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Dew, fog and hygroscopic food as a source of water for desert arthropods

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Utilization of dew and damp hygroscopic material as water sources by desert arthropods has been demonstrated. The arthropods that were observed drinking dew or eating hygroscopic material include isopods, ants, heteropteran bugs, carabid, coccinellid and several tenebrionid beetles, including one day-active species. The amount of water gained by the tenebrionid beetles following intake of hygroscopic material was measured in field experiments and found to be substantial.

Introduction

Most desert arthropods live far from any source of open water. Although they inhabit areas that are almost totally dry in summer, certain species occur in large numbers. The question arises; how are they able to obtain the necessary water?

Edney (1974) summarized the sources of water which may be available to desert arthropods. Besides the water content of their food, he mentioned the possibility of oral and anal uptake from moist surfaces and the direct absorption of water from unsaturated air. But surprisingly little attention has been paid to the phenomena of dew and fog in desert areas, and to the possibility of their regular absorption by desert animals. The possible utilization of hygroscopic (mostly plant) material, which has absorbed water vapour from unsaturated air, has also been neglected.

Taylor (1968), however, demonstrated the use of hygroscopic food as a source of water by desert antelopes in Kenya, while Louw (1972) and Hamilton & Seely (1976) gave interesting information on the use of the advective fog as a source of water by tenebrionid beetles in the Namib Desert. (See also Seely, 1978.) This paper attempts to demonstrate the use of these sources of water by the many arthropods that inhabit the desert areas of Israel.

Material and Methods

The region at which the observations were made is located immediately south of the city of Arad, Israel (600 m above sea level), 35°15′ N, 31°15′ E. The mean annual rainfall is 152 mm. This region is classified by Meigs (1952) as an 'arid area' (Ac 23).

The area of the observations consists of a little valley with moderate slopes. The slopes are almost barren but, in the valley proper, the vegetation is relatively dense and consists of

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two dominant plants: *Atriplex spongiosa* (Muell.) and *Atriplex leucoclada* (Boiss.). The former was introduced to Israel from Australia.

Observations were carried out by regular investigation of strips of ground in the area. At night, this was done with the aid of flashlights. Microclimatological measurements were carried out at the beginning of each observation period. Temperature was measured at a height of 5 cm above ground by a YSI tele-thermometer. Humidity was measured at the same height by the dry-bulb and wet-bulb method, using YSI thermistor probes. The probes were inside a special screen, which will be described elsewhere. Body temperatures of beetles were measured by a YSI tele-thermometer with probe No. 524 (24 gauge). In every observation period, samples of hygroscopic plant fragments were collected in sealed vessels. Their water content was later determined in an oven.

Numerous field observations were carried out. Here only a description of one typical night and early morning observation (12 October 1972) will be given. On that night, a very dry and hot week, a heat wave, came to an end with the occurrence of dense fog. The fog continued until late the following morning, and dozens of nocturnal insects moved in the wet area, alongside diurnal forms.

Nocturnal tenebrionids (*Trachyderma philistina* (Reiche.)) and diurnal tenebrionids (*Adesmia dilatata* (Klg.)) were used in the field experiments. The beetles were taken to the laboratory, marked individually, weighed in a Mettler balance accurate to the nearest 1 mg and put under desiccating conditions. They were reweighed and subsequently returned to the field during nights when dew fell. There they were released in containers (55 cm in diameter and 16 cm high), but without covers or bottoms, in an area covered with leaves and fruit of *Atriplex* which were wet with dew. In the control groups, the upper layer of leaves and fruit was carefully removed, so that only dry plant material remained. At the end of the experiments, the beetles were once more collected and reweighed.

Results

A. *Drinking drops of dew*

During the early morning, specimens of the bug *Scanthius aegyptius* (Cast.) (Pyrrhocoridae) were observed standing on wet stones, the proboscis curved and extended at right angles to the substrate. They sucked tiny drops of water from the rough surface of the stone. Ants of the species *Monomorium subopacum* (Smith) were observed walking in 'ant-paths'. At the ends of the paths, some wet stones were covered with scores of ants whose mouthparts were moving inside the tiny pores on the surface of the stones as they drank the dew (Plate 1).

Predatory beetles, *Carabus impressus* (Klg.) (Carabidae), were observed travelling on an *Atriplex leucoclada* bush, 'harvesting' dew drops from the surface of the leaves. They moved their big mandibles, one on each side of the leaf blade, collecting large drops of water (Plate 2). Specimens of *Coccinella septempunctata* (L.) (Coccinellidae) were seen on the same bushes. The heads of these little predatory beetles were seen in contact with drops of dew, in such a way that the drops formed a meniscus between the leaf and the beetles' mouthparts.

The nocturnal tenebrionid beetle *Blaps sulcata* (Cast.), usually to be found walking on the ground, was seen on the top of a dead plant (*Carthamus palaestinus* (Compositae)), 50 cm above ground, sitting on the head of the fruit (capitulum) and drinking dew (Plate 3).

B. *Obtaining water from wet material*

The soil in the observation area is loess. After a night rich with dew or heavy fog, the upper layer of the soil is partially covered by wet patches. At sunrise, specimens of the isopod *Hemilepistus reaumuri* (Aud. & Sav.) were observed outside their holes, eating dead fragments of *Atriplex* which had been wetted by the dew. Other specimens were seen scratching and eating the wet loess.

Excluding ants, the most common insects to be seen in the observation area were tenebrionid beetles. Among the many different species observed, mention will only be made of *clada* (Boiss.). The former

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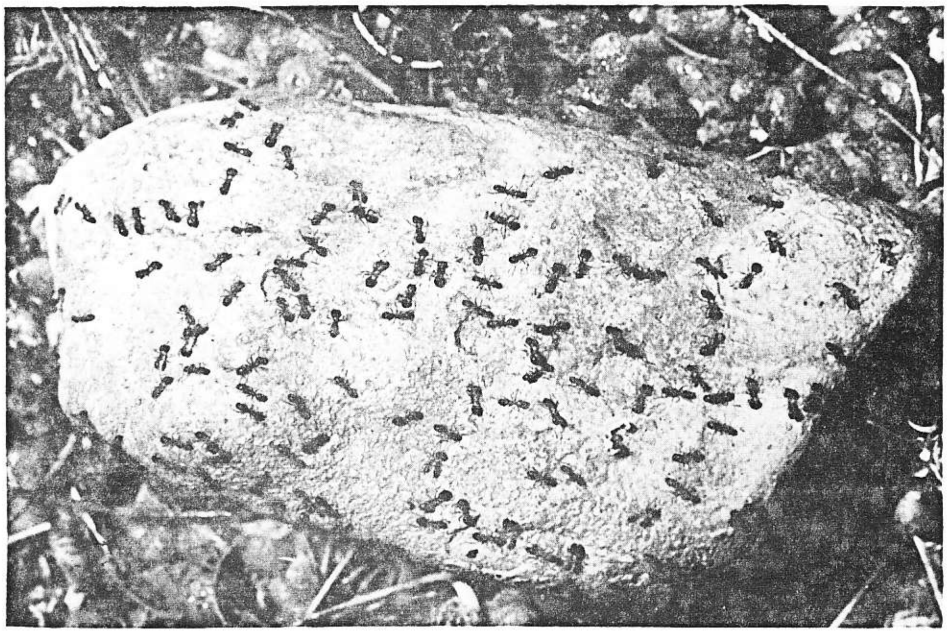

Plate 1. Ants of the species *Monomorium subopacum* (Smith) collecting drops of dew from the tiny pores on the surface of stone.

Plate 2. The predatory beetle *Carabus impressus* (Klg.) collecting drops of dew from the surface of leaves.

[*facing page 44*]

Plate 3. The ground-dwelling tenebrionid beetle *Blaps sulcata* (Cast.) climbing high above the ground to drink dew which had been gathering in the fruit of a composite plant.

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three nocturnal ones: *Blaps sulcata* (Cast.), *Pimelia derasa* (Klg.) and *Trachyderma philistina* (Reiche). Many dozens were noticed actively eating and drinking on dewy nights. Most were seen taking water from the damp hygroscopic plant material. More than three dozen were seen eating wet plant fragments during a two-hour period on 12 October 1972.

Diurnal, thermophilic insects warm themselves by solar radiation, before activity begins. The same radiation also causes dew to evaporate. An attempt was made by observing the tenebrionid beetle *Adesmia dilatata* (Klg.) to discover how diurnal insects reconcile their need for sunlight with their need for water.

Observations on the activity of *Adesmia*, during the last week of September 1972, showed the well-known pattern of beetles warming themselves at the beginning of the day. Activity began only after body temperature had reached 33·5–34·5 °C. By that time, there had occurred a partial drying of the wet hygroscopic plant material (Table 1; 22 September 1972).

The second week of October 1972 was very dry and hot, a heat wave. An observation which was made during the middle of this heat wave, and a second, made on the morning on which the heat wave came to an end, are summarized in Table 1.

During the heat wave (9 October 1972) we did not observe any activity of *Adesmia* in the area. During the morning of 12 October 1972, however, when the heat wave ended there was heavy fog and very humid conditions. The *Adesmia* beetles then came out in large numbers and did not wait until they were warmed. The beetles were active when their body temperatures were very low—about 20·5 °C. They were seen eating wet hygroscopic plant material.

C. *Field experiments*

In addition to the above observations, additional experiments were carried out in the field. Particulars of the exact conditions and the results are given in Table 2.

Table 2 shows that specimens of *Trachyderma* sp. which had been put into a container with wet material on dewy nights, increased their body weight significantly—by eating the wet plant fragments or sucking water from them. They increased their total body weight by an average of 14·0 per cent, while there was, on average, no increase in the control group. Although two control specimens increased their body weight by 1·2 per cent, the remainder lost weight.

If it is assumed that all the weight gained was due to water, the insects would have increased their moisture content by approximately 27 per cent. But, since it is possible that they may also have eaten the hygroscopic material, which contained 68·2 per cent water and 31·8 per cent dry material, it can be calculated that only 68·2 per cent of the increase in weight is due to water (Table 2). This would mean that their water content increased by 19·5 per cent.

The test group of *Adesmia* increased their total body weight by a lower value—only 7·6 per cent—but this is still a substantial increase compared with the controls which showed an average increase in weight of only 1·2 per cent of initial body weight. By evaluating the amount of water which the control beetles could have absorbed from the dry material that they had eaten, we arrive at an insignificant value, due to the low percentage of water in the food, of only 16·4 per cent (Table 2).

Discussion

Botanists and meteorologists have, for a long while, believed that dewfall drastically influenced the water balance of plants (Ashbel, 1936; Duvdevani, 1964). However, in later works (Evenari *et al.*, 1971), it has been claimed that dew has no importance as a source of water for higher desert plants, although dew is known to be the main water source for desert lichens and algae (Lange *et al.*, 1970; Berner, 1974).

In contrast, apart from the works of Louw (1972) and Hamilton & Seely (1976) almost no attention had been drawn to the possible effects of dew and fog on desert animals. Louw

Table 1. *Microclimate condition and activity of* Adesmia dilatata *at the Arad highlands after dew-nights and during a dry period for comparison* (*time*: $GMT+2$)

Date	Temperature and relative humidity near the ground 0400 h	0800 h	% of water on samples of dead leaves and fruits taken before sunrise	No. of *Adesmia* seen in the observation area between 0600 and 0800 h	The activity of *Adesmia* between 0600 and 0800 h	Temperature of beetles at beginning of activity
22 September 1972	18 °C 100% r.h.	29·5 °C 67% r.h.	—	4	Warming	33·5–34·5 °C
9 October 1972	12·5 °C 97% r.h.	31·8 °C 62% r.h.	66·0–77·1	0	—	—
12 October 1972	16·8 °C 100% r.h.	26·2 °C 86% r.h.	78·0–90·5	22	Slow moving, eating dead plant material which absorbed dew	20·5–21·0 °C

Table 2. *Eating of hygroscopic material by one nocturnal species and one diurnal species of tenebrionid beetles, during field experiments**

Test organism	Treatment	No. of specimens	Loss of weight during desiccation (% of initial weight) (preconditioning)†	Body water content before the experiment (% of total weight†)	Relative humidity near the ground at beginning and end of the experiment (%)		Water in the hygroscopic material in the arena (%)	Gain of weight during the experiment (% of the weight before eating†)
Trachyderma philistina	Test	7	23·0 ± 4·30	61·4 ± 3·09	90	96	68·2	14·0 ± 3·89
	Control	10	21·6 ± 4·27	61·9 ± 3·13			37·5	0
Adesmia dilatata	Test	10	17·8 ± 4·87	72·8 ± 2·94	78	33	52·7	7·6 ± 2·29
	Control	10	17·9 ± 2·12	73·5 ± 2·87			16·4	1·2 ± 0·31

* Date and time of the field experiments:
Nocturnal beetles (*T. philistina*): 19 October 1972, 01.30–05.30 h.
Diurnal beetles (*A. dilatata*): 24 October 1972, 06.15–10.00 h.
(Time: GMT+2.)

† Mean ± S.D.

and Hamilton & Seely describe the drinking of drops of fog by two species of tenebrionid beetles in the Namib sand-dunes. The observations reported here extend the phenomenon to many other arthropods with different feeding habits. These include carabid and coccinelid beetles which are predators. It has previously been thought that they obtain all their water from the body fluids of their prey. But, after a dry period they are also able to use dew as a source of moisture to make up their water deficit.

The behaviour of *Adesmia dilatata* was even more comprehensive. The genus *Adesmia* (Tenebrionidae) consists of many thermophilic, diurnal species in Africa and Asia (Cloudsley-Thompson, 1963). The preferred temperature of the various species previously investigated has been found to lie between 34 and 39 °C (Bolwig, 1957; El Rayah, 1970; Broza, 1977). Although the overall range of activity occurs at body temperatures between 20 and 40 °C (El Rayah, 1970; Broza, 1977), body temperatures below 25 °C have been measured previously only when the beetles leave or enter their night retreats. According to the results given here, however, beetles of the species *Adesmia dilatata* change their behavioral pattern of activity and their temperature response when they can thereby satisfy their need for water at an unusual hour of the day. During fog, they feed at dawn alongside nocturnal insects.

Another question considered was whether the amount of water obtained from dew is sufficient to serve as a main source of water for small desert animals throughout the year. The following information supports this hypothesis. Information concerning the occurrence of dew and fog in the desert areas of the world is very scarce, but some work has been carried out in Israel (McGinnis *et al.*, 1968).

In the desert area of Israel, there are regions with over 200 dew-nights and more than 30 mm dew per year. These are the arid regions near the Mediterranean sea-shore and the Negev Highland regions. Indeed, the amount of dew decreases greatly in other Negev areas and, at the southern end of the Jordan rift valley, only 4–20 dew-nights, per year, have been recorded (Ashbel, 1949; Gilead & Rosnan, 1954; Evenari *et al.*, 1971).

In Avdat (34°46′ N, 30°47′ E, 65 km southwest of our observation area, the yearly dewfall is more than one-third of the mean annual rainfall. Even more important is the fact that the amount of dew tends to be fairly constant from year to year, in contrast to the extremely variable rainfall. Rain falls for an average of 16 days a year in the Negev Highlands, but only during the winter. Dew not only appears throughout the whole year, but is more frequently encountered during the dry season when, on average, two out of every three nights in Avdat are moist (Evenari *et al.*, 1971).

Fog is also common in the northern part of the Israel desert area and is of a radiational type. There is an average of 42 foggy nights a year; most of them during the dry period of the year (Levi, 1967). From the point of view of this study, foggy nights played approximately the same rôle as dew-nights. Indeed, they are recorded in our dew gauge as dew-nights.

The amount of dew formed in a dew-night is very small. But, according to Ashbel (1949), we can multiply the amount of dew on the gauge by four to obtain an estimate of the amount that may be deposited on plants. Furthermore, dew is deposited unevenly: the result is that it condenses in significantly large drops of water, enough to satisfy the requirements of small animals—at least in the Negev Highlands and sea-shore in Israel.

Summary

Utilization of dew and damp hygroscopic material as a source of moisture by desert arthropods was demonstrated. During field observations, two relevant phenomena were observed: direct drinking of dew drops and eating of hygroscopic material which had absorbed water during the night. The field observations reported herein were carried out immediately after the end of a heat wave. The arthropods that were observed drinking dew or eating hygroscopic material include isopods, ants, bugs, carabid and coccinellid beetles and several

tenebrionid beetles, including one diurnal species. The amount of water gained by tenebrionid beetles following intake of hygroscopic material was measured in field experiments and found to be substantial.

Information on the occurrence of dew and fog in the desert area of Israel is summarized. It is concluded that these sources of water may cover the needs of many desert arthropods.

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