, 1989 [new synonym of *S. canariensis*]**

This taxon cannot be reliably identified because the original description of Thompson (1989) is insufficient and because Pacheco and Mackay (2013) could not find any type specimen in the three depositories stated by Thompson. The redescription by Pacheco and Mackay (2013) does not allow identification of a species (see Introduction), and in just the most discriminative character ML/CS (= WL/CS in Pacheco and Mackay), they gave an impossible value of 0.669 (calculated from their mean values of six specimens). The synonymization proposed here

is based only on a scanning electron microscope image of the petiole profile in Thompson’s original description showing the posterior slope of the node to be much steeper than the anterior one.

***Solenopsis saudiensis* Sharaf & Aldawood, 2011 [new synonym of *S. canariensis*]**

A specimen from the holotype series collected on the campus of King Saud University, Riyadh, was not made available after repeated inquiries. Image evaluation of a paratype specimen CASENT0249866 (image available on <https://www.antweb.org>) from Wadi Hanifa, 24°39'N, 46°36'E, 633 m, 15 January 2010, resulted in data fully compatible with *S. canariensis*. The paratype was placed by LDA with $p > 0.999$ in the same cluster with the *Solenopsis canariensis* types when the first three principal components extracted from 10 characters were used or when run in LDA using the characters FL, ML, and CW (see also Figs 4–6). As for the holotype specimen, Sharaf and Aldawood (2011) report ML = 0.38 mm and CW = 0.31 mm. This would mean ML/CW 1.226, and, assuming the worst possible rounding error (i.e., 0.384 mm vs. 0.306 mm), this results in 1.255. The stereomicroscopic measurements reported here result in ML/CW of 1.290 ± 0.016 [1.262, 1.313] in 13 *Solenopsis canariensis* workers and 1.410 ± 0.028 [1.358, 1.467] in 13 *S. carolinensis* workers. This excludes *S. carolinensis*. Accordingly, there is a fair probability that the Riyadh and Wadi Hanifa samples belong to the same species.

Description of worker (Fig. 6; Table 1). Only data of directly investigated specimens are provided. Extremely small and probably monomorphic, CS $338 \pm 7 \mu\text{m}$. Head more elongated than in *S. carolinensis*, CL/CW 1.273 ± 0.027 . Paramedian dents on the clypeal margin rather short and blunt, with a lower distance than in *S. carolinensis*, CISpLM/CS 0.049 ± 0.005 , CISpD/CS 0.122 ± 0.008 ; lateral dents very blunt and short, having the shape of a broad bulge, CISpLL/CS 0.018 ± 0.003 . Distance of frontal carinae much lower than in *S. carolinensis* (FL/CS 0.202 ± 0.006 , FR/CS 0.189 ± 0.006). Eye very small and preocular distance moderately large (EL/CS 0.102 ± 0.004 , PrOc/CS 0.172 ± 0.010). Scape shorter than in *S. carolinensis*, SL/CS 0.704 ± 0.015 . Mesosoma much shorter and slightly narrower than in *S. carolinensis* (ML/CS 1.135 ± 0.021 , MW/CS 0.577 ± 0.014). Metanotal groove shallower than in *S. carolinensis*, MGr/CS 0.027 ± 0.004 . Petiole moderately wide and high (PeW/CS 0.262 ± 0.011 , PeH/CS 0.359 ± 0.007); in contrast to *S. carolinensis*, the posterior slope of the petiole node is much steeper than the anterior one (Fig. 6). Postpetiole moderately wide and high (PpW/CS 0.329 ± 0.011 , PpH/CS 0.294 ± 0.012). Seta on pronotum shorter than in *S. carolinensis*, PnHL/CS 0.209 ± 0.020 . All body parts pale yellowish. Surfaces of the head, mesosoma, waist, and gaster smooth and shiny, except for small foveolae at the seta bases.

Table 1. Morphometric characters of workers of *Solenopsis canariensis* and *S. carolinensis* by direct stereomicroscopic measuring, presented as arithmetic mean \pm standard deviation [minimum, maximum]; data of the type specimens of *Solenopsis texana*, *S. saudiensis*, and *S. truncorum* extracted by image evaluation.

	<i>S. texana</i> type (<i>n</i> = 1) from image	<i>S. saudiensis</i> type (<i>n</i> = 1) from image	<i>S. truncorum</i> type (<i>n</i> = 1) from image	<i>S. canariensis</i> (<i>n</i> = 13) by direct investigation	ANOVA $F_{24,1}$; <i>p</i>	<i>S. carolinensis</i> (<i>n</i> = 13) by direct investigation
CS [μ m]	348	337	351	338 \pm 7 [329, 352]	10.59 0.003	353 \pm 21 [330, 385]
CL/CW	1.224	1.293	1.252	1.273 \pm 0.027 [1.237, 1.311]	9.95 0.004	1.248 \pm 0.022 [1.199, 1.283]
SL/CS	0.704	0.700	0.729	0.704 \pm 0.015 [0.681, 0.733]	29.88 0.000	0.745 \pm 0.019 [0.719, 0.766]
FL/CS	0.193	0.199	0.223	0.202 \pm 0.006 [0.194, 0.210]	98.66 0.000	0.229 \pm 0.008 [0.216, 0.243]
FR/CS	0.183	0.183	0.207	0.189 \pm 0.006 [0.182, 0.200]	34.96 0.000	0.210 \pm 0.013 [0.186, 0.223]
EL/CS		0.095		0.102 \pm 0.004 [0.096, 0.111]	30.85 0.000	0.113 \pm 0.007 [0.103, 0.124]
PrOc/CS				0.172 \pm 0.010 [0.155, 0.187]	11.21 0.003	0.186 \pm 0.012 [0.166, 0.201]
CLSPLM /CS				0.049 \pm 0.005 [0.040, 0.057]	4.37 0.047	0.039 \pm 0.008 [0.030, 0.054]
CLSPLL /CS				0.018 \pm 0.003 [0.013, 0.024]	2.55 n.s.	0.023 \pm 0.003 [0.017, 0.028]
CLSPD /CS	0.157	0.119	0.159	0.122 \pm 0.008 [0.108, 0.132]	65.11 0.000	0.146 \pm 0.005 [0.133, 0.151]
ML/CS	1.134	1.157	1.186	1.135 \pm 0.021 [1.098, 1.168]	143.41 0.000	1.254 \pm 0.024 [1.217, 1.288]
MW/CS	0.560	0.582	0.569	0.577 \pm 0.014 [0.550, 0.598]	11.87 0.002	0.593 \pm 0.015 [0.571, 0.622]
MpGr/CS				0.027 \pm 0.004 [0.017, 0.033]	20.80 0.000	0.041 \pm 0.006 [0.025, 0.046]
PEW/CS	0.282	0.267	0.282	0.262 \pm 0.011 [0.243, 0.281]	4.68 0.041	0.270 \pm 0.023 [0.247, 0.310]
PPW/CS	0.335	0.320	0.313	0.329 \pm 0.011 [0.311, 0.354]	0.18 n.s.	0.324 \pm 0.005 [0.317, 0.330]
PEH/CS				0.359 \pm 0.007 [0.345, 0.370]	15.74 0.001	0.369 \pm 0.003 [0.362, 0.373]
PnHL/CS				0.209 \pm 0.020 [0.171, 0.252]	44.78 0.000	0.273 \pm 0.028 [0.232, 0.324]

Geographic distribution. Largely unknown. Confirmed for heated greenhouses in Norway, England, and Germany and outdoor habitats in Texas, Saudi Arabia, and Tenerife. Tramp species with the potential to become distributed over subtropical and tropical regions worldwide.

Biology. Largely unknown. If all observations reported by Sharaf and Aldawood (2011) and Sharaf et al. (2020) for the Arabian Peninsula refer to *Solenopsis canariensis*, it was frequently observed in date palm groves and highly disturbed urban habitats but also in semi-natural habitats such as nature reserves. The populations in greenhouses in Germany and England were reported to be small and did not occur there as pests (Hamer and Turner 2024; Freyhof and Janke 2024). Most probably, it is a species foraging in soil and litter. As nest sites, Sharaf and Aldawood (2011: 476) reported “the base of a date palm tree, where many decayed falling dates were present” (holotype sample), whereas the nest with the paratype

CASENT0249866 was “a large colony containing hundreds of individuals nesting under a rock, on a rotten used carpet, and among roots of graminæ plants” (Sharaf and Aldawood 2011: 477).

Solenopsis carolinensis Forel, 1901

Solenopsis texana r. *carolinensis* Forel, 1901 [direct type investigation]

This taxon was described from “Caroline du Nord” [North Carolina]. Pacheco and Mackay (2013) published a lectotype designation in a series from Faisons, North Carolina, USA, collected in 1899, which is stored in USNM Washington. This specimen was not available. Identification is based on direct investigation of three worker paratypes from the type locality, labeled “*S. texana* Em r. *carolinensis* Forel type Faisons N.C. Forêtale tenuite



Figure 6. Lateral aspect of waist segments of *Solenopsis canariensis*; Germany, Berlin-Mahrzahn, greenhouse, 30 January 2024, sample 2. The posterior slope of the petiole node is much steeper than the anterior one.

27. VII,” “Typus,” “*r. carolinensis* For.,” “ANTWEB CASENT0908858”; depository: Muséum d’histoire naturelle de Genève. All type specimens were placed in all analyses mentioned above in the same cluster with $p > 0.999$ (see also Figs 4, 5)).

***Solenopsis texana* r. *truncorum* Forel, 1901** [image evaluation; syn. *carolinensis*]

According to Forel (1901), the type locality is the same as in *Solenopsis carolinensis*: “Meme localité que la *r. carolinensis*.” The identification was based on images of the paralectotype worker CASENT0908857 provided on antweb.org and labeled “*S. texana* Em *r. truncorum* Type Forel, Faissons NC ds tronc 28 VIII.” The specimen is allocated with $p > 0.999$ to the *Solenopsis carolinensis* cluster in a wild-card run of LDA using the first three principal components as characters. The lateral aspect of the waist is not fully visible in the image, but at least it allows the conclusion that the posterior slope of the petiole node is not much steeper than the anterior slope. This supports the NUMOBAT classification.

Description of worker (Fig. 7; Table 1). Only data of directly investigated specimens are provided. Very small

and probably monomorphic, CS $353 \pm 21 \mu\text{m}$. Head less elongated than in *S. canariensis*, CL/CW 1.248 ± 0.022 . Paramedian dents on the clypeal margin rather short and blunt, with a larger distance than in *S. canariensis*, CISpLM/CS 0.039 ± 0.008 , CISpD/CS 0.146 ± 0.005 ; lateral dents very blunt and short, having the shape of a broad bulge, CISpLL/CS 0.023 ± 0.003 . Distance between frontal carinae much larger than in *S. canariensis* (FL/CS 0.229 ± 0.008 , FR/CS 0.210 ± 0.013). Eye slightly larger than in *S. canariensis* and preocular distance moderately large (EL/CS 0.113 ± 0.007 , PrOc/CS 0.186 ± 0.012). Scape longer than in *S. canariensis*, SL/CS 0.745 ± 0.019 . Mesosoma much longer and slightly wider than in *S. canariensis* (ML/CS 1.254 ± 0.024 , MW/CS 0.593 ± 0.015). Metanotal groove deeper than in *S. canariensis*, MGr/CS 0.041 ± 0.006 . Petiole moderately wide and high (PeW/CS 0.270 ± 0.023 , PeH/CS 0.369 ± 0.003); in contrast to *S. canariensis*, the posterior slope of the petiole node is not much steeper than its anterior slope (Fig. 7). Postpetiole moderately wide and high (PpW/CS 0.324 ± 0.005 , PpH/CS 0.291 ± 0.007). Seta on pronotum longer than in *S. canariensis*, PnHL/CS 0.273 ± 0.028 . All body parts yellowish. Surfaces of the head, mesosoma, waist, and gaster smooth and shiny, except for small foveolae at the seta bases.



Figure 7. Lateral aspect of waist segments of *Solenopsis carolinensis*; Norway, Gjerstad, greenhouse, 9 December 2015. The posterior slope of the petiole node is not much steeper than the anterior one.

Geographic distribution. Largely unknown. Confirmed for heated greenhouses in Norway, France, and England and outdoors in North Carolina, USA. *Solenopsis carolinensis* is a tramp species with the potential to become distributed over tropical and subtropical regions worldwide, but it does not seem to occur as a pest species.

Biology. Unknown. Most probably a species foraging in soil and litter. It was found by Forel (1901) in rotten tree stumps and in soil in close association with nests of other ant species or termites.

Discussion

There are no taxa described before 1901 that are morphologically similar to the two focal species, which renders the naming proposed here stable. The two-species hypothesis appears to be very clear, but it cannot be excluded that some taxa synonymized here under *Solenopsis canariensis* and *S. carolinensis* may be shown to be separate cryptic species when large standardized data sets become available. The error of image evaluation (see also Csósz et al. 2023a) would then become a true issue. There is so far no convincing analysis of gyne morphologies that have been used to justify the existence of cryptic species.

Pacheco and Mackay (2013) repeatedly emphasized the diagnostic role of gynes in separating *Solenopsis texana* from related species (e.g., pp. 57, 61, 332), but their statements are contradictory. Two characters they repeatedly considered to be diagnostic—coloration and eye size—are both inconsistent within the work: eight different coloration terms, ranging from black to yellow, are used to describe the gyne of *S. texana*. The greatest eye diameter, identical to the EL used here, is reported either as “0.17–0.20 mm” or as “0.16 mm.”

The status of *Solenopsis molesta* var. *castanea* Wheeler, 1908, synonymized by Pacheco and Mackay (2013) with *S. carolinensis*, and of *Solenopsis texana* subsp. *catalinae* Wheeler, 1904, synonymized by Pacheco and Mackay (2013) with *S. texana*, are unclear because no type specimens or evaluable images are currently available.

The similar species *Solenopsis abjectior* Pacheco & Mackay, 2013 from Argentina obviously belongs to the same species group but is certainly heterospecific. According to image analysis of the holotype specimen CASENT0908829 (<https://www.antweb.org>), *Solenopsis abjectior* differs from both *S. canariensis* and *S. carolinensis* by much wider waist segments, additionally from *S. canariensis* by a much longer mesosoma, and from *S. carolinensis* by a much shorter scape.

There are no reports from the keepers of tropical greenhouses that the two *Solenopsis* species dealt with here have caused any problems. As soil and litter foragers, they escape attention and are unlikely to climb up to food dispensers placed on bushes or trees to feed animals living in the houses. However, their population size, demographic structure, and behavior are unknown, and they might possibly have an influence on small soil arthropods. There are also no reports that *Solenopsis canariensis* was observed as a pest ant in outdoor habitats of the Arabian Peninsula (Sharaf et al. 2020). However, studying the biology and geographical range expansion of these species is of interest. In a genetic study of Sharaf et al. (2020), specimens of *S. canariensis* from Saudi Arabia were placed in the same clade as five New World species and separate from the clade with 10 Old World species. Accordingly, the region of origin of *Solenopsis canariensis* and *S. carolinensis* should be the New World subtropics or tropics.

A final comment is provided here on methods of species discrimination in very small ants. There are a large number of ant taxonomists who applied very simple measurement systems rounded to 0.01 mm during the last 40 years for the description of very small ants (e.g., DuBois 1986; Radchenko 1989; Collingwood and Agosti 1996; Bolton 2007; Pacheco and Mackay 2013; Brassard et al. 2020; Sharaf et al. 2020). As it is often impossible to recognize discriminative characters of cryptic species by subjective eye inspection, their exact numeric recording is essential (A) to become aware of these differences and (B) to assess their validity. Authors who investigate very small ants should realize that they have to adapt their methodology to the size of the objects—an issue that has already been addressed by Creighton (1950, pp. 233–234). For example, in the two species compared here, interspecific differences of diagnostic characters are very small: only 0.013 mm in frontal lobe distance FL or only 0.025 mm in scape length SL. Using insufficient optical systems and recording these characters only to the second decimal place would inevitably disguise the value of these useful characters. To conclude, morphological taxonomy has no chance to depict the true structure of biodiversity without adapting the methodology to the size of objects, and it fails to make hypotheses testable without describing any character numerically—this applies to linear or angular measurements, counts of elements, evaluation of color structures, and similar characters.

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Supplementary material 1

Occurrences and morphological data

Authors: Bernhard Seifert

Data type: xlsx

Explanation note: Morphometric data and geographical coordinates of *Solenopsis canariensis* and *S. carolinensis*.

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