



TRENDS IN SCORPION DIVERSITY AND RICHNESS IN MOROCCO

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Authors EHMA and TO designed the study. Authors EHMA, ALM and LEM wrote the protocol, and wrote the first draft of the manuscript. Authors EA and TO managed the analyses of the study. Authors EA and LEM managed the literature searches. Authors EHMA and TO performed maps. All authors read and approved the final manuscript.

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ABSTRACT

To date, Vachon's study (1952) remains the only synthetic work that has addressed scorpion species and their distribution in North Africa. However, in spite of this important contribution to the description of the Moroccan scorpions, a great biodiversity of this fauna continues to be revealed, especially since revisions of the classical scorpion groups have allowed the description of new species as well as new genera. Thus, the aim of this study is to update the inventory and analyze the distributional pattern of the Moroccan scorpion fauna. A previous list of scorpions from Morocco, is updated, based on a survey conducted during several separate expeditions, and completed by published data. More than 1200 specimens, representing more than 400 point-locality records, were examined for the study. Notes on the ecology and distribution of the scorpions in Morocco are provided. 61 scorpion species in twelve genera of two families (Buthidae and Scorpionidae) are recorded from the area, which presently has the richest scorpion fauna in Northern Africa, if not the Mediterranean basin, and ranks among those with the richest scorpion faunas in the world. The high diversity of scorpions in Morocco is attributed to the heterogeneity of landforms, substrata and habitats in the area. The analysis of species richness

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points "Hotspots" indicates that most central regions of Morocco contain at least one species of scorpion. The greatest diversity of genera and species occurs central areas. A high endemism characterizes Moroccan scorpion-fauna, with 73% of the species is restricted to Morocco.

Keywords: Scorpion species; biodiversity; richness; mapping; Morocco.

1. INTRODUCTION

Predictable, non-random patterns are typical of the spatial distribution of most taxa [1,2], and with scorpions being no exception. Scorpion distribution has interested bio-geographers for over a century [3-12]. Scorpions provide unique opportunities for ecological and biogeographic studies compared to other arthropods. Indeed, one of the reasons for considering scorpions as a model taxon for biogeographic studies is their long history. Indeed, fossil studies show that scorpions have existed since the mid-Silurian, more than 400 M.A., and have remained almost unchanged morphologically to the present [7,13,14]. Morphological similarity between fossil and actual scorpions may imply similarity in ecological requirements [15]. Several ecological factors influence the spatial distribution of scorpions, including temperature, precipitation, soil characteristics, topography and vegetation [16]. Some of these factors, such as substrate, are a determining factor in their evolution and may affect trends in their geographic distribution [16-19]. The importance of knowing the distribution of dangerous scorpions from a medical perspective is yet another reason to study their distribution [20,21]. To date, Vachon's study [22] remains the only synthetic work that has addressed scorpion species and their distribution in North Africa. However, in spite of this important contribution to the description of the Moroccan scorpions, a great biodiversity of this fauna continues to be revealed, especially since revisions of the classical scorpion groups have allowed the description of new species as well as new genera. From these, it is evident that the knowledge of this fauna and consequently its distribution has changed with respect to those described in the works of Vachon [22]. The present study constitutes an analysis of the knowledge acquired on the inventory of the Moroccan scorpion fauna through surveys conducted during several separate expeditions, and completed

2. MATERIAL AND METHODS

2.1 Study Area

Morocco is located in northwestern Africa at latitude 28°57'36.00" North and longitude 9°07'48.00" West. It is bounded on the north by the Mediterranean Sea,

on the south by Mauritania, on the east by Algeria and on the west by the Atlantic Ocean.

2.2 Distribution Data

The location points of each species were collected from published data. The monograph of Vachon (1952), was used for all the first location data. The remaining records were obtained from the following works: [11,23-51]. The location data from the literature were supplemented by our observations during our field surveys.

2.3 Field Work and Scorpion Collection

Specimens collected during the expeditions were mostly found at night using UV light detection. Additional specimens were collected during the day by turning stones and excavating burrows. A portable GPS device was used for recording the geographical coordinates of collection localities in the field

2.4 Georeferencing

All the geographical localization data, with enough precision, were gathered to create a dataset of geographical location to map the distribution areas of the scorpion fauna. Locations defined in degrees and minutes of latitude and longitude were used preferentially, whenever possible, because of their high level of spatial resolution. All these locations were converted to decimal degree format for GIS data entry. Uncertain localities, controversial in the literature, which could not be verified, are not considered. The presence data set for 455 points was subjected to GIS mapping and spatial analysis.

2.5 Spatial Analysis of Scorpion Fauna Distribution in Morocco

The digital distribution maps were made for each species by overlaying the location points on a set of shape files representing the administrative boundaries of Morocco, using ArcView GIS Version 10.2. A spatial assembly was then conducted by overlaying the scorpion distribution maps onto a shape file representing the QDS grid of Morocco, in order to determine distribution hotspots, i.e. areas of species richness and endemism [52], at the scale of a QDS. Hotspot determination is based on measures of species richness (the 61 species inventoried so far in

Morocco) and endemism at the Moroccan level, which may reflect centers of endemism, or regions of speciation, since all scorpion species are sedentary [16,53].

3. RESULTS AND DISCUSSION

3.1 Analysis of Moroccan Scorpion Species Composition

According to the Vachon's works [22], the inventory of the Moroccan scoriofauna counted 27 species, subspecies and varieties. Today it counts 61 species and subspecies, distributed on two families Buthidae and Scorpionidea. However, the majority of species (88%) belong to the family Buthidae while the family

Scorpionidea represents only 12%. In other words, the family Buthidae is represented by 11 genera (*Androctonus*, *Buthacus*, *Butheoloides*, *Buthus*, *Compsobuthus*, *Cicileiurus*, *Hottentota*, *Microbuthus*, *Orthochirus*, *Lissothus* and *Saharobuthus*) that is 90% of the total number of genera while the family Scorpionidae is represented only by the genus *Scorpio* (Fig. 1). The genus *Buthus* currently contains 35% of scorpion species and subspecies in Morocco, followed by *Androctonus* (13%), *Buthacus* and *Scorpio* (11%), *Butheoloides* (9%). The other genera are represented by a number of species less than or equal to 3%. (Fig. 1) A high rate of endemism characterizes the scoriofauna of Morocco, so 73% of species is strictly reserved for Morocco, including 92% of species of Buthidae and 8% of scorpionidae.

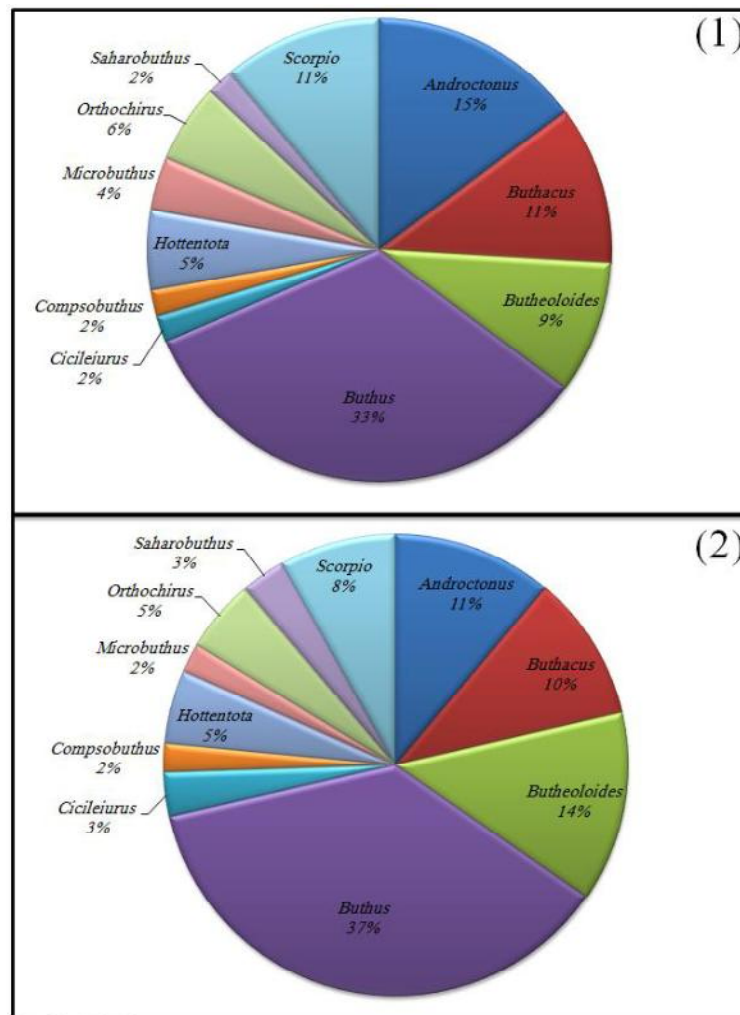


Fig. 1. (1) Species and subspecies proportions of scorpion in Morocco according to genus. (2) Proportions of species and subspecies endemic to Morocco according to genus

3.2 Species Richness Analyses

Analysis of the high species richness points indicates that most of the central regions of Morocco contain at least one scorpion species (Fig. 2a). The apparent absence of scorpions in large parts of the south and north is probably due to sampling artifact. Despite the bias caused by under-sampling in these areas, the inventory of scorpion species in Morocco can be considered fairly complete for one group of arthropods. Seven primary hotspots (each containing 4-6 species) are located in the central region of Morocco. Three are located in the eastern region on the line between Ouarzazat and M'hamid elghizlane. Two hotspots are located in the Agadir region. The other two hotspots are isolated and located respectively in the region of Marrakech and Tata. Twenty-eight secondary hotspots (with 3 species) are concentrated in the region of Marrakech- Tensift-Alhaouz as well as the region of Souss-Massa-Draa. Other secondary hotspots are found in the provinces of Tata, Zagora, Tarfaya, Rabat and Oujda (Fig. 2a). The endemic species hotspots show a similar trend to that of the total species distribution (Fig. 2b). Two primary hotspots (3-5 endemic species) are located in the vicinity of Marrakech and only one in the Agadir region. The secondary hotspots (3 endemic species) are concentrated in the region of Marrakech- Tensift-Alhaouz and Souss-Massa-Draa in addition to other isolated hotspots in the provinces of Tata, Tarfaya, Tan-Tan and Boumalne (Fig. 2b). Two trends will be considered from the hotspot analysis. First, most of the high species richness hotspots are located in the arid or semi-arid half of central Morocco, or in the arid regions of the western half, suggesting a climate effect. Also, the majority of hotspots are found in

heterogeneous environments with rugged topography. Hotspots are generally less represented in regions with homogeneous environments such as the Saharan regions of Morocco. As already stated by Vachon at his time, the distribution of scorpions in northern Africa can be explained by paleogeography and paleoclimatology [22].

The climatic changes experienced by North Africa during recent geological periods (Quaternary), and in particular the expansion of the Sahara Desert zone [54] have acted on scorpion populations as speciation factors. The reactions of populations to abiotic pressures must have depended on their biogeographic characteristics, adaptive and reproductive strategies [39]. The consequences of these changes have certainly been variable, regressions or even disappearance of populations, and ruptures of formerly continuous distributions. The transformations of the environment often lead to the reduction of the distribution of certain species. Indeed, some organisms that are attached to particular biotopes, because of the reduction of these ecologically viable geographical areas, see their distribution areas diminish very strongly. Populations are thus isolated and evolve independently. Climatic pressures can therefore be at the origin of allopatric speciation [17]. This last hypothesis seems to be appropriate for certain species such as the different new species of *Buthus* described in the central and southern regions of Morocco. All these mainly mountainous regions and the water points in the arid zones would have played the role of refuges allowing the survival of certain populations, which, isolated on these "ecological islands" would have diverged morphologically and formed new species [17].

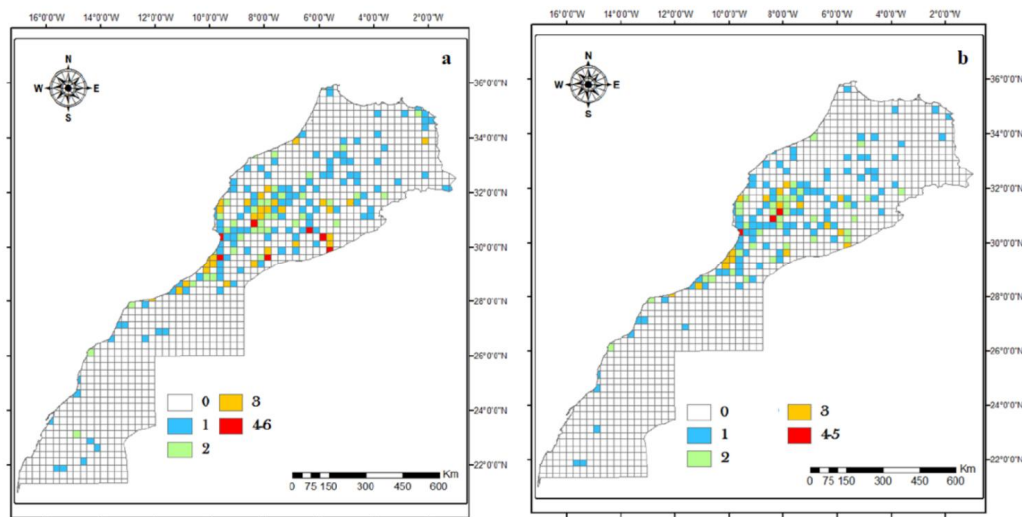


Fig. 2. Distribution maps of high species richness points of scorpion species in Morocco. (a) total species richness, (b) species richness of endemic species

4. CONCLUSION

Overall, our work suggests that in the studied region, scorpion diversity and richness is focused in central regions marked by heterogeneous environments with rugged topography. Hotspots are generally less represented in regions with homogeneous environments such as the Saharan regions of Morocco. Moreover, our study had shown a high endemism characterizes Moroccan scorpion-fauna, with 73% of the species is restricted to Morocco.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- MacArthur RH. Geographical ecology, Harper and Row, New York; 1972.
- Myers AA, Giller PS. Process, pattern and scale in biogeography, in: Analytical Biogeography: An Integrated Approach to the Study of Animal and Plant Distributions, A.A., Myers and P.S., Giller, eds., Chapman and Hall, London. 1988;3-21.
- Hewitt J. Facts and theories on the distribution of scorpions in South Africa. *Trans. R. Soc. S. Afr.* 1925;12:249-276.
- Lawrence RF. The unequal distribution of some invertebrate animals in South Africa. *S. Afr. J. Sci.* 1952;48:308-310.
- Lamoral BH. A reappraisal of the suprageneric classification of Recent scorpions and of their zoogeography, in: *Verhandlungen 8. Internationaler Arachnologen-Kongress Abgehalten an der Universität für Bodenkultur Wien, 7-12 Juli, 1980*, J. Grüber, ed., H. Egermann, Vienna. 1980;439-444.
- Stockwell SA. Revision of the Phylogeny and Higher Classification of Scorpions (Chelicerata). Ph.D. Dissertation, University of California, Berkeley, California, USA. 1989; 319.
- Sissom WD. Systematics, biogeography and palaeontology, in: *The Biology of Scorpions*, G.A. Polis, ed., Stanford University Press, Stanford, CA. 1990;64-160.
- Nenilin AB, Fet V. Zoogeographical analysis of the world scorpion fauna (Arachnida: Scorpiones). *Arthropoda Selecta*. 1992;1:3-31.
- Lourenço WR. The biogeography of scorpions, *Rev. Suisse Zool.*, Vol. hors série II:437-448 [Proceedings of the XIIIth International Congress of Arachnology, Geneva, 3-8 September 1995, V. Mahnert, ed.]; 1996.
- Lourenço WR. Pan-biogéographie, les distributions disjointes et le concept de famille relictuelle chez les scorpions. *Biogeographica*. 1998 ;74:133-144.
- Lourenço WR. A new species of *Buthacus* Birula from Morocco (Arachnida: Scorpiones: Buthidae). *Faunistische Abhandlungen Staatliches Museum für Tierkunde Dresden*. 2000;22 (1):5-9.
- Soleglad ME, Fet V. The scorpion sternum: Structure and phylogeny (Scorpiones: Orthosterni). *Euscorpius*. 2003;5:1-34.
- Jeram A. Carboniferous Orthosterni and their relationship to living scorpions. *Palaeontology*. 1994;37:513-550.
- Selden PA. Fossil arachnids—recent advances and future prospects. *Mem. Queensl. Mus.* 1993;33:389-400.
- Sissom, WD. Systematics, biogeography and palaeontology, in: *The Biology of Scorpions*, G.A. Polis, ed., Stanford University Press, Stanford, CA. 1990;64-160.
- Jeram A. When scorpions ruled the world. *New Scientist*. 1990;126:52-55.
- Polis GA. Ecology, in: *The Biology of Scorpions*, G. A. Polis, ed., Stanford University Press, Stanford, CA. 1990;247-293.
- Prendini L. Substratum specialization and speciation in southern African scorpions: the Effect Hypothesis revisited, in: *Scorpions 2001. In Memoriam Gary A. Polis, V. Fet and P. A. Selden*, eds., British Arachnological Society, Burnham Beeches, Bucks, UK. 2001; 113-138.
- Lamoral BH. Soil hardness, an important and limiting factor in burrowing scorpions of the genus *Opisthophthalmus* C.L. Koch, 1837 (Scorpionidae, Scorpionida). *Symp. zool. Soc. Lond.* 1978;42:171-181.
- Williams SC. Scorpions of Baja California, Mexico, and adjacent islands. *Occas. Pap. California Acad. Sci.* 1980;135:1-127.
- Newlands G. Review of southern African scorpions and scorpionism. *S. Afr. Med. J.* 1978;54:613-615.
- Newlands G, Martindale CB. The buthid scorpion fauna of Zimbabwe-Rhodesia with checklists and keys to the genera and species, distributions and medical importance (Arachnida: Scorpiones). *Zeitschrift für Angewandte Zoologie*. 1980;67:51-77.
- Vachon M. Etudes sur les scorpions. *Publications de l'Institut Pasteur d'Algérie*. 1952 ;482.
- Delacour J, Dupre G. Présence de *Microbuthus fagei* Vachon, 1949 au Maroc (Scorpionida, Buthidae). *Arachnides*. 1991;15:23-24.

24. El-Hennawy HK. A catalogue of the Scorpions described from the Arab countries (1758-1990) (Arachnida: Scorpionida). Serket. 1992; 2(4):95-153.
25. Goyffon M. Les scorpions des régions montagneuses. Actes 116° Congr. Nat. Soc. sav., 29 avril-4 mai 1991, Chambéry, C.T.H.S. eds. 1991;241-254.
26. Kovarik F. First report of *Orthochirus innesi* (Scorpionida: Buthidae) from Morocco. Klapalekiana; 31: 19-21 Lourenço, 1999; 1995.
27. Lourenço WR. Two new species of *Compsobuthus* Vachon (Scorpiones, Buthidae) from Africa. Entomol. Mitt. Zool. Mus. Hamburg. 1999;13(160):85-94.
28. Lourenço WR. Further taxonomic considerations on the Northwestern African species of *Buthacus* Birula (Scorpiones, Buthidae), and description of two new species. Entomol. Mitt. Zool. Mus. Hamburg. 2001; 13(163): 255-269.
29. Lourenço WR, Slimani T, Berahou A. Le genre *Butheoloides* Hirst (Scorpiones, Buthidae); description d'une nouvelle espèce pour le Maroc avec des considérations écologiques et biogéographiques. Biogeographica. 2003; 79(1): 19-30.
30. Lourenço WR. New considerations on the Northwestern African species of *Buthacus* Birula (Scorpiones, Buthidae) and description of a new species. Rev. Iber. Arachnol. 2004; 10:225-231.
31. Lourenço WR, Slimani T. Description of a new scorpion species of the genus *Buthus* Leach, 1815 (Scorpiones, Buthidae) from Morocco. Entomol. Mitt. Zool. Mus. Hamburg. 2004; 14(169):165-170.
32. Slimani T, Stockmann R. Inventory commented of the scorpions of Morocco. Abstract 16th Int. Congr. Arachnol; 2-7, Gent (Belgium). 2004;142.
33. Touloun O, Boumezzough A. Inventaire et répartition des peuplements de scorpions du sud ouest marocain. Journ. Sc. Env. Scorp. 2004 ;9 juillet 2004, Fac. Sc. Settat.
34. Kovarik F. Taxonomic position of species of the genus *Buthacus* Birula, 1908 described by Ehrenberg and Lourenço, and description of a new species (Scorpiones: Buthidae). Euscorpius. 2005;28:1-13.
35. Lourenço WR, Geniez P. A new scorpion species of the genus *Buthus* Leach, 1815 (Scorpiones, Buthidae) from Morocco. Euscorpius. 2005;19:1-6.
36. Lourenço WR. Further considerations on the genus *Buthacus* Birula, 1908 (Scorpiones, Buthidae) with a description of one new species and two new species. Bol. SEA. 2006; 38:59-70.
37. Lourenço WR, Qi JX. A new species of *Buthus* Leach, 1815 from Morocco (Scorpiones, Buthidae). Entomol. Mitt. Zool. Mus. Hamburg. 2006;14(173):287-292.
38. Geniez P. Découverte au Maroc d'*Androctonus australis* (Linnaeus, 1758) (Scorpiones, Buthidae). Poirertia. 2009;1:1-4.
39. Lourenço WR, Duhem B. Saharo-Sindian buthid scorpions; description of two new genera and species from Occidental Sahara and Afghanistan. ZooKeys. 2009;14:37-54.
40. Lourenço WR. A new species of *Butheoloides* Hirst, 1925 from Morocco (Scorpiones, Buthidae). Entomol. Mitt. zool. Mus. Hamburg. 2010;15(183):183-189.
41. Nickel H, Hornung J, Koch M. Scorpions of Morocco. Part 1. Reptilia. 2010;70:45-51.
42. Touloun O, Slimani T, Boumezzough A, Stockmann R. Synthèse des données récentes sur la répartition de *Microbuthus fagei* Vachon, 1949 (Scorpiones, Buthidae) au Maroc. Poirertia. 2010;2:1-6.
43. Lourenço WR, Leguin EA. Further considerations on the species of the genus *Orthochirus* Karsch, 1891 from Africa, with description of three new species (Scorpiones: Buthidae). Euscorpius; 2011a;123:1- 18.
44. Lourenço WR, Leguin EA. One more new species of the genus *Orthochirus* Karsch, 1891 from Africa (Scorpiones : Buthidae). Euscorpius. 2011b;135:1-8.
45. Lourenço WR, Touloun O, Boumezzough A. The genus *Butheoloides* Hirst, 1925 (Scorpiones, Buthidae) in Morocco, with a description of a new species. Euscorpius. 2011; 113:1- 7.
46. Sousa P, Harris DJ, Froufe E, van der Meijden A. Phylogeographic patterns of *Buthus* scorpions (Scorpiones: Buthidae) in the Maghreb and South-Western Europe based on CO1 mtDNA sequences. J. Zool. 2012;288: 66-75.
DOI:10.1111/j.1469-7998.2012.00925.x
47. Touloun O, Boumezzough A. Contribution à l'inventaire et à la répartition des scorpions de la province de Sidi Ifni (Maroc). Poirertia. 2011; 3:8-15.
48. Lourenço WR, Touloun O, Boumezzough A. Un nouveau *Buthus* Leach, 1815 (Scorpiones, Buthidae) du Nord du Maroc ; possible lien entre les populations marocaines et européennes. Revista Ibérica de Aracnologia. 2012;21:21-25.

49. Touloun O, Boumezzough A. Nouvelle donnée sur la répartition de *Butheoloides* (*Butheoloides*) *slimanii* Lourenço, 2010 (Scorpiones, Buthidae) au Maroc. *Poiretia*. 2013;5:15–19.
50. Touloun O, Slimani T, Qninba A, Boumezzough A. Nouvelles observations sur les scorpions des régions sahariennes du Maroc. *Poiretia*. 2014;6:16–21.
51. Touloun O, El Hidan M, Boumezzough A. Inventory and distribution of scorpion fauna in eastern Morocco (Arachnida, Scorpiones). *Serket*. 2014;14:73–79.
52. Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GAB, Kent J. Biodiversity hotspots for conservation priorities. *Nature*. 2000; 403:853-858.
53. Harington A. Character variation in the scorpion *Parabuthus villosus* (Peters) (Scorpiones, Buthidae): a case of intermediate zones. *J. Arachnol*. 1984;11:393-406.
54. Furon R. Les grandes lignes de la paléogéographie de la Berbérie et du Sahara; leur sens biogéographique. *Comp. Rend. Somm. Séan. Soc. Biogéog*. 1951;241: 46-48.