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Responses of the whipscorpion, *Mastigoproctus liochirus* (Arachnida, Uropygi) to environmental humidity

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Abstract: *Experiments were conducted to determine the responses of third-instar nymphs of the whipscorpion Mastigoproctus liochirus to various moisture (relative humidity) levels under constant temperature conditions, using a linear humidity gradient apparatus. No previous data exist on the water relations of this uropygid. Under saturated conditions (100% RH) animals showed no preference for any section of the chamber. When a humidity gradient was established (20 to 100% RH), whipscorpions exhibited a marked preference for an area of the chamber characterized by 70 to 80% RH.*

Key words: *Humidity preferences, Humidity gradient, Mastigoproctus liochirus.*

Introduction

It is well known that the distribution and activity of terrestrial arthropods are strongly influenced by ambient temperature and moisture levels (Pulz, 1987; Cloudsley-Thompson, 2001). Additionally, the survival of terrestrial arthropods is strongly related to their ability to maintain a water balance associated with body fluids (Edney, 1977; Punzo and Chapla, 2002). Although this ability is especially important in desert arthropods where animals must deal with frequent hot and xeric conditions (Cloudsley-Thompson, 1991), and where rate of desiccation due to evaporative water loss (EWL) can be acute (Punzo, 2000a), it is important for animals living in more mesic habitats as well.

Previous research has shown that many terrestrial arthropods exhibit marked preferences for a certain range of temperature (thermal preference) and relative humidity (humidity preference) (Punzo, 1989). Although there have been numerous studies on the effects of temperature and relative humidity (RH) on survival in insects (May, 1985) and spiders (Cloudsley-Thompson, 1983; Pulz, 1987), there is little information available for other orders of arachnids including uropygids.

A uropygid that has received some attention with respect to temperature and water relations is *Mastigoproctus giganteus* (Lucas) (Arachnida, Uropygi), a common inhabitant of desert regions in the southwestern United States (Crawford, 1981). It is a relatively large (40 to 80 mm in length) arachnid that is typically nocturnal in its behavior, foraging actively at the ground surface where it feeds on a variety of arthropods (Punzo, 2000b, 2001). Ahearn (1970) showed that evaporative water loss (EWL) was exponentially related to body size in this species, and a significant increase in rate of EWL occurred at 37.5 °C and 45% RH. Additionally, smaller desiccated whipscorpions (< 2.0g) were able to recover large proportions of water from saturated substrates to a greater extent than adults. This was achieved primarily via drinking and cuticular absorption. Crawford and Cloudsley-Thompson (1971) showed that immatures and adults exhibit EWL even at a non-stressful temperatures (26 °C), suggesting that the cuticle of this arachnid is not a particularly effective barrier to EWL. They also reported that desiccated individuals exhibited a marked preference for the hydrated area of a humidity gradient chamber. The purpose of this study was to utilize a humidity gradient apparatus to assess the humidity response of another species within this genus, *Mastigoproctus liochirus* (Pocock), for which no comparable data are available. Adults of this whipscorpion range in length from 22 to 32 mm (Haupt, 2000), and are found in semiarid and mesic habitats in southern Mexico and Central America (Rowland and Cooke, 1973).

Materials and Methods

All animals used in this study were third-instar nymphs of *M. liochirus* obtained from a laboratory (captive-bred) population initiated from adults originally collected from semiarid habitats near Chihuahua city (Chihuahua, Mexico). They were offsprings from 3 different females, and were maintained at 22 ± 0.2 °C, 62 to 65% RH, with a 12L:12D photoperiod regime, in Percival Model 85A environmental chambers. Body length of animals ranged from 13 to 14 mm. Nymphs were housed individually in plastic containers (13 x 13 x 9 cm) provided with a substrate of vermiculite. They were given access to water *ad libitum*, and fed twice per week on a diet consisting of nymphs of crickets (*Acheta domestica*) and adult vestigial fruitflies (*Drosophila melanogaster*).

An analysis of relative humidity preference was conducted according to the protocol described by Braulick *et al.,* (1988) for insects. A constant temperature linear humidity gradient chamber with a similar design (Fig. 1) was used in the present study. To summarize, constant temperature was maintained by submersing the experimental chamber (Fig. 1, EC) and all associated tubes and flasks under water in a water bath (WB). The EC (60 x 12 x 10 cm) was made of glass and was covered with a glass lid. This lid was sealed using a silicone sealant before the start of each experiment.

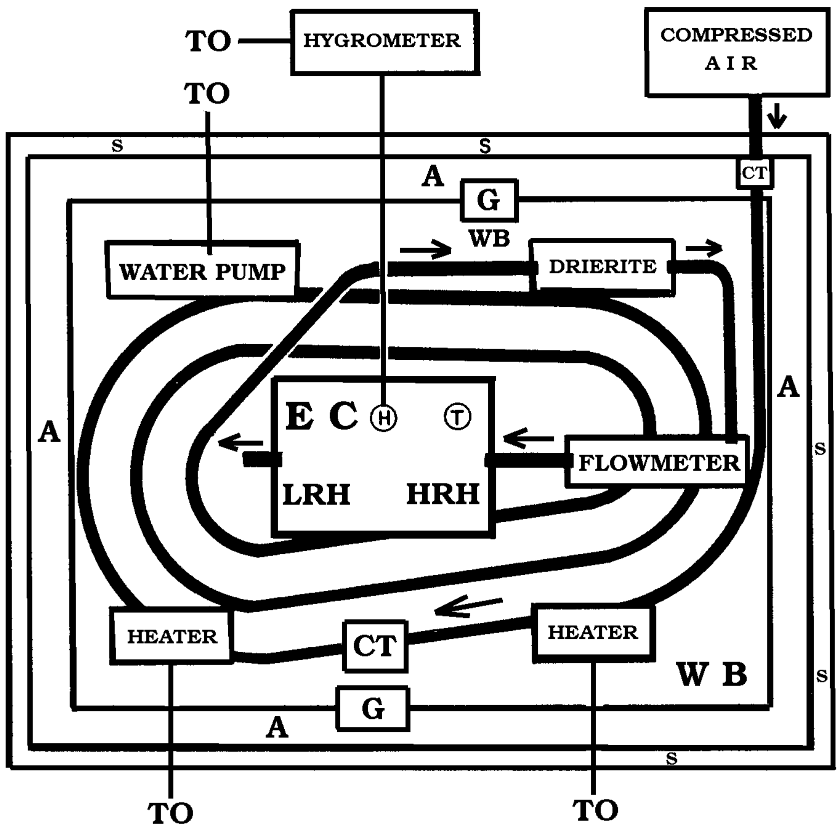

Fig. 1: Dorsal view showing diagrammatic representation of the apparatus used to establish a linear relative humidity gradient chamber. A (dead air space); CT (copper tubing); EC (experimental chamber = humidity gradient); G (glass walls of aquarium); H (hygroscopic sensor); LRH/HRH (low and high relative humidity); S (styrofoam insulation); T (mercury filled thermometer); TO (wires to electrical outputs); WB (water bath). See text for further details.

Water was circulated within the WB by a water pump (WP) with a flow rate of 760 l/hr. The apparatus was insulated from light and temperature changes by a 4 cm thick styrofoam box (S). Compressed air was circulated from an external tank and allowed to equilibrate with the temperature of the WB as it flowed through a coiled length of copper tubing (CT). The heated air was then passed through a compartment containing Drierite®, a drying agent. Dry air leaving the compartment was monitored using a linear flowmeter (Central Scientific, Chicago, Illinois). A linear flow rate of 100± 0.3 mm / min was maintained during all experiments. Air flowed directly from the flowmeter into the EC. Temperature and RH within the EC were measured using a mercury filled thermometer (T) and a hygroscopic sensor (Warren Component Corporation, Model 2C-B) coupled to an electronic hygrometer (Model 716A, World Instruments, Sarasota, Florida).

A RH gradient of 20 to 100% was established by placing a 30 ml jar filled with a 19:1 mixture of ethylene glycol:water at one end of the EC (low RH), and a jar filled with distilled water at the opposite end (high RH). All connections within the apparatus were sealed using a silicone sealant. Moisture was monitored at 10 cm intervals within the chamber every 6 hr using moisture-sensitive thermocouples. To assess the humidity responses of animals to saturated conditions (control chamber), jars of distilled water were placed at both ends of the EC yielding a RH value of 100%. The EC was allowed to equilibrate for 4 hr after inserting the various jars at their respective positions. For all experiments, the temperature inside the EC was maintained at 24±0.3 °C. Both control and experimental chambers were in constant darkness for all experiments.

At the beginning of each trial, 10 whipscorpions were randomly assigned to one of 10 groups (n = 100) and introduced into the center of the EC. The lid on the EC was fastened with sealant and submerged in the water bath. Each group of 10 animals was tested once. The position of each animal within the EC was recorded after a period of one hr, and the RH value of that section of the EC recorded. Similar trials were run for control animals (n = 100; 10/group; 10 groups).

All statistical tests were performed according to procedures discussed by Sokal and Rohlf (1995). A Kolmogorov Smirnov test was used to assess whether whipscorpions showed any preferences in a RH gradient (experimental groups). A Chi Square test was used to determine whether

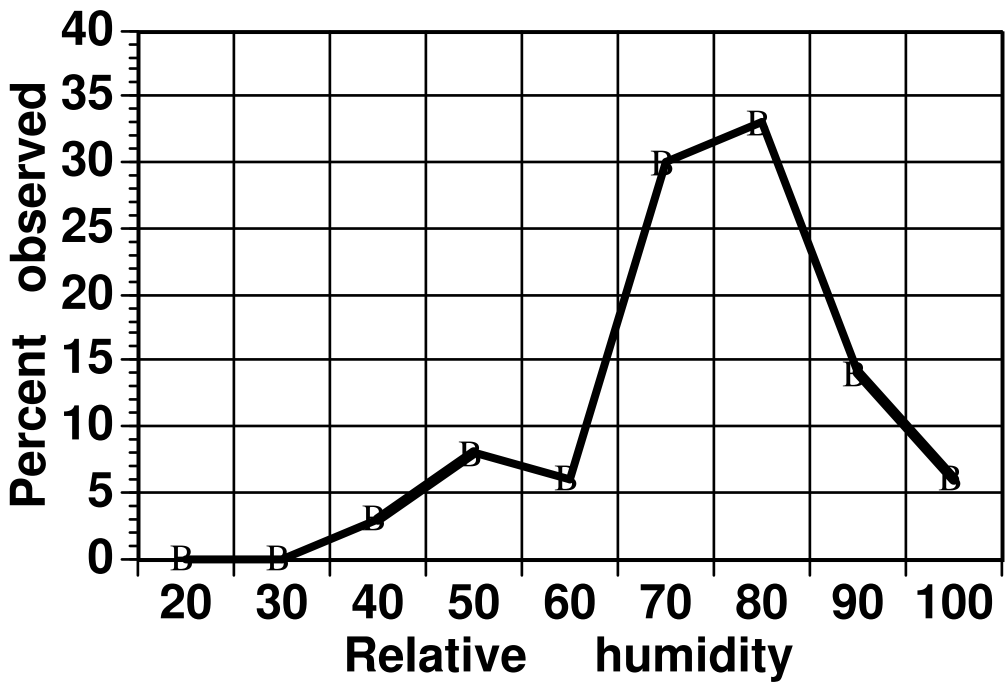

Fig. 2: Percentage of third-instar nymphs of *Mastigoproctus liochirus* observed at various relative humidity values when tested in a linear relative humidity gradient (20 to 100% RH). Animals were tested in 10 groups, each group consisting of 10 individuals.

animals distributed themselves evenly over the floor of the EC.

Results and Discussion

Control animals tested under saturated conditions (100% RH) distribute themselves evenly over the floor of the EC, showing no position preference for any particular location ($X^2 = 2.05$, $p > 0.50$). Results for experimental groups are shown in Fig. 2. Whipscorpions showed a marked preference for RH values between 70 and 80% in the RH gradient ($D = 0.75$, $p < 0.05$).

Depending on geographic location, *M. liochirus* can be found in both xeric and mesic habitats (Cloudsley-Thompson, 1968). Although animals used in these experiments were offspring of parents collected from semiarid habitats, they chose higher RH values in the EC. This may be attributed to the fact that *M. liochirus* is nocturnal and feeds on a variety of succulent arthropods (pers. observ.). As a result, even in desert areas this whipscorpion avoids high ambient temperatures that would enhance EWL, and may obtain sufficient water from its diet. *Mastigoproctus giganteus*, a species that is also found in xeric as well as more mesic habitats (Crawford, 1981), exhibits similar patterns in its diel periodicity and diet composition (Punzo, 2000b) as well as relatively high rates of EWL (Crawford and Cloudsley-Thompson, 1971). Rate of water loss was found to approach 0.3% / hr at 30^{O}C, an evaporation rate that is similar to that shown by lycosid and theraphosid spiders (Punzo and Jellies, 1983; Punzo, 1991), and approximately an order of magnitude greater than rates exhibited by solifugids and scorpions under similar conditions (Ahearn, 1970; Cloudsley-Thompson, 1991). Hydrocarbon composition and thickness of the epicuticular layer of the integument determine the efficacy of arthropod integuments to function as effective barriers against EWL (Cloudsley-Thompson, 1975). What few data are available for uropygids indicate that integuments of whipscorpions that inhabit xeric habitats are characterized by higher rates of EWL than are typically found in centipedes, millipedes, scorpions and solifugids (Hadley, 1984; Punzo, 1998).

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