Termites in arid environments: The waterbalance of *Psammotermes allocerus* Silvestri

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Abstract: In the central Namib desert (Namibia) the subterranean termite *Psammotermes allocerus* Silvestri (Isoptera: Rhinotermitidae) builds its nest structures nearly 30 cm deep into the dry sand of the Kuiseb river. Gallery systems protect the insects against unfavourable climatic conditions and reduce body-water loss occuring in all humidities below 98% rh. Furthermore the social structure of a termite colony contributes essentially to a reduction of individual water loss in subsaturated atmospheres as well as to a more efficient water uptake. Water vapour uptake from the atmosphere is not possible and free liquid water cannot be used as a water resource because of the strong surface tension of the water droplets. However, with the aid of their hypopharynx pseudergates of *P. allocerus* are able to extract water from the capillary system of loamy sand. The role of "water-sacs" in connection with water uptake and storage is still unknown.

Key words: termites, waterbalance, social effects, water vapour absorption, hypopharynx

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Introduction

The availability of water is the most crucial factor for the distribution of termites in the warmer regions of the world. All Isoptera except dry wood termites need microclimatic humidity conditions ranging between 98% rh and saturation for survival (Lüscher 1961). The central Namib desert in Namibia with its extremely low precipitation (< 28 mm p. a.) and long dry periods appears not to be a favourable place for termites. Besides erratic rainfalls water is supplied by fog coming from the coast to the central Namib on nearly 40 days p. a. or by early morning dew during the winter months which moistens the soil surface and seeps away into the sand. In addition extensive rainfalls in the inner region of Namibia may flood the Kuiseb twice a year for about 3 or 4 days.

Despite this overall poor water supply termites of several families and with different habits are found in the central Namib, i. e. one species of the genus *Microcerotermes* (Termitidae), the harvester termite *Hodotermes mossambicus* (Hodotermitidae) and the subterranean termite *Psammotermes allocerus* (Rhinotermitidae).

The following investigations focus on the water balance of *P. allocerus* building its nests in a depth of approximately 30 cm in the sandy soil of dry river beds. The relative humidity in the interstices of the surrounding soil is ca. 70%. The nests are built with carton-like material, 20 to 30 cm in diameter, and regularly deep infoldings occur on the nest surface. The number of individuals found in single nest spheres ranged from 2000 to 4000, however it is most likely that a colony inhabits several nest spheres within a system of connecting galleries.

Materials and Methods

Colonies of *P. allocerus* were collected in the central Namib desert (Namibia) and were established in laboratories of our institute. Pseudergates of *P. allocerus* were taken for all investigations. Test humidities were controlled by saturated salt solutions and temperature was adjusted at 21°C. Body water mass as well as water loss and uptake rates were obtained for single individuals from an ultra-micro-balance accurate to 1µg (Cahn G2 Electrobalance). The fine structure of the hypopharyngeal surface was studied by scanning electron microscope (SEM).

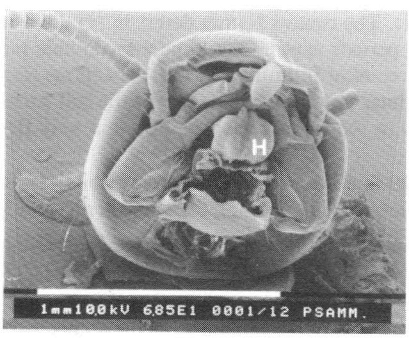
Results

When picked up from the colony pseudergates have an average body water content of 75,5% ± 4% (n=70).Individuals which were isolated from the colony and maintained in constant relative humidities ranging from 33% to 93% rh survived for only 5 to 19 hr. They continuously lost body water amounting to 63% in 33% rh and 20% in 93% rh respectively of total body water mass within 19 hr test period. Even in nearly saturated atmospheres losses accumulated to some 9% of body water mass.

When kept in groups of ten individuals the survival time clearly exceeded the 19 hours test period in all humidities except 33% rh. In high humidities of 93% rh and 98% rh water losses were significantly lower i. e. 7,9% ± 3% and 2,3% ± 2% respectively ,as compared to those of isolated individuals.

P. allocerus is not able to actively absorb water vapour from the atmosphere. Even after suffering a loss of 19% of total body water mass during a five hours stay in dehydrating conditions (33% rh) pseudergates were not able to gain water when subsequently transferred into almost saturated atmospheres of 98% rh. They showed further losses amounting to 6,5% within 5 hours.

Free surface water like condensed dew droplets cannot serve as a source of water supply for *P. allocerus*. When water was sprayed to a smooth surface termites actively visited these sites and started to drink. However, due to the high surface tension termites were not able to retract their heads from the water droplets at the end of drinking process and 8 out of 10 test individuals finally died being tangled in the water film. When the water was offered in meshs of a fine nylon gauze (mesh size 0.33 mm), termites were able to to finish drinking successfully. During water uptake the oral cavity is opened widely and the hypopharynx is firmly pressed onto the moist gauze. Termites remained in this position up to half an hour. After exhaustion of water in the meshes of the drinking site the hypopharynx was retracted from the gauze and pressed to a neighbouring moist site.



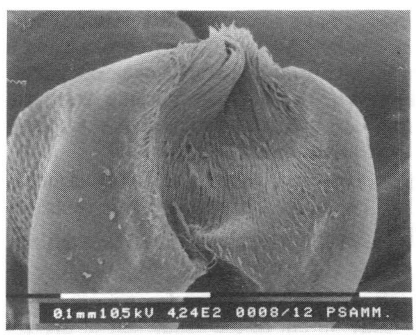


Fig. 1: Scanning electron micrograph of the head (ventral view) of *P. allocerus* (Pseudergates) showing the mouthparts and the hypopharynx (H). The labrum has been cut off. Scale: 1 mm

Fig. 2: Scanning electron micrograph of the frontal area of the hypopharynx . The apical region is covered with strictly unidirectional arranged trichoms. Scale: 0.1 mm

The duration of drinking process and the amount of water imbibed were determined using partially dehydrated pseudergates, i.e. individuals which have been maintained for 42 hs in 93% rh in either groups of 5 or 9 termites. Individuals of the smaller test group showed losses of body weight of 4,7% ± 2% and those of the larger groups 0,9% ± 0,2%. During the subsequent drinking period groups of 5 individuals showed the most efficient water uptake. Average drinking time ranged from 2 to 19 minutes and their average water gain amounted to 7,5% ± 3% of total body mass; within the larger groups of 9 individuals drinking time was shorter on the average and the amount of water picked up was only 1,6% ± 0,4% of body mass.

The function of the hypopharynx in the course of water uptake from capillary systems of substrates elucidates from the fine structure of the hypopharyngeal surface (Fig. 1). The tongue-like organ of the Pseudergates of *P. allocerus* has a dorsal length of ~ 0.4 mm and an apical width of ~ 0.23 mm. The apical area is slightly bent down ventrally and covered with a dense mat of hairs with decreasing density to the peripheral area. These acellular trichoms have their maximal density and length along the dorso-ventral centre line and are strictly unidirectionally arranged to the tip of the hypopharynx and forme a "flame" (Fig. 2). Their surface structure is comparable to a string of beads (Fig. 3).

Fig. 3: Detail of the apical acellular trichoms at the tip of the hypopharynx showing their surface structure. Scale: 10 μm

The capillary spaces between these trichoms come into direct contact with the capillary system of the substrate, when the hypopharynx is pressed onto it during water uptake and water can pass via the hair mat into the oral cavity. At the end of water uptake the termites abruptly removed their head from the substrate with a jerking movement, this overcoming the capillary force of the water.

Mechanisms of water transfer from the trichoms into the termite body are still unknown as is the compartment of the termite body to which the water is transferred . Dyed water, which was imbibed by the pseudergates, could never be found in the labial gland reservoirs, the so called "water-sacs", but in all parts of the digestive system.

Discussion

Pseudergates of *P. allocerus* inhabiting dry and warm habitats with extremely low precipitation do not show any additional water proofing devices as compared to species from moist climates. To avoid severe water losses, occuring in all humidities below 98% rh, their activities are strictly confined to subterranean systems of galleries and caverns. The remarkably lower water losses of the termites in groups, in comparison to solitary individuals, shows that sociality is essential to ensure the continued survival of the colonies. A lack of contact with nestmates in individual termites leads to higher water loss, resulting from erratic locomotor activity and further respiratory water losses.

Pseudergates of *P. allocerus* possess a specifically equipped hypopharynx with an extensive trichom mat. The hypopharynx is the decisive organ for the water vapour uptake from the atmosphere in some insect groups like Psocoptera (Rudolph 1982), Phthiraptera (Rudolph 1983) and cockroaches (O'Donnell 1977). However, even despite some resemblence of the hypopharyngeal hairfields of *P. allocerus* and the desert cockroach *Arenivaga investigata*, the former is not able to take up water vapour from the air. This was also shown for several other termite species (Rudolph et al. 1990).

The only reliable source of water supply for *P. allocerus* is the water confined in the soil capillary system; to get access to this water the hypopharyngeal surface is firmly pressed to the soil surface. The mat of unidirectionally arranged trichoms provide the necessary reduction in water activity to overcome the capillary forces of soils. Remarkable forces of such hairfields in reducing water activities were shown by O'Donnell (1981) and Lys & Leuthold (1994).

Literatur

Lüscher, M. 1961. Air-conditioned termite nests. Sci. Americ. 205: 138-145

Lys J. A. & Leuthold R. 1994. Forces affecting water imbibition in *Macrotermes* workers (Termitidae: Isoptera). Ins. Soc. 41: 79-84

O'Donnell M. J. 1977. Hypopharyngeal bladders and frontal glands: novel structures involved in water vapour absorption in the desert cockroach, *Arenivaga investigata*. Am Zool. 17: 902

O'Donnell M. J. 1981. Water vapour absorption by the desert burrowing cockroach, *Arenivaga investigata*: evidence against a solute dependent mechanism. J. exp. Biol. 96: 251-262

Rudolph D. 1982. Site, process and mechanism of active uptake of water vapourfrom the atmosphere in the psocoptera. J. Ins. Physiol. 28 (3): 205-212

Rudolph D. 1983. The water vapour uptake system of the Phthiraptera. J. Ins. Physiol. 29 (1): 15-25

Rudolph D. et al. 1990: On the role odf different humidity parameters for the survival, distribution and ecology of various termite species. Sociobiology 17 (1): 129-140