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Karyotype for *Nebo hierichonticus* (Simon 1872) from the Palestinian Territories (Scorpiones: Scorpionidae)

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Summary In this paper we report the first karyotypic data on *Nebo hierichonticus* (Simon 1872) from the occupied Palestinian territories. The karyotype consists of 50 chromosomes which appear acrocentric except for pair 3, likely representing the XY. With additional data on scorpionidae coming through, we suggest that a model of chromosomal evolution might involve changes in chromosome numbers that relate to chromosomal stability in the nucleus and recombination affecting adaptability as previously suggested and supported by studies of salmonid fish chromosomes.

Key words Karyotype, *Nebo hierichonticus*, Palestinian territory, Scorpion.

The order Scorpiones is a fascinating order of arthropods with over 2000 species. Its taxonomy continues to undergo revision, and new species are described as new data accumulate, including data on morphology and DNA analysis (*e.g.* Prendini *et al.* 2003, Sousa *et al.* 2011). In the Eastern Mediterranean region, some morphological work on scorpions was done by Vachon (1966, 1974), Levy and Amitai (1980), Lourenço (1999, 2002b), Amr and Al-Oran (1994), Kabakibi *et al.* (1999), and Stathi and Lourenço (2003).

A review showed that only about 80 of over 2000 known species of scorpions have been evaluated by chromosome studies (Moustafa *et al.* 2005, Schneider *et al.* 2009). We recently reported the karyotypes of three species from Palestine: *Leiurus quinquestriatus*, *Hottentotta judaicus*, and *Scorpio maurus fuscus* (Qumsiyeh *et al.* 2013). The only other study of chromosomes in the Middle East was done in Egypt of some members of the genus *Androctonus*, which had a fairly uniform $2n=24$ (Moustafa *et al.* 2005).

Traditionally, *Nebo hierichonticus* was placed under the family Diplocentridae. However, Soleglad and Fet (2003) abolished this family and downgraded it to a subfamily rank in the family Scorpionidae. The karyotype of 15 species of this family was investigated, with $2n$ ranging from 52 in *Scorpio marus fuscus* (Qumsiyeh *et al.* 2013) to 175 in *Urodacus novaehollandiae* (Shanahan 1989b).

In this paper, we report the first chromosomal data for *Nebo hierichonticus*, and we comment on the variation seen in chromosome number and possible evolutionary origin of this variation.

Materials and methods

The collection of scorpions was done during the day by turning rocks or objects where they

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Table 1. Locality coordinates from which *Nebo hierichonticus* were collected.

Locality	N	E
Battir	31°43′	35°08′
Bil'in	31°93′	35°07′
EinFashkha	31°42′	35°27′
EinYabroud	31°56′	35°15′
Jebel KafrNe'mah	31°93′	35°10′
Wadi AlQuf	31°34′	35°02′
WadiFukeen	31°71′	35°10′

may hide, and during the night *via* walking and scanning the ground with ultraviolet flash lights. All specimens were retained in the nascent Palestine Natural History Museum (PMNH). Table 1 indicates the coordinates of localities from which materials were collected.

Karyotyping

Karyotyping was done from gonadal tissues dissected in saline solution by the method of Schneider *et al.* (2009). We found that the success rate is variable, and that it depends on the seasonality of reproduction in scorpions. Specimens collected in May to July gave us good results. For each specimen, at least five mitotic and/or meiotic cells were analyzed/counted.

Results

The karyotype for *N. hierichonticus* consists of 50 chromosomes. The chromosomes graded by size all appeared acrocentric with the exception of pair three, which in males appeared slightly heteromorphic, indicating it is likely the XY chromosome (Fig. 1). This is the first karyotypic data on *N. hierichonticus*.

Discussion

In Palestine, we reported the karyotypes of *Hottentotta judaicus* $2n=16$, *Leiurus quinquestriatus* $2n=22$, and *Scorpio maurus fuscus* $2n=52$ (Qumsiyeh *et al.* 2013). The data above for *Nebo* adds an important element as it represents the first karyotype on the diplocentrid group within the Scorpionidae *sensu lato*.

Karyotypes of roughly 5% of the species of scorpions in the world are now available and show significant inter-genus and inter-specific variation (Schneider *et al.* 2009). However, our data on *Nebo hierichonticus* and a review of available data shows an interesting pattern —the karyotype of the Buthidae *sensu lato* ranges from $2n=6$ to $2n=48$, while that of the Scorpionidae *sensu lata* range from $2n=29$ to $2n=175$ (Shanahan 1989a, 1989b, Mattos *et al.* 2013). Schneider *et al.* (2009) stated that the low diploid numbers were restricted to the most cytogenetically investigated family (Buthidae) and in Opiliones, but not in the Scorpiones groups. There are complications to studying chromosomes of scorpions. Parthenogenesis was noted in some species including a number of species of *Tityus* (Lourenço 2002b). Other species (*e.g. Urodacus novaehollandiae*) were noted to have high chromosome numbers, perhaps suggesting polyploidy (Shanahan 1989a). Even if we exclude those two phenomena, we still have to explain why there is such a high variation in chromosome numbers.

Schneider *et al.* (2009) does not explain the possible evolutionary advantage of chromosome number in scorpions. Qumsiyeh (1994, 1995) proposed a model in which increases and decreases in chromosome number in mammals are selected based on their effect on recombination and stability

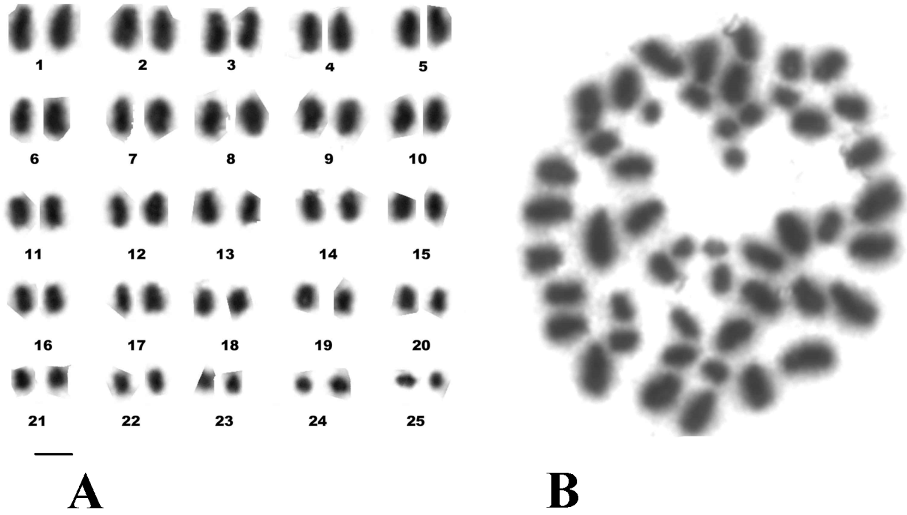

Fig. 1. A. Karyotype and B. metaphase of a male *N. hierichonticus* from Battir. Pair 3 is likely the XY. Bar=2μm.

of chromosomes in interphase nuclei. The model seemed useful to explain chromosomal variation in salmonid fish (Phillips and Ráb 2001), and it would be interesting to study its applicability in scorpions, especially as more ecological and reproductive data are collected.

Most of the reported species of Buthidae *sensu lata* are apoikogenic, while most of the reported species of Scorpionidae *sensu lata* are katoikogenic in the sense that was developed by Laurie (1896). The phylogenetic difference remains if we take the modifications of this classification of apoikogenic and katoikogenic by Lourenço *et al.* (1986), Lourenço (2002a) and Warburg (2010). Lourenço *et al.* (1986) suggested that the Buthidae have the most complex gradient of embryonic development, while Scorpionidae species have less complexity. Variables like adaptability to different habitats and reproduction strategies should be correlated to karyotypic data in species of scorpions to understand evolutionary strategies. Better understanding of these strategies will come as more data accumulate including better phylogenetic trees based on molecular data.

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