

## GEOGRAPHIC VARIATION IN THE COCONUT MITE, *ACERIA GUERRERONIS* KEIFER (ACARI: ERIOPHYIDAE): A GEOMETRIC MORPHOMETRIC ANALYSIS

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**ABSTRACT** - The coconut mite, *Aceria guerreronis* Keifer (Prostigmata: Eriophyidae), is a major pest in several coconut production areas worldwide. Information on region of origin and sources of recent introductions of this mite are important aspects to guide evaluation of biological control agents and adoption of quarantine measures. Studies on the geographic pattern of morphological variation among populations of the coconut mite from different countries and continents can provide some of the biogeographic information required. Geometric morphometric analyses allow us to quantify and visualize shape variation, eliminating the effect of size, position and orientation, within and among samples of organisms. The objective of this study was to investigate the morphological variation of the prodorsal shield, coxigenital and ventral regions of the *A. guerreronis* idiosoma throughout its distribution in America, Africa and Asia, using Relative Warp Analysis (*thin-plate splines* function) and to attempt to relate this variation to the area of geographic origin from among the studied populations. Variation in the configurations of prodorsal shield, coxigenital and ventral regions were observed. For the last two body regions, this variation was related to the origin of populations. Considerable morphometric variability was observed between American populations, which in turn were distinct from the African and Asian populations. The latter were morphologically similar. These results support previous indications that *A. guerreronis* is of American origin and that it was introduced to Asia from Africa, or from the same source as that of the African populations. Some considerations on the use of the geometric morphometric analyses in taxonomic studies of eriophyoid mites are presented.

**Keywords** - Acari, Eriophyoidea, Eriophyidae, morphometry, *Cocos nucifera* L., Relative Warp Analysis, Africa, America, Asia.

### INTRODUCTION

*Aceria guerreronis* Keifer (Prostigmata: Eriophyidae), the coconut mite, is an invasive species that became a key pest of coconut (*Cocos nucifera* L.) in the Americas, Africa and recently in Indo-Oceanic countries. The species was described by Keifer (1965) from specimens from Guerrero, Mexico. However, some collection records indicate that it was already present in other regions in South-America (Robbs and Peracchi, 1965; Doreste, 1968; Zuluaga and Sánchez, 1971). Almost simultaneously with its original description, the mite was reported in Africa (Cabral and Carmona, 1969; Mariau, 1969). The most recent records of the coconut mite were in Asia, more specifically in India and Sri Lanka, where the spe-

cies was unknown until the end of the 1990s (Sathiamma *et al.*, 1998; Fernando *et al.*, 2002).

Acaricides are frequently applied to control this mite. However, in most production areas, coconut is traditionally grown by small-scale farmers who cannot afford the continuous use of acaricides (Moore and Howard, 1996; Muthiah and Bhaskaran, 2000; Ramaraju *et al.*, 2002). The major prospects for management and control of *A. guerreronis* involve the utilization of biological control agents.

The knowledge about the origin of the coconut mite is important to determine priority areas to be considered in the search for effective natural enemies (Moraes and Zacarias, 2002). Preventive measures to avoid the introduction of *A. guerreronis* should be applied in production

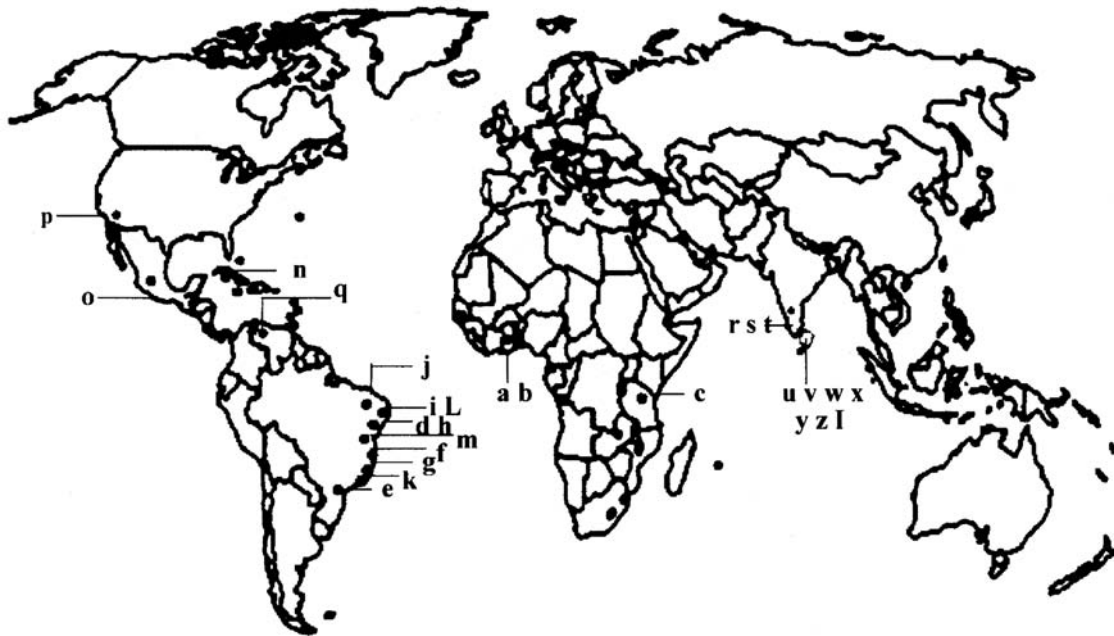


Fig. 1. Sampled *Aceria guerreronis* populations - **AFRICA**: **a** - Ipinkle; **b** - Ouidah, **Benin**; **c** - Micuranga, **Tanzania**. **AMERICA**: **d** - Aracaju, Sergipe; **e** - Ilha Bela, São Paulo; **f** - Ilhéus, Bahia; **g** - Janaúba, Minas Gerais; **h** - Lagarto, Sergipe; **i** - Maceió, Alagoas; **j** - Petrolina, Pernambuco; **k** - Quissamã, Rio de Janeiro; **L** - Recife, Pernambuco; **m** - São Félix, Bahia, **Brazil**; **n** - Havana, **Cuba**; **o** - Ayatolac de Alvarez, Guerrero, **Mexico**; **p** - San Diego, California, **EUA**; **q** - Paéz, Zulia, **Venezuela**. **ASIA**: **r** - Kasaragod, Kerala; **s** - Kayankulam, Kerala; **t** - Vellanikara, Kerala, **India**; **u** - Hingurakgoda; **v** - Kalpitiya; **x** - Madampe; **w** - Laksha Uyana; **y** - Madurankuliya; **z** - Unagala Vehera; **I** - Wanathavillu, **Sri Lanka**.

areas where the pest is still not present. Information on the sources of *A. guerreronis* invading new areas may guide the adoption of quarantine measures. Studies on the phenotypic and genetic variability among *A. guerreronis* populations from different countries and continents may provide some of the information required to understand the biogeography and invasion history of the coconut mite.

Shape variation may be interpreted as changes occurring during the evolutive history of a taxon. In this way, geometric morphometric analysis provides information that may be used in order to obtain evidence of similarity among taxa/populations and may be useful in testing hypotheses related to ecology, systematics and or evolution (Rohlf and Marcus, 1993; Premoli, 1996). The utilization of geometric morphometry in shape studies has promoted the development of biometric analyses (Rohlf and Marcus, 1993; Bookstein, 1996). Geometric morphometric methods allow the quantification and visualization of morphological variation within and between samples of organisms (Alibert *et al.*, 2001).

Studies on historical biogeography using geometric morphometry have been conducted with the most diverse groups of organisms, from plants, for example the olive tree, *Olea europaea* L. (Terral *et al.*, 2004), to fishes, for example *Mugil cephalus* L. (Corti and Crosetti, 1996). In Acarology, studies using this tool are restricted to ticks (Metastigmata: Ixodidae) (Pretorius and Clarke, 2000,

2001; Clarke and Pretorius, 2005) that also correspond to the first studies with Arachnida. However, the idea of standardizing the shape of structures, comparing setal positions using "deformation grids" and quantifying the variation of these positions even antedates the development of modern geometric morphometry techniques. Rowell *et al.* (1978) conducted studies of this type to determine homologies in the chaetotaxy of prodorsal shield of Phytoseiidae in relation to Ascidae with the objective of adopting the first family to the nomenclature proposed by Lindquist and Evans (1965).

Studies on the genetic variability and morphological variation of quantitative traits, using multivariate analyses, of *A. guerreronis* populations searching for information on origin and invasion history have been conducted by Navia *et al.* (2005) and Navia *et al.* (2006).

The objective of the present study was to investigate morphological variation between populations of *A. guerreronis* within its distribution in America, Africa and Indo-Oceanic region, using the geometric morphometrics based on Relative Warp Analysis (RWA), and to relate this variation with the geographic origin of the studied populations. Results were analyzed taking into account the historic distribution data of the mite around the world in order to provide or support information on biogeographical aspects and to contribute our knowledge of its taxonomy.

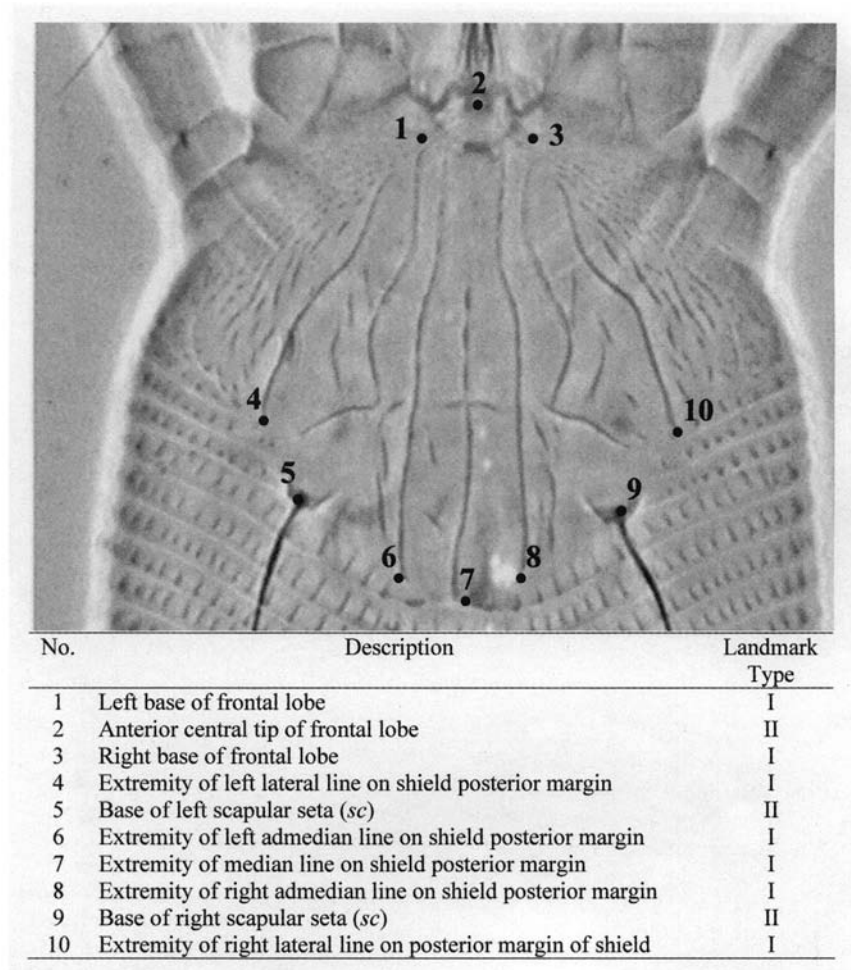


Fig. 2. Morphological landmarks selected from the prodorsal shield of *Aceria guerreronis* according to Bookstein (1991).

## MATERIAL AND METHODS

**Material examined** - Twenty-seven *A. guerreronis* populations from countries in Africa (Benin, Tanzania), Americas (Brazil, Cuba, Mexico, USA and Venezuela) and Asia (India and Sri Lanka) were analyzed (Fig. 1). All populations were collected from coconut fruits except for a population from San Diego, California, USA, collected from developing tips of young Queen Palm, *Syagrus romanzoffiana* (Cham.) Glassm. (Arecaceae). Mites were collected through direct examination using a stereomicroscope, preserved in 70% ethyl alcohol (no longer than 3 months) and subsequently mounted on slides in modified Berlese medium (Amrine and Manson, 1996). The twelve best females (specimens in perfect condition common to all populations) mounted in dorsoventral position from each population were selected for evaluation. Specimens examined were deposited in the mite reference collection of the "Escola Superior de Agricultura Luiz de Queiroz", Piracicaba, SP, Brazil.

**Image capturing** - Images of body regions of the selected specimens were obtained using a video system, consisting of a phase contrast optical microscope (Leica DMLS) connected to a digital camera that in turn was connected to a computer. Images of the prodorsal shield and coxigenital region were obtained using a 100x magnification objective and images of the ventral region were obtained using a 40x magnification objective. Landmarks were recorded and their positions transformed into Cartesian coordinates (x and y) using the Tpsdig program (Rohlf, 2000).

It was not possible to obtain good images of the ventral aspect of specimens from Ouidah, Benin (b) and Havana, Cuba (n) because most had the opisthosoma in dorsolateral position.

**Landmark digitization** - Three *A. guerreronis* body regions were separately evaluated in this study - prodorsal shield, coxigenital and ventral (including coxigenital region and opisthosoma). These regions were selected due to their taxonomic importance and high number of landmarks that could be defined. Ten landmarks in

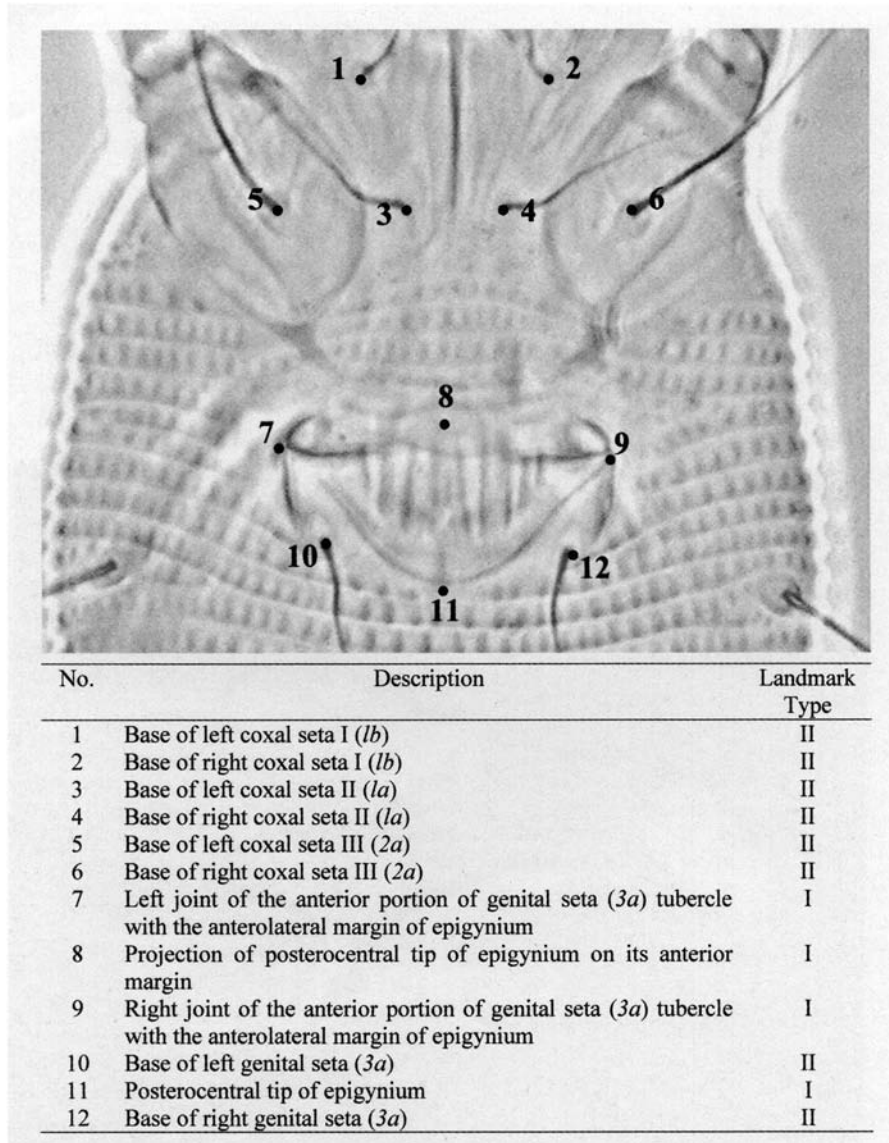


Fig. 3. Morphological landmarks selected from the coxigenital region of *Aceria guerreronis* according to Bookstein (1991).

the prodorsal shield (Fig. 2), 12 in the coxigenital (Fig. 3) and 19 in the venter were selected (Fig. 4). The classification of landmarks was according to Bookstein (1991). The description of homologous landmarks and their classification are specified in the respective figures (Figs. 2-4).

**Geometric morphometric analysis** - The RWA was based on *thin-plate splines* function. RWA is the Principal Components Analysis (PCA) of the covariance matrix of the partial warp scores and is performed with  $\alpha = 0$  (Bookstein, 1991). In other words, relative warps with  $\alpha = 0$  is a PCA of shape expressed in terms of partial warps, but not dependent on them (Rohlf, 1993).

The *TpsSmall* program was used to determine if the shape variation of the *A. guerreronis* body regions studied was sufficiently small for the application of the deformation analysis to be possible. This program allows the assess of the accuracy of the approximation of shape space by the tangent space (Rohlf, 1997).

Configurations of the anatomical landmarks were superimposed by the least-squares method that transforms a landmark configuration, superimposing it on a reference (consensus) configuration translating, scaling and rotating one of them so that the sum of squares of the distances between the corresponding points among configurations would be the least possible (Monteiro and Reis, 1999). The variation of each landmark was represented by the

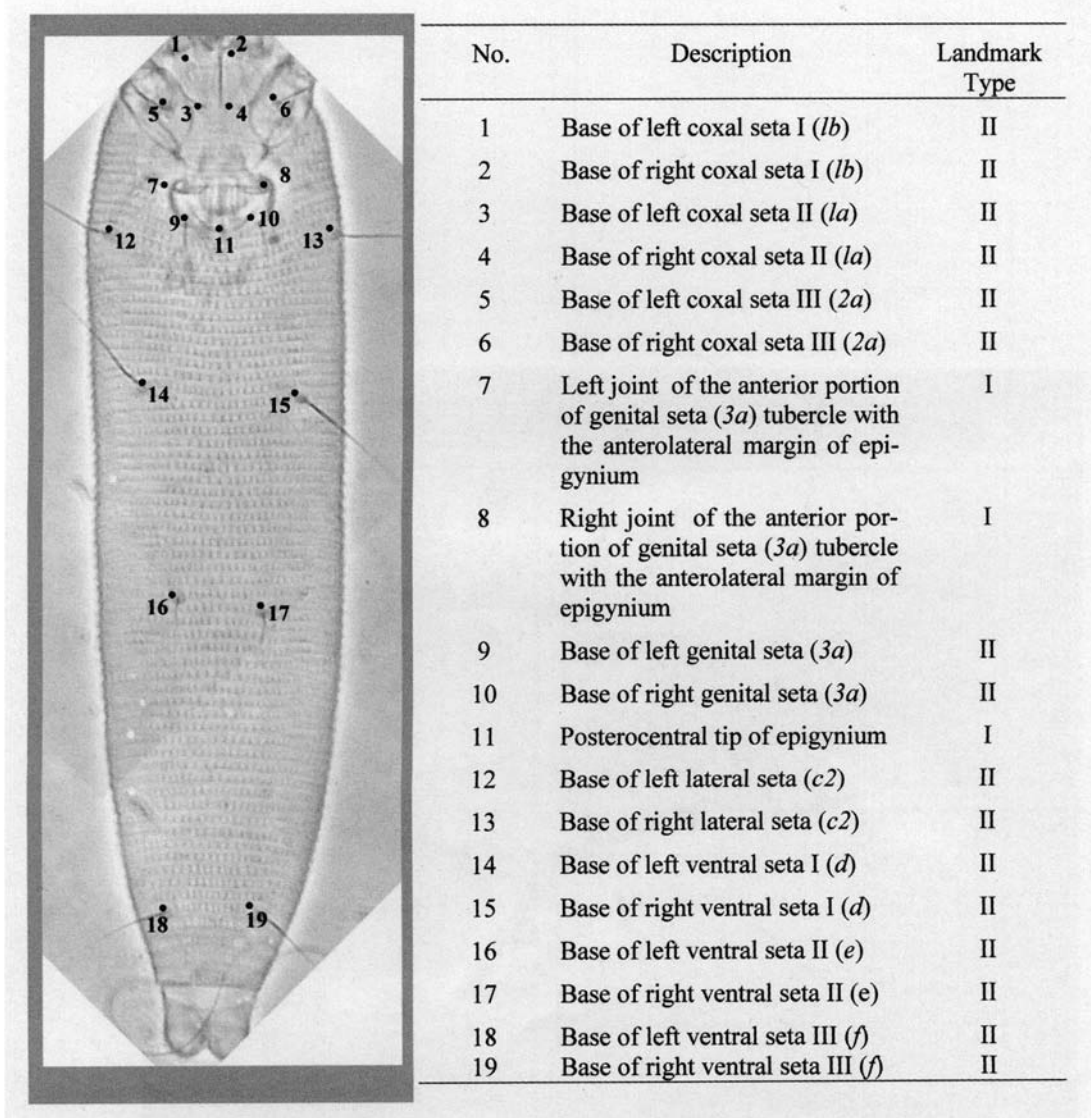


Fig. 4. Morphological landmarks selected from the ventral region of *Aceria guerreronis* according to Bookstein (1991).

dispersion and extension of vectors ( $\rightarrow$ ) in relation to the medium position (consensus configuration), represented by the point of origin of vectors. The variation of landmarks of each body region of *A. guerreronis* was analyzed for: 1) all specimens; and 2) population averages. The consensus configuration was separately obtained for each body region and population with the objective of analyzing differences between population averages using RWA. In the last series of analyses, the program *Tpsrelw* was used (Rohlf, 1998).

The warps, represented by the *thin-plate splines* function, were determined and decomposed in shape descriptors which had uniform components that described stretching, compression or scission (global variation) and localized components corresponding to changes that occurred at specific regions (Bookstein, 1991). Relative

warps were obtained through the matrix of the scores. Ordination graphs and deformation grids associated with each axis of the relative warps (RW) were computed for each studied body region following Rohlf (1993).

## RESULTS

Analyses were conducted to describe the morphological variation between populations of *Aceria guerreronis*. The variation in shape found in each set of data was small enough and allowed the statistical analyses to be performed in the tangent space (which is linear) approximate to Kendall's shape space (which is nonlinear).

**Prodorsal Shield** - It was observed that there is variation in the prodorsal shield configuration (Figs. 5a, b). This variation is mainly observed between individuals

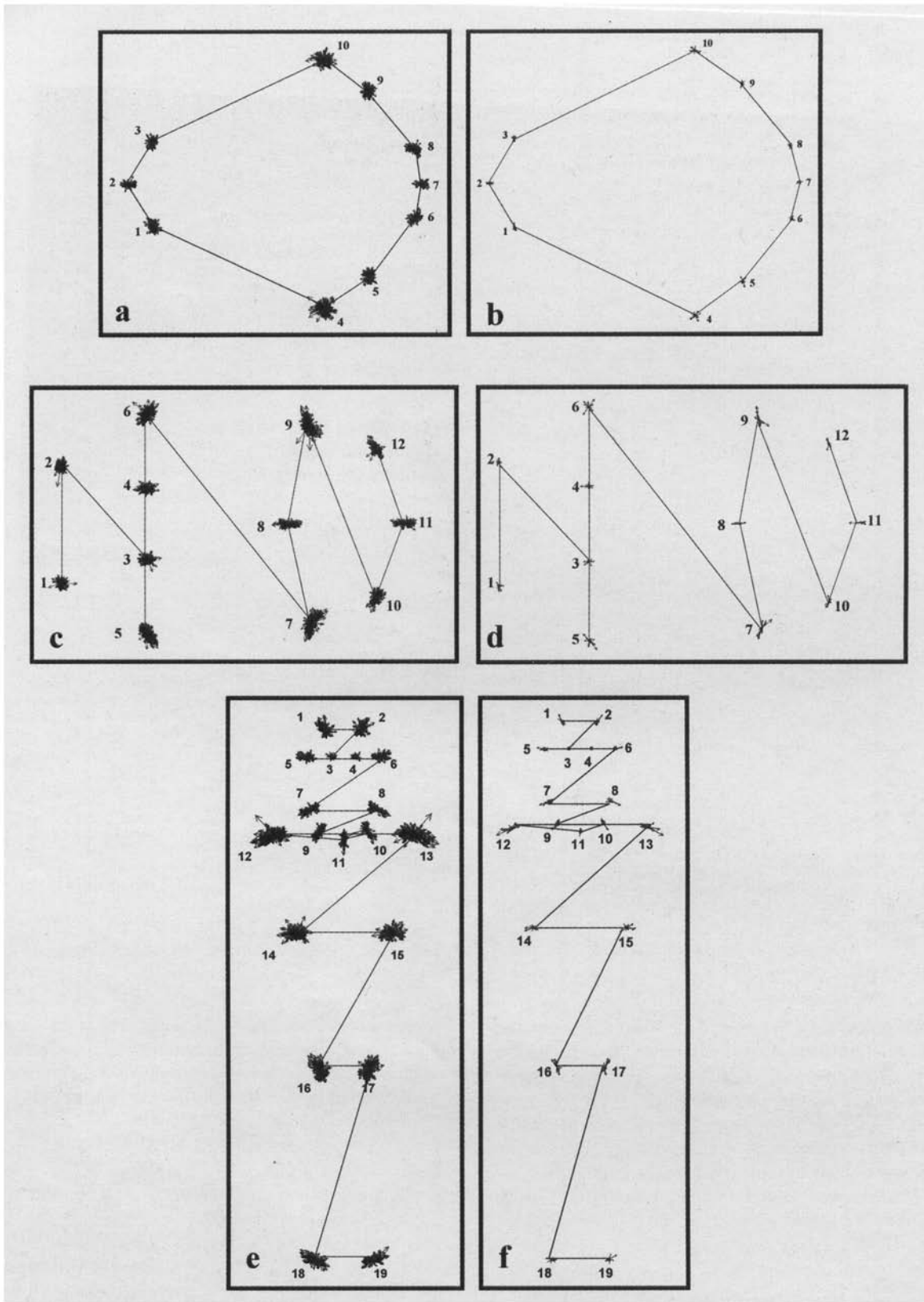


Fig. 5. Configuration of *Aceria guerreronis* anatomical landmarks obtained by superimposing figures created by the least-square procedure. Lines connect landmarks of configurations and variation in shape can be observed around each landmark. Figures on the left are consensus of all individuals and on the right are of an individual population (a, b - prodorsal shield; c, d - coxigenital; e, f - ventral region).

(Fig. 5a). The variation in the position of these landmarks between populations is minimal (Fig. 5b). These results indicated significant intra-population variability in the shape of the prodorsal shield of this mite.

In the consensus configuration, the most evident variation between populations was observed around landmarks 4 and 10 (posterior extremity of the left and right lateral line, respectively) (Fig. 5b). These landmarks are related to the width of the prodorsal shield (displacement of the laterals) and to the position of the lateral lines in relation to the posterolateral margin shield.

The 10 landmarks of the prodorsal shield generated 16 relative deformations for populations. The two first axes of the relative deformations jointly explained 49.3% of the total shape variation, the first one explained 32.0% and the second one, 17.3% of the variation.

In the dispersion graph, where *A. guerreronis* populations were projected against axes of prodorsal shield relative deformations (Fig. 6), it was observed that: 1) All non-Brazilian American populations (Havana (n), Guerrero (o), California (p) and Zulia (q)), presented variations in the shape of the shield represented by negative deviations of RW1 and RW2 axes, being located in the left inferior quadrant between these axes; 2) All the African populations (Ipinkle (a) and Ouidah (b), Benin and Micuranga (c), Tanzania) as well as Indian populations (Kasaragod (r), Kayangulam (s) and Vellanikara (t)) presented variation in the shield represented by positive deviations along RW1 axis. 3) Populations from Brazil and Sri Lanka presented variation represented by positive and negative deviations of RW1 and RW2 axes, being distributed in the four quadrants of the graph.

Populations showing variation in the prodorsal shield region represented by deviations along positive RW1 axis (Fig. 6A) presented more elongated frontal lobe and prodorsal shield (Fig. 6A), while populations with variation due to the displacement along the negative RW1 axis (Fig. 6B) presented shorter shield (Fig. 6B). Prodorsal shield variation represented by deviations along the positive RW2 axis (Fig. 6C) presented closer landmarks 4 and 10; suggesting narrowing of the posterolateral region of the shield. In contrast, variation represented by a deviation along the negative RW2 axis (Fig. 6D) presented more distance between landmarks 4 and 10; suggesting a wider posterolateral region of the shield. It was observed that: 1) non-Brazilian American populations have wider and shorter prodorsal shields; 2) African and Indian populations have more elongated prodorsal shields, with closer or more distanced landmarks 4 and 10; 3) populations from Brazil and Sri Lanka have varied configurations of prodorsal shield.

**Coxigenital** - Relative variation of coxigenital landmark regions, considering the consensus configuration of all individuals and of each population are shown in Figs. 5c and 5d, respectively. It was observed that variation in

this body region are due to differences between individuals (Fig. 5c) and also between populations (Fig. 5d). This indicated that there is intra- and inter-population variability in this region of *A. guerreronis*. Relative variation of landmarks, considering the consensus between populations (Fig. 5d) showed that more accentuated variations occurred around landmarks: 1) 7 and 9, which are left and right junctions of the anterior portion of the genital seta (3a) tubercle with anterolateral margin of epigynium, respectively. These landmarks collectively represent the epigynium width in its anterolateral portion; 2) 5 and 6, which are left and right bases of coxal setae III (2a), respectively, and representing the space between these setae; and 3) 8 and 11, which are extremes of the anterior and posterior margins of the epigynium, respectively and collectively represent the epigynium length. Landmarks 7 and 9 in combination with 8 and 11 reflect the epigynium position and shape (length and width).

The 12 landmarks of the coxigenital region generated 20 relative deformations for *A. guerreronis* populations. The first two axes of relative deformations jointly explained 74.7% of the total variation of this region, the first one explained 61.9% and the second one, 12.8% of this variation. In the dispersion graph, where *A. guerreronis* populations were projected against relative deformations axes of the coxigenital region (Fig. 7), it was observed that: 1) All Brazilian populations (Aracaju (d); Ilha Bela (e); Ilhéus (f); Janaúba (g); Lagarto (h); Maceió (i); Petrolina (j); Quissamã (k); Recife (L) and São Félix (m)) showed relative variation represented by deviations along the negative RW1 axis. The population from Petrolina (j) have extreme deviation along this axis; 2) All non-Brazilian American populations (Havana (n); Guerrero (o); California (p); Zulia (q)) have relative variation represented by deviations along the negative RW2 axis and most of them, similar to the Brazilian populations, along the negative RW1 axis. Only the population from Zulia (q), Venezuela, which had the greatest displacement along the negative RW2 axis, have variation represented by a small deviation along the positive RW1 axis; 3) All Asian populations (r, s, t, u, v, w, x, y, z, I) and two from West Africa, Benin (a,b), have variation along the positive RW1 axis, being the Indian population of Vellanikara (t) the one that presented extreme deviation along this axis; 4) African populations (a, b, c) were closely ordinated, in line, having relative variation represented by deviation along the positive RW2 axis. The population from Micuranga (c) have a slight displacement along the negative RW1 axis, while populations from Ouidah and Ipinkle (a, b) have variation represented by deviations along the positive RW1 axis.

Populations showing variation in the coxigenital region represented by deviations along the positive RW1 axis (Asian and West African), have a more elongated coxigenital region, and also an epigynium proportionately

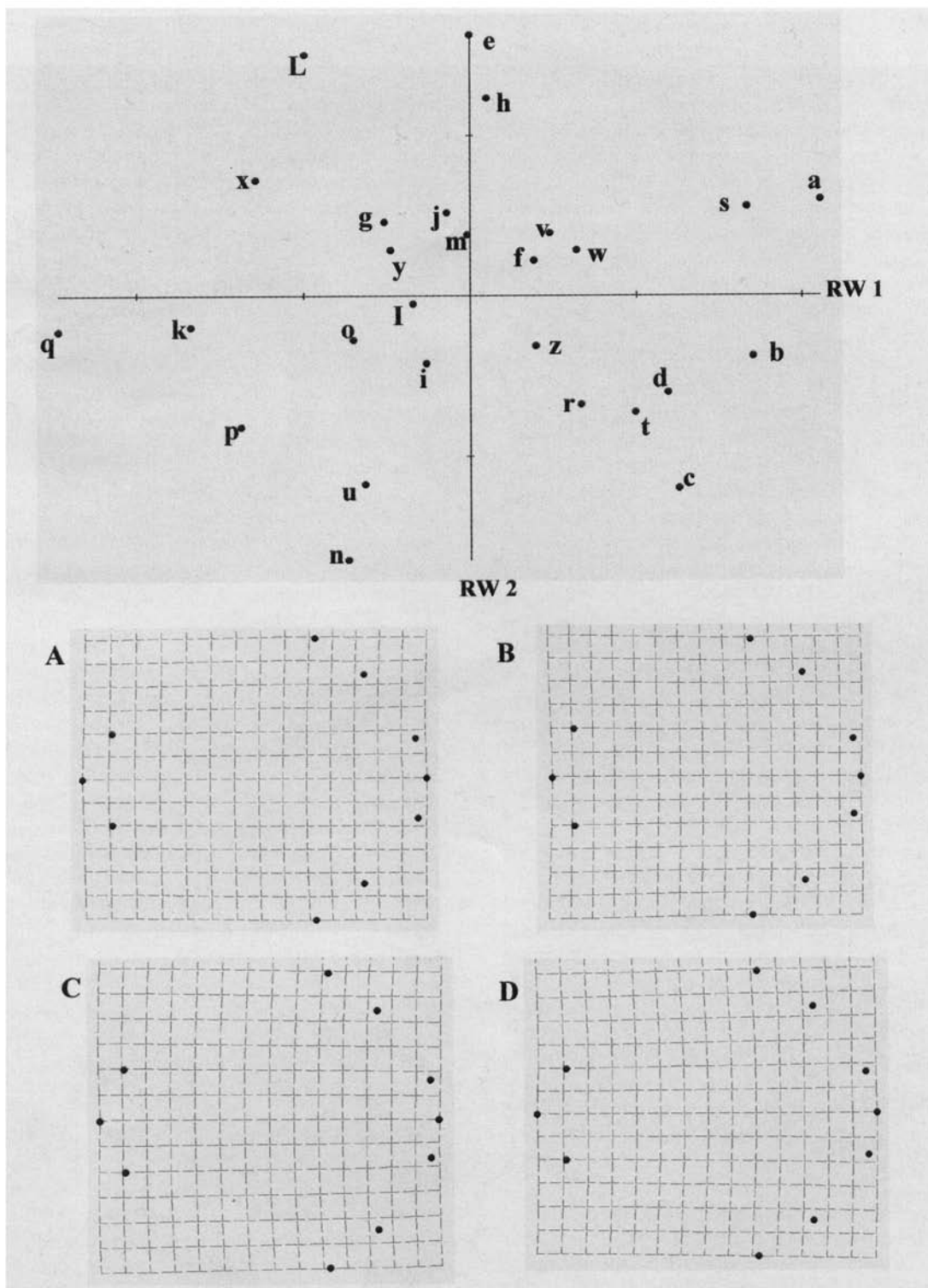


Fig. 6. Relative Warps (RW) for values  $\alpha = 0$  of the prodorsal shield of *Aceria guerreronis*. grids of relative warps show hypothetical shapes. Variation in the shape of the prodorsal shield are shown as **A** - positive deviations of the mean in the axis of relative warps 1; **B** - negative deviations of the mean in the axis of relative warps 1; **C** - positive deviations of the mean in the axis of relative warps 2; and **D** - negative deviations of the mean in the axis of relative warps.



more elongated (more distance between landmarks 8 and 11) and narrower (landmarks 7 and 9 closer) (Fig. 7A). In contrast, populations showing variation represented by deviations along the negative RW1 axis (Brazilian) have shorter coxigenital region, with the epigynium closer to the coxae and also proportionally shorter (landmarks 8 and 11 closer) and wider (more distance between landmarks 7 and 9) (Fig. 7B). Populations showing variations in the coxigenital region relative to deviations along the positive RW2 axis (non-Brazilian Americans) have wider epigynium (more distance between landmarks 7 and 9) in relation to the position of coxal setae III (2a), which are closer (landmarks 5 and 6 closer) (Fig. 7C). In contrast, populations showing variations represented by deviations along negative RW2 axis (for example, African) have a narrower epigynium (landmarks 7 and 9 closer) in relation to the coxal setae III (2a), which were far apart (more distance between landmarks 5 and 6) (Fig. 7D).

**Ventral** - Relative variation of ventral region landmarks considering the consensus configurations of all individual and of each population are shown in Figs. 5a and 5b, respectively. It was observed that variation in the *A. guerreronis* ventral region were due to differences between individuals (Fig. 5c) and also between populations (Fig. 5f). However, the intra-population variability was more evident. Relative variations of landmarks, considering the consensus configuration of populations (Fig. 5f) showed that more accentuated variation occur around landmarks: 1) 12 and 13, which are left and right lateral setae (c2) position, respectively, and jointly represent the distance between them; 2) 7 and 8, which are junctions between left and right anterior portion of the genital seta (3a) tubercle on the anterolateral margin of the epigynium, respectively, and which represents the epigynium position and width; and 3) 14 and 15, which are left and right bases of the ventral setae I (d) and collectively represent the distance between them.

The 19 landmarks of *A. guerreronis* ventral region generated 26 relative deformations. The first two axes of relative deformations jointly explained 83.7% of the total variation, the first one explained 75.9% and the second one, 7.8% of this variation.

In the dispersion graph where *A. guerreronis* populations were projected against relative deformation axes of the ventral region (Fig. 8), it was observed that: 1) African (a, c) and Asian (r, s, t, u, v, w, x, y, z, I) populations have variation represented by deviations along the positive RW1 axis; 2) American populations (d, f, g, h, i, j, L, m, p) have variation in the ventral region represented by deviations along the negative RW1 axis, except for populations from Quissamã (k) and Zulia (q), which have slight deviations along the positive RW1 axis, but projected a greater distance from African and Asian populations; 3) Brazilian populations from Aracaju (d) and Maceió (i) were both projected a greater distant from other American populations due to accentuated deviations along the negative RW2 axis.

Landmarks of the ventral region reflect the shape of idiosoma. Populations showing variations in this region, represented by deviations along the positive RW1 axis (African and Asian), have an idiosoma proportionately narrower and more elongate (with a smaller relative distance between bases of homologous setae and, simultaneously, greater distances between non-homologous setae) (Fig. 8A). In contrast, populations showing variation represented by deviations along the negative RW1 axis (American), presented a proportionally shorter and wider idiosoma (Fig. 8B). Variation related to deviations along the positive RW2 axis represented populations with a greater distance between coxal setae I (1b) and III (2a) in relation to the lateral setae (c2) (12 and 13), which are closer, and also ventral setae III (f) which are more distant from each other (opisthosoma wider posteriorly) (Fig. 8C). In contrast, deviations along the negative RW2 axis represented populations with coxal setae I (1b) and III (2a) closer together in relation to the lateral setae (c2) (12 and 13), which are farther apart (wider opisthosoma in the lateral seta region), and narrower opisthosoma closer to ventral setae III (f) (Fig. 8D).

## DISCUSSION

Morphometric differences in the prodorsal shield, coxigenital and ventral region configurations were detected among *A. guerreronis* populations along their area of geographic distribution using RWA.

Ordination of populations in the letterplot between axes of the two main relative deformations (RW) of prodorsal shield (Fig. 6) showed that shape variation in the analyzed configurations were not entirely related to the geographic origin of the sampled populations, although some tendencies have been observed, as mentioned above. These results may have been obtained due to limitations in the localization of the landmarks. The *A. guerreronis* prodorsal shield shape could be better represented if landmarks could have been selected on its lateral margin, in such way that their width would be better represented. However, some difficulties were encountered in the definition of other landmarks in the lateral area of the prodorsal shield other than those considered in this study. In eriophyoid mites, the prodorsal shield is often a relief area and it is not possible to focus simultaneously on an extensive area and to obtain a good image. In some specimens, lateral landmarks on the prodorsal shield could be recorded, but not in real specimens. This limited the number of specimens that could be studied in each population. Small variation during the preparation of slides (quantity of medium, drying period) may have interfered with the curvature of this region during preparations. It is also important to note that the percentage of variation among *A. guerreronis* populations of the prodorsal shield configuration using the two main relative deformations (RW1 and RW2) was less than 50%. This suggests that besides the two main relative deformations

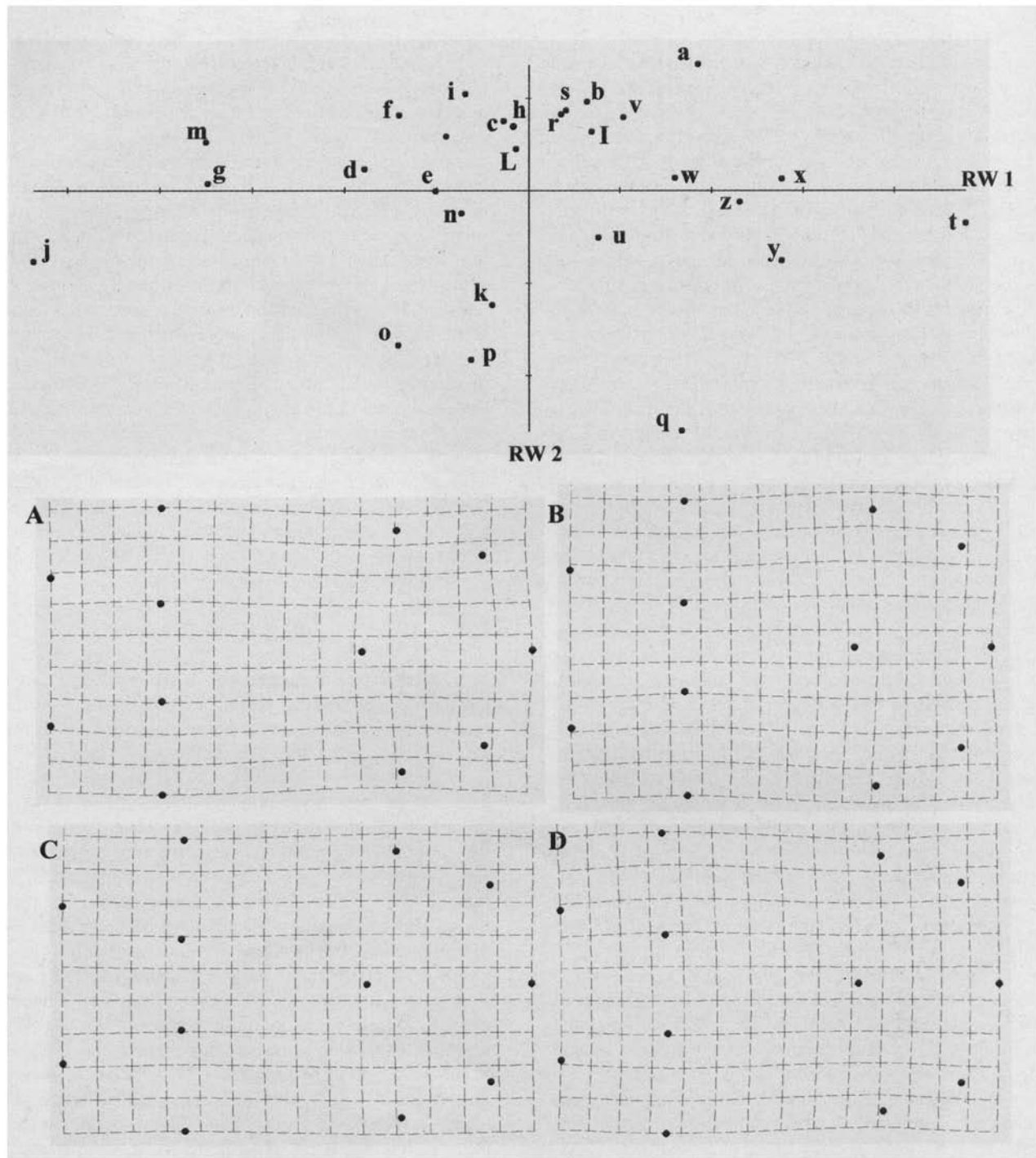


Fig. 7. Relative Warps (RW) for values  $\alpha = 0$  of the coxigenital region of *Aceria guerreronis*. Grids of relative warps showed a hypothetical shape. Variation in the shape of the coxigenital region foreseen as **A** - positive deviations of the mean in the axis of relative warps 1; **B** - negative deviations of the mean in the axis of relative warps 1; **C** - positive deviations of the mean in the axis of relative warps 2; and **D** - negative deviations of the mean in the axis of relative warps.

represented on the two-dimensional graph, other deformations were also important in explaining variation between configurations. It is possible that if the other deformations could be represented on a multidimensional

graph, ordination of populations would be different from that observed in two-dimensionals.

In contrast, it was observed on the ordination scatterplot of populations between axes of the two main

relative deformations of the coxigenital and ventral regions (Figs. 7 and 8), that shape variation was related to the geographic origin of the populations sampled. The majority of populations from one continent were closer to each other, indicating that they had a similar deviation along the RW1 and RW2 axes.

Ordination of the *A. guerreronis* populations on the scatterplot of the coxigenital and ventral regions (Figs. 7 and 8) were similar in general. Asian and African populations were projected along the positive RW1 axis and American populations were projected along the negative RW1 axis.

Results of the deformation analysis applied to coxigenital (Fig. 7) and ventral (Fig. 8) regions of *A. guerreronis* specimens were concordant. Populations showing shorter and wider configuration of the ventral region also have the epigynium closer to the coxae. On the other hand, populations showing longer configuration of the ventral region also have a narrower and longer epigynium, more distant from the coxae. These results may be expected considering that the ventral aspect configuration includes the coxigenital region. However, it is important to note that separate analyses of the coxigenital region deformations, obtained at a higher magnification, allowed better visualization of variations of this taxonomically important region when compared to the analyses of the entire ventral aspect of the opisthosoma.

Results obtained in this study for coxigenital and ventral regions, using morphometric geometric methods, were in agreement with that obtained using molecular markers and supported inferences about the origin and invasion history of the coconut mite using mitochondrial (16S) and nuclear (ITS) sequences (Navia *et al.*, 2005). High morphometric variability between American populations corroborated the hypothesis of an American origin of the species. The morphometric similarity between African and Asian populations suggested a common origin and that they have been separated within a short period of time. A detailed discussion about the historic biogeography of the coconut mite is presented by Navia *et al.* (2005). This agreement between genetic and morphometric variation corroborates with the view of Alibert *et al.* (2001) about shape variation (adopting the concept of "shape" as a feature not affected by size or rotation), and their affirmation that it reflects a variation in the genetic constitution of populations. In addition, according to Alibert *et al.* (2001) morphometric similarity is expected among populations that maintain a genetic flow between them because they are genetically continuous along their geographic distribution, or that in the recent past, they maintained a genetic flow because they have a common origin.

The *Aceria guerreronis* population from Queen Palm, *Syagrus romanzoffiana* (Cham.) Glassm., seemed to be morphometrically close to American populations from *Cocos nucifera* L. in coxigenital and ventral region analyses. This indicates that this population does not pres-

ent a host-associated morphometric variation as observed in other eriophyoid species (Boczek *et al.*, 1984; Skoracka *et al.*, 2002). There has been a first report of mites growing in tips of *S. romanzoffiana* (Ansaloni and Perring, 2002). It is possible that the adoption of *S. romanzoffiana* by *A. guerreronis* as a host has only occurred recently and that there has been insufficient time for morphological differentiation to occur, as would be expected, especially considering that not only hosts but also attacked plant organs are rather different in this case.

Similarly, results obtained in this study were in agreement with those obtained using multivariate morphometry (Navia *et al.*, 2006). Besides the general congruence between geometric morphometry and multivariate morphometry of *A. guerreronis* within its geographical range, it is possible to identify some specific similarities: 1) RWA applied to prodorsal shield and ventral region showed that Brazilian populations from Aracaju (d) and Maceió (i) are distinct from the other Brazilian populations. This was also clear in Canonical Discriminant analysis; 2) RWA applied to the coxigenital and ventral regions showed that the Brazilian population from Quissamã (k) is closer to the non-Brazilian American populations from Havana (n), California (p), Guerrero (o) and Zulia (q) than to the other Brazilian populations.

The utilization of both multivariate and geometric morphometry, when biological material well preserved, may allow significant contributions to systematic studies on eriophyoid mites. Although the analyses conducted in this study was preliminary, the results suggest that geometric morphometric methods may be useful in understanding morphological variability of this group of mites.

The evaluation on intra-specific morphometric variation in an eriophyoid mite using geometric morphometry allows us to propose some systematic implication. The shape of the prodorsal shield, coxigenital region and idiosoma may vary significantly between populations from a species associated with the same host plant and even between specimens from the same population. In the case of *A. guerreronis*, the prodorsal shield region presented especially high intra-population variation. Thus, it appears to be important to present a number of illustrations and to measure a larger number of specimens. New taxa should be described from specimens of the same population. This limitation could be partially compensated through illustrations and measurements of a larger number of individuals. It is possible that, for each species, some body regions have greater variation in relation to others, presenting differentiated variation amplitudes. Few studies on intra-specific variability of eriophyoid mites have been conducted and they are restricted to populations associated with different hosts. A better knowledge on intra- and inter-population variability of eriophyoid mites could contribute enormously to the systematics of the group.

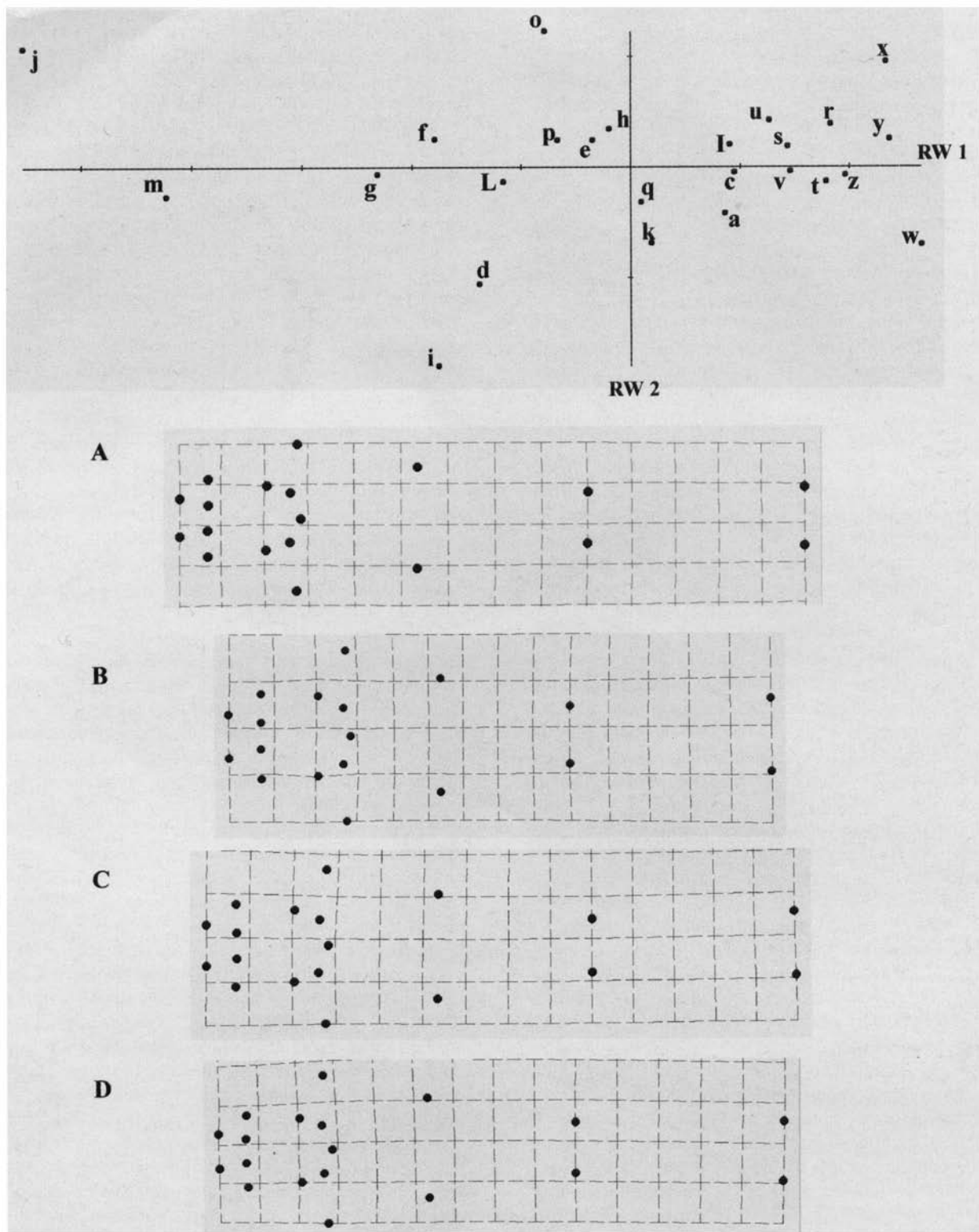


Fig. 8. Relative Warps (RW) for values  $\alpha = 0$  of the ventral region of *Aceria guerreronis*. Grids of relative warps showed a hypothetic shape. Variation in the shape of the ventral region foreseen as **A** - positive deviations of the mean in the axis of relative warps 1; **B** - negative deviations of the mean in the axis of relative warps 1; **C** - positive deviations of the mean in the axis of relative warps 2; and **D** - negative deviations of the mean in the axis of relative warps.

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