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# The influence of biological soil crusts on dew deposition in Gurbantunggut Desert, Northwestern China

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SUMMARY

Dew is an important source of moisture for plants, biological soil crusts, invertebrates and small vertebrates in desert environments. In this paper, measurements were taken to investigate the effects of three different types of biological soil crusts (cyanobacteria, lichen and moss) and bare sand on dew deposition in the Gurbantunggut Desert. Dew quantities were measured using micro-lysimeters with a diameter of 6 cm and a height of 3.5 cm. The results showed that the total amount of dew deposited increased with the development of soil crusts, from bare sand to cyanobacterial crust to lichen crust to moss crust. The average amount of dew deposited daily on the moss crust was the highest of all and it was significant higher than the other three soil surfaces (lichen crust, cyanobacterial crust and bare sand) ($p < 0.05$). During the period of the study, for each type of crust studied, the maximum amount of dew recorded was several times greater than the minimum. Moss crust was characterized by having the greatest amount of dew at dawn and also the maximum amount of dew deposited, whereas bare sand yielded the lowest amount of dew, with lichen crust and cyanobacterial crust exhibiting intermediate values. However, this was not the case for dew duration, as bare sand retained moisture for the longest period of time, followed by cyanobacterial crust, moss crust and finally lichen crust. Dew continued to condense even after sunrise. Furthermore, the differences in dew deposition may be partially attributed to an effect of the biological soil crusts on surface area. This study demonstrates the important effect of biological soil crusts upon dew deposition and may assist in evaluating the role of dew in arid and semi-arid environments.


## Introduction

Water availability is the most important limiting factor in arid lands where any additional source of water can have a positive impact upon the ecosystem. In arid and semi-arid areas, apart from precipitation in the form of rain or snow, dew and fog play a vital role in providing an essential source of water for plants, invertebrates, small vertebrates and biological soil crusts. This is especially the case in desert environments, where water resources are severely limited and dewfall and early morning evaporation are the most important processes affecting the daily water balance of the upper soil layer (Broza, 1979; Duvdevani, 1964; Jacobs et al., 1999; Moffett, 1985).

Dew and fog are features of many deserts (Kidron, 1999, 2000b; Zangvil, 1996). In Avdat, in the heart of the Negev Desert Highlands, 195 days of dewy and foggy mornings were recorded, providing a mean annual yield of 33 mm of dew and fog precipitation during 17 years of measurements (Evenari, 1981). Although supplying relatively small amounts of moisture, the fact that fog and dew provide a constant and stable water source may be of greater value in arid and semi-arid zones than ephemeral rainfall events. It has been suggested that the seed germination of annual plants in deserts is enhanced if dew occurs regularly (Gutterman and ShemTov, 1997) and droplets of dew that condense on the canopies of vascular plants can provide sufficient moisture to enable them to survive throughout the dry season. The role of dew as a factor in the stabilization of sand dunes has been recognized as an important meteorological factor in arid regions (Subramaniam and Kesava Rao, 1983).

Biological soil crusts which have extraordinary abilities to survive desiccation, extreme temperatures (up to 70 °C), high solar radiation, high pH, and high salinity, have been found in desert areas world wide and may constitute as much as 70% of the living ground cover of some plant communities (West, 1990). The presence of biological soil crusts, however, implies that some moisture must be available on a regular basis. Mosses, lichens, fungi and cyanobacteria, the components of biological soil crusts in arid

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areas, have evolved various mechanisms for desiccation tolerance, suspending metabolism during dry periods, then absorbing water rapidly and recommencing photosynthesis soon after precipitation events. Thus absorption of moisture from dew may be significant in determining the total period of potential net $CO_2$ uptake by biological soil crusts, providing relatively long phases of photosynthesis during the early morning daylight hours (Lange et al., 1998, 1992) before the moisture evaporates as the temperatures increase.

Dewfall is a process whereby atmospheric water vapour condenses and is deposited in the form of droplets on any cool surface, especially at night. During the night, free liquid water on the earth's surface can originate from three separate sources: the air (dewfall), the soil (dewrise) and plants (guttation) (Garratt and Segal, 1988). Deserts are characterized by low soil moisture and very low percentage of perennial vegetation cover, consequently moisture on the soil surface is primary due to dewfall (Jacobs et al., 2000). Numerous observations and simulations of dew deposition have been carried out in deserts, arid and semi-arid areas, humid tropical islands, rural areas, urban areas and forests (Clus et al., 2008; Jacobs et al., 1999, 2000, 2002; Kidron, 2000a; Liu et al., 2006; Malek et al., 1999; Moro et al., 2007; Richards, 2004; Zangvil, 1996). The amount of dew deposited varies with altitude, angle and aspect (Kidron, 1999, 2005). Some studies have found out that there were significant differences in daily dew amount among different kinds of soil surfaces (bare soil, gravel and sand mulches, and sandy soils with biological soil crusts) (Li, 2002; Liu et al., 2006; Ninari and Berliner, 2002).

Various dew-measuring devices are described in the literature, some measure the amount of dew deposited, some measure the duration of dew, and yet others are used to measure both the duration and the amount of dew (Agam and Berliner, 2006). There is no standard method or instrument that has been internationally accepted for measuring dew (Zangvil, 1996). Estimates of the actual amount of dewfall can be made by direct methods, for example, by using micro-lysimeters or the eddy correlation technique (Jacobs et al., 2000, 2002).

To quantify overnight dew deposition and evaporation during the early morning, measurements were made within an interdune area of the Gurbantunggut Desert, where different types of biological soil crusts are commonly found. This data will increase our understanding of the water balance in arid areas and provide valuable scientific information that can be utilized in policy-making for the management of desert ecosystem.

## Study areas

The Gurbantunggut desert (44°11′–46°20′N, 84°31′–90°00′E) is situated in the center of the Jungger Basin, Xinjiang Uygur Autonomous Region of China. It is the second largest desert in China with an area of $4.88 \times 10^4$ km$^2$. The Himalayan Range to the south produces a "blocking effect" so that, moist air currents from the Indian Ocean fail to reach the area, resulting in a vast expanse of arid terrain. Mean annual precipitation is approximately 79.5 mm, falling predominantly in spring. In sharp contrast, the mean annual pan evaporation is 2606.6 mm. The average temperature is 7.26 °C. Wind speeds are greatest during late spring, with average 11.17 m s$^{-1}$, and are predominantly from the WNW, NW and N directions. The natural vegetation is dominated by *Haloxylon ammodendron* and *H. persicum* (Amaranthaceae subfamily Chenopodioideae), with vegetation cover of less than 30%. The area is covered by massive, dense semi-fixed sand dunes with stable moisture content. Biological soil crusts are abundant in the desert. Most growth occurs during cool, wet periods (fall and early spring) when moisture from dew, fog or ephemeral rainfall events can be utilized by the component species of the soil crusts (Kidron et al., 2002; Zhang et al., 2007). This study was conducted in the southern part of the Gurbantunggut Desert on biological soil crusts typical of those found throughout the desert (Zhang, 2005; Zhang et al., 2007).

In extremely dry conditions, much of the sand surface of this desert is covered by biological soil crusts, which grow as hard, rigid crusts (Fig. 1) dominated by the cyanobacterium *Microcoleus vaginatus*, with occasional lichen and moss patches in interdune areas. The dominant species of each type of biological soil crusts are shown in Table 1.

## Materials and methods

In this study, the dewfall and early morning evaporation were measured using micro-lysimeters with a surface diameter of 6 cm and a height of 3.5 cm (Boast and Robertson, 1982). This method allows a soil core to be taken while leaving the surface intact, thus observations can be repeated using the same sample.

The observation areas were located in interdune areas of the Gurbantunggut Desert. The micro-lysimeters were pushed into the ground to collect undisturbed soil columns covered by representative biological soil crusts (cyanobacterial crust, lichen crust and moss crust respectively) and bare sand for control. The edges of the micro-lysimeters were close to the flat surface of the ground and their bases were covered. Each treatment was replicated five times. Crusts were not collected near shrub canopies in order to avoid any possible impacts shrubs might have on microclimate. During the experiment, there were 12 plots (1 m × 1 m) for each type of soil crust and five samples were taken from each plot every time.

The soil samples were weighted using a balance to a precision of ±0.01 g. The dew amount for each day was determined by calculating the difference between the weight in the morning and that at sunset of the previous day. In order to obtain a better insight into the time-course of dew deposition and dew duration, intensive measurements were carried out for several days on different samples. The weighing intervals are 2-h and 30-min for the time-course of dew deposition and dew duration respectively. The quantity of dew deposition (in millimeters) was calculated from these weights.

The soil temperature was measured by temperature sensor which was buried 5 cm below the soil surface covered with or without biological soil crusts. The soil temperature was recorded at 1 h intervals using a datalogger. For the whole observation period, the surface temperature and humidity were measured synchronously using a hygrothermograph (HC-520).

SPSS 11.5 statistical package was used to process the data. The effects of the biological soil crusts on dew condensation were compared using one-way ANOVA followed by post hoc LSD's honestly significant difference test.

## Results

### *Dew amounts on different types of biological soil crusts*

The variation in the dew amounts deposited on the different types of biological soil crusts and bare sand surface are shown in Fig. 2. Sixty-five records for dew amounts were obtained during the experimental period (7–23 May, September and October in 2008) (Fig. 2), when dew was recorded on almost every day other than on rain days. A general trend indicated the total amount of dew deposited increased with the developmental level of biological soil crusts, following the order: sand < cyanobacterial crust < lichen crust < moss crust (Fig. 2).