Species or morphological variation? A multivariate morphometric analysis of *Afroleius simplex* (Acari, Oribatida, Haplozetidae)

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Population differences of *Afroleius simplex* Mahunka have been studied by means of multivariate morphometric analyses based on nine variables measured from 87 specimens. Principal component (PCA), discriminant function, and cluster analyses were performed. There is no separation of specimens into clusters and therefore the specimens are regarded as a single species.

Key words: *Afroleius simplex*, principal component analysis, discriminant function analysis, cluster analysis

The oribatid genus *Afroleius* Mahunka (Haplozetidae) comprises three known species, *A. deformis*, *A. minor*, and *A. simplex*, all described by Mahunka (1984), and they have thus far been recorded only from the type localities in the Western Cape Province of South Africa. The Acarology collection of the National Museum (Bloemfontein, South Africa) contains many more specimens of this genus, including species new to science, collected in other parts of South Africa.

The genus *Afroleius* is diagnosed by the presence of sacculi, movable pteromorphs, absence of translamella, moderately long rostral and lamellar setae, minute or very short interlamellar, notogastral, epimeral and ventral setae, presence of foveolae on dorsal and ventral surfaces (to a certain extent), six pairs of genital setae, and all adanal setae (three pairs) located posterior to the adanal lyrifissure. The species are mainly distinguished by the shape, size, and orientation of the sensillus, shape, size, and distribution of the foveolae, and the shape of the notogaster, especially in lateral view.

Certain specimens collected from various localities in South Africa are very similar to *A. simplex*, but differ from the type material in the presence of foveolae in the epimeral region (Fig. 1A,B), the length of the lamellar setae, and body size, including individuals with intermediate character states. Multivariate morphometric analyses were carried out to try to resolve the uncertainty as to whether these specimens belong to *A. simplex* or to a different (new) species.

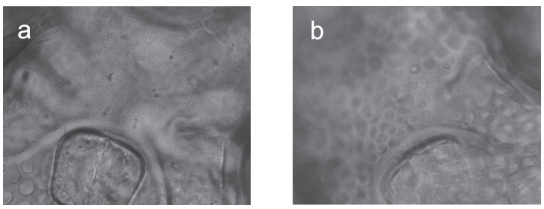

Figure 1 Epimeral region (A) specimen without foveolae (locality 1632), (B) specimen with foveolae (locality 1769).

MATERIALS AND METHODS

Eighty-seven specimens from 39 samples were used for the morphometric analyses. The samples were pooled to form eight groups, clustering the samples based on proximity of collection site and habitat (Fig. 2). Group A: 58 Tzitzikama forest (33°S, 23°E) litter in indigenous forest; 66, 68 Knysna (34°S, 23°E) litter in indigenous forest; 97 Knysna (33°S, 22°E) bark; 99, 3288, 3290, 3291 George (33°S, 22°E) litter in indigenous forest. Group B: 653, 790 Mtunzini (28°S, 31°E) soil and plant litter in natural forest; 3302 Vernon Crookes Nature Reserve (30°S, 30°E) litter and soil; 3730, 3740, 3741, 3745, 3749 Cape Vidal (28°S, 32°E) litter in indigenous forest; 3751 St Lucia (28°S, 32°E) litter in riverine forest. Group C: 3 King Williamstown (32°S, 27°E) moss and bark; 6, 2061 Queenstown (31°S, 26°E) litter and soil. Group D: 249, 3878 Fouriesburg (28°S, 28°E) litter and compost; 1632, 1635, 1638 Leliehoek (29°S, 27°E) litter and soil. Group E: 1774 Clarens (28°S,

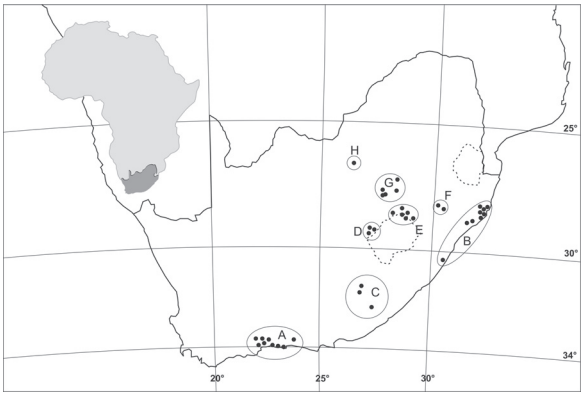

Figure 2 Map of South Africa with collection sites illustrated.

28°E) litter; 1776, 3460 Golden Gate (28°S, 28°E) litter and soil; 1783 Witsieshoek (28°S, 28°E) litter and soil; 2905 Royal National Park (28°S, 29°E) litter in indigenous forest. Group F: 1878, 1880 Dundee (28°S, 30°E) litter and soil. Group G: 335 Lindley (27°S, 27°E) litter; 1728, 1743 Frankfort (27°S, 28°E) litter and soil; 1768, 1769 Edenville (27°S, 27°E) litter and soil. Group H: 3241 Coligny (26°S, 26°E) litter and soil.

Temporary preparations were made from which camera-lucida drawings were produced. Landmark points (homologous points) (Houck & OConnor, 1998) were selected so that measurements can be taken with both points sharply focused simultaneously. Distances from the left and right side of the body were averaged for each specimen.

Data

Measurements (Fig. 3A,B): Dorsal side: 1) total length, 2) length of lamellar seta *le*, 3) distance between insertion points of lamellar setae *le*, 4) distance between insertion points of interlamellar setae *in*, 5) distance between insertion points of notogastral setae *la*, 6) distance between insertion points of notogastral setae *lp* and h_3. Ventral side: 7) diagonal distance between insertion points of epimeral seta *1a* left and *3a* right, and vice versa, 8) distance between posterior border of genital opening *gen* and anterior border of anal opening *an*. Ordinal data: 9) presence or absence of foveolae in the epimeral region (1, present; 2, vague; 3, absent).

Statistical procedures

Data were standardized [(measurement – sample mean)/standard deviation] to compensate for the use of continuous data as well as ordinal data (Quinn & Keough, 2002), and also to eliminate the effect of non-normal distribution. A principal component analysis (PCA) and discriminant function analysis (DA, also referred to as canonical analysis) were performed. The use of standardized data is the standard transformation used in PCA and DA when variables are considered equally important (Fowler et al., 1998). A cluster analysis was also performed on the standardized data using Euclidian distances and unweighted pair-group averages (UPGMA) as linkage method (Quinn & Keough, 2002). All analyses were performed using STATISTICA v.6.

RESULTS

Principal component analysis

The first four components contribute 77.9% of the total variance (Table 1). Component 1 is a general component (all coefficients of the same sign) and is related to size, whereas components 2, 3, and 4 are bipolar (containing positive and negative coefficients) and are related to shape (Pimentel, 1979) (Table 2). A scatterplot of component 1 against component 2 (Fig. 4) of all cases show no clustering of the cases (specimens).

Discriminant function analysis

A summary of the results of the DA is given in Table 3, with the variables listed in order of significance of contribution to the model. The last 3 variables (distance between the insertion points of the interlamellar setae, distance between genital and anal plates, and distance between the insertion points of *1a* on the left and *3a* on the right, and vice versa) are statistically not significant. The length of the lamellar setae, presence or absence of foveolae on the epimeres, and total length are the variables that contribute most to the dis-

Table 1 Eigenvalues and percentage of variance.

Component	Eigenvalue	% total variance	Cumulative %
1	4.026	44.7	44.7
2	1.188	13.2	57.9
3	0.976	10.9	68.8
4	0.817	9.1	77.9

Table 2 Eigenvectors based on the correlation matrix.

	Component			
Variable	1	2	3	4
Total length	0.428	-0.022	-0.189	-0.095
Length lamellar seta	0.189	-0.196	0.846	0.055
Distance *le-le*	0.378	0.218	0.104	0.065
Distance *in-in*	0.283	0.296	0.158	0.673
Distance *la-la*	0.436	0.053	-0.161	0.015
Distance *lp-*h_3	0.265	-0.461	-0.337	0.160
Distance *1a-3a*	0.302	-0.201	0.220	-0.620
Distance *gen-an*	0.441	-0.071	-0.151	-0.032
Epimeral foveolae	0.095	0.751	-0.028	-0.344

Table 3 Discriminant function analysis: summary (n = 87).

Variable	Wilks' λ	Partial λ	F	P
Length lamellar seta	0.070	0.442	12.827	<0.001
Epimeral foveolae	0.053	0.584	7.219	<0.001
Length	0.048	0.645	5.581	<0.001
Distance *lp-*h_3	0.045	0.687	4.631	<0.001
Distance *le-le*	0.043	0.721	3.926	0.001
Distance *la-la*	0.040	0.780	2.853	0.011
Distance *in-in*	0.037	0.830	2.079	0.057
Distance *gen-an*	0.036	0.849	1.801	0.100
Distance *1a-3a*	0.035	0.877	1.421	0.210

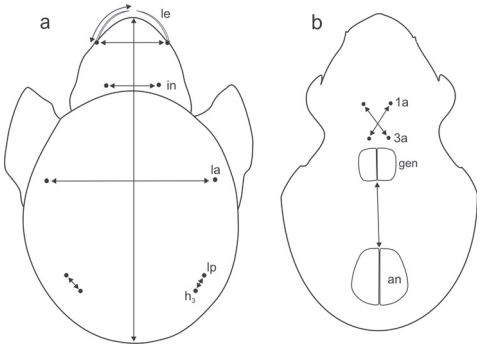

Figure 3 Diagram of *Afroleius simplex* indicating landmark points; (A) dorsal view, (B) ventral view.

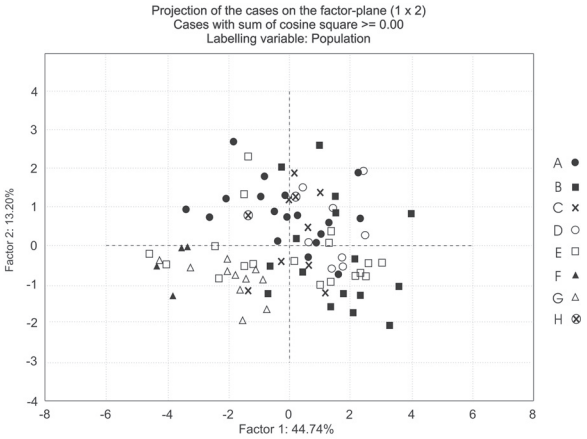

Figure 4 Principal component analysis: projection of cases, components 1 × 2.

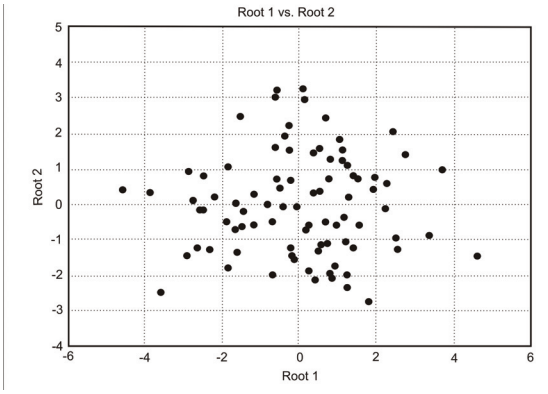

Figure 5 Discriminant function analysis: projection of cases, root 1 × root 2.

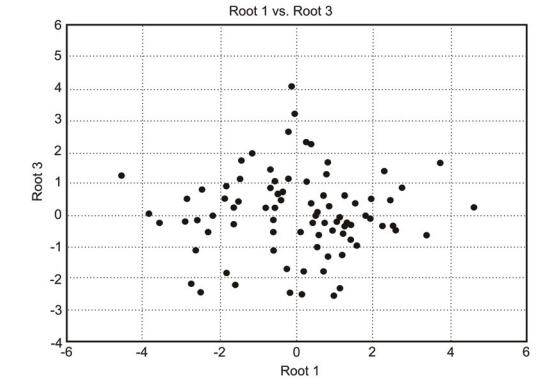

Figure 6 Discriminant function analysis: projection of cases, root 1 × root 3.

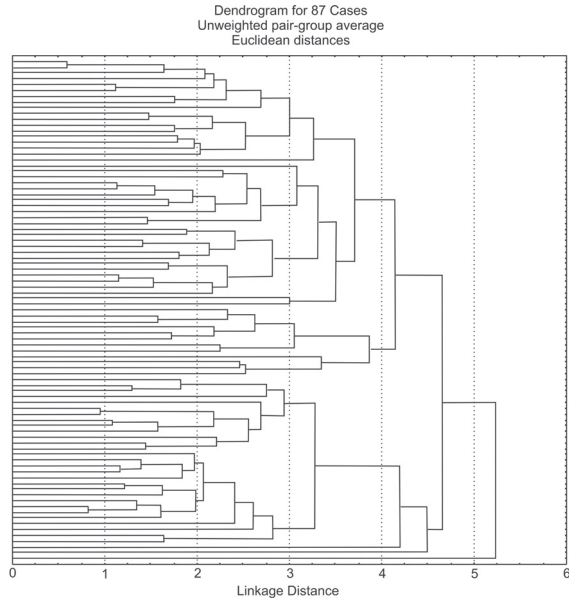

Figure 7 Dendrogram of cases (case names omitted).

crimination of cases (low partial lambda and high F-value). Scatter plots of the canonical scores of all cases show no clustering (root 1 vs. 2, Fig. 5; root 1 vs. 3, Fig. 6).

Cluster analysis

A dendrogram of the Euclidian distances of all 87 cases (Fig. 7) indicates no distinct clustering of any of the cases.

DISCUSSION

The multivariate analyses show no clustering of specimens on the basis of the selected morphometric measurements and the degree of expression of foveolae in the epimeral region. Therefore all the specimens investigated may be identified as *A. simplex*. The diagnosis of the species should be broadened to include the variation displayed. The foveolae on the epimeral region can be present, absent, or vaguely expressed, the apices of the left and right lamellar setae may or may not meet anteriorly, and the total length varies between 262 and 357 µm, with an average of 309 µm. Measurements taken on the ventral side of the body are remarkably constant, irrespective of the size of the specimen, and show the lowest discriminatory power in these analyses.

Acknowledgments

I am grateful for the help of Dr Lizel Hugo, National Museum, Bloemfontein.

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