Soil Biology & Biochemistry 41 (2009) 2387–2393

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

Influence of dew on biomass and photosystem II activity of cyanobacterial crusts in the Hopq Desert, northwest China

Benqiang Rao [a,b,c], Yongding Liu [a,*], Weibo Wang [a,c], Chunxiang Hu [a], Li Dunhai [a,**], Shubin Lan [a,c]

[a] State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, Chinese Academy of Sciences, No.7 DongHu South Road, Wuhan, Hubei 430072, PR China
[b] College of Life Sciences, Xinyang Normal University, Xinyang 464000, PR China
[c] Graduate School of the Chinese Academy of Sciences, Beijing 100039, PR China

ARTICLE INFO

Article history:
Received 28 October 2008
Received in revised form
26 May 2009
Accepted 7 June 2009
Available online 26 June 2009

Keywords:
Biological soil crust
Dew
Cyanobacteria
Biomass
Photosynthetic activity
Rainfall
Desertification
Hopq Desert

ABSTRACT

Dew is an important water source for desert organisms in semiarid and arid regions. Both field and laboratory experiments were conducted to investigate the possible roles of dew in growth of biomass and photosynthetic activity within cyanobacterial crust. The cyanobacteria, *Microcoleus vaginatus* Gom. and *Scytonema javanicum* (Kütz.) Born et Flah., were begun with stock cultures and sequential mass cultivations, and then the field experiment was performed by inoculating the inocula onto shifting sand for forming cyanobacterial crust during late summer and autumn of 2007 in Hopq Desert, northwest China. Measurements of dew amount and Chlorophyll *a* content were carried out in order to evaluate the changes in crust biomass following dew. Also, we determined the activity of photosystem II(PSII) within the crust in the laboratory by simulating the desiccation/rehydration process due to dew. Results showed that the average daily dew amount as measured by the cloth-plate method (CPM) was 0.154 mm during fifty-three days and that the crust biomass fluctuated from initial inoculation of 4.3 μg Chlorophyll *a* cm^{-2} sand to 5.8–7.3 μg Chlorophyll *a* cm^{-2} crust when dew acted as the sole water source, and reached a peak value of approximately 8.2 μg Chlorophyll *a* cm^{-2} crust owing to rainfalls. It indicated that there was a highly significant correlation between dew amounts and crust moistures ($r = 0.897$ or $r = 0.882$, all $P < 0.0001$), but not a significant correlation between dew and the biomass ($r = 0.246$ or $r = 0.257$, all $P > 0.05$), and thus concluded that dew might only play a relatively limited role in regulating the crust biomass. Correspondingly, we found that rains significantly facilitated biomass increase of the cyanobacterial crust. Results from the simulative experiment upon rehydration showed that approximately 80% of PSII activity could be achieved within about 50 min after rehydration in the dark and at 5 °C, and only about 20% of the activity was light-temperature dependent. This might mean that dew was crucial for cyanobacterial crust to rapidly activate photosynthetic activity during desiccation and rehydration despite low temperatures and weak light before dawn. It also showed in this study that the cyanobacterial crusts could receive and retain more dew than sand, which depended on microclimatic characteristics and soil properties of the crusts. It may be necessary for us to fully understanding the influence of dew on regulating the growth and activity of cyanobacterial crust, and to soundly evaluate the crust's potential application in fighting desertification because of the available water due to dew.

1. Introduction

Biological crusts have been considered significant desert colonizers and can occur under a large range of harsh conditions. Their importance in stabilization of dunes and promotion of desert soils have been extensively recognized (Brotherson and Rushforth, 1983; Pluis and de Winder, 1989; Johansen, 1993; Eldridge and Greene, 1994; Danin et al., 1998; Hu et al., 2002a; Belnap, 2003). It was concluded that the formation of biological crusts was driven by growth of the sheath-forming and exopolysaccharides (EPS)-excreting filamentous cyanobacteria (West, 1990; Belnap and Gardner, 1993; Mazor et al., 1996).

In deserts, biological crusts undergo various environmental stresses such as desiccation, irradiation and fluctuation of temperature, etc. Particularly, desiccation may be the most notable ecological factor influencing the crusts in arid and semiarid regions, and organisms inhabiting the crusts must have developed survival

* Corresponding author. Tel./fax: +86 27 687 80371.
** Corresponding author. Tel./fax: +86 27 687 80715.
E-mail addresses: liuyd@ihb.ac.cn (Y. Liu), lidh@ihb.ac.cn (L. Dunhai).

0038-0717/$ – see front matter © 2009 Published by Elsevier Ltd.
doi:10.1016/j.soilbio.2009.06.005

acclimations that are capable of reversibly and rapidly activating physiological activities during frequent desiccation and rehydration cycles (Harel et al., 2004). Remarkably, the mechanisms whereby cyanobacteria within the crusts can activate photosynthetic activity may be of considerable importance during diurnal desiccation and rehydration owing to dew. As indicated, dew is an important source of moisture for animals, plants, and especially for microorganisms comprising biotic crusts (Danin et al., 1989; Degen et al., 1992; Lange et al., 1992; Simon et al., 1994; Jacobs et al., 1999). Jacobs et al. (1999) suggested that in arid environments dew was available at every turn and was able to permit cyanobacterial photosynthesis to occur. However, very little information can be obtained regarding the roles of dew in growth and activity of cyanobacterial crust.

The objective of the present study was to evaluate the possible roles acted as by dew during early growth of cyanobacterial crust by measurements of dew quantities, crust biomass and photosynthetic activity within the crust. Here, the attractive points deserving of studying may be produced as follows: 1) What are the relationships between dew amount and cyanobacterial crust biomass; 2) How to activate PSII activity of the crust following dew; 3) What are the mechanisms of dew deposition and its drying on the crust? The researches may be necessary for better understanding of the acclimation of cyanobacterial crust against drought in dewy conditions, and for better understanding the significance of the crust in resisting desertification and in soil erosion.

2. Materials and methods

2.1. Study area

The present study area is located in the South fringe of Hopq Desert in Inner Mongonia of China, with an altitude of 1040 m above sea level, and is characterized by a mass of sand dunes with average height of 5 m above the ground. The rainy season usually occurs between September and October, and the average annual rain precipitation is about 293 mm with mean annual evaporation 2448 mm. Fog and dew are abundant in this region and happen on more than 40% of the mornings. The climate belongs to typical continental monsoon pattern, with the average annual temperature 6.1 °C, and with windy days (>5 m s^{-1}) more than 180 d y^{-1}. The monthly average rain precipitation, evaporation and relative humidity based on 28 years records are shown in Fig. 1. In the area, soil bulk density is approximately 1.55 g cm^{-3} and soil pH is about 8.56. The average contents of Total N, organic C and $CaCO_3$ are 0.19 g kg^{-1} dry soil, 0.41 g kg^{-1} dry soil and 4.48 g kg^{-1} dry soil, respectively (Wang et al., 2008).

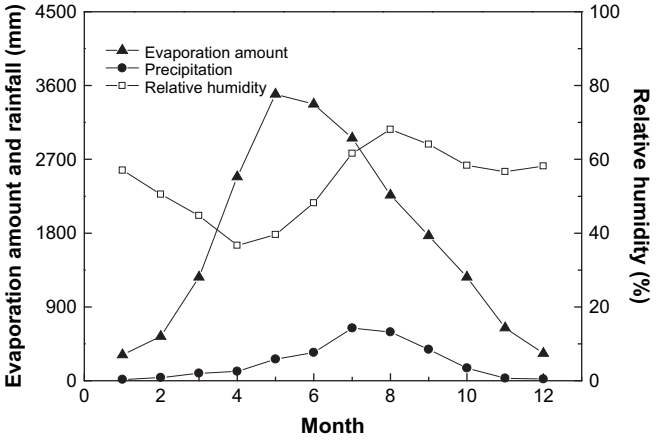

Fig. 1. Monthly average rain precipitation, evaporation and relative humidity in Hopq Desert based on the records of 28 years.

2.2. Cyanobacteria cultivation

Two species of cyanobacteria, *Microcoleus vaginatus* Gom. and *Scytonema javanicum* (Kütz.) Born et Flah., were isolated from desert biotic crusts, and were selected as inocula. The reason that *M. vaginatus* and *S. javanicum* were chosen for inocula was due to their potential ability to rapidly form cyanobacterial crusts (Belnap and Gardner, 1993; Garcia-Pichel and Belnap, 1996; Hu et al., 2000). The two cyanobacteria were begun with stock cultures by carefully homogenizing their cells using sterilized glass homogenizers. Subsequently, *M. vaginatus* in BG-11 and *S. javanicum* in BG-11_0 were all maintained at the temperature of 25 ± 1 °C and under the cool fluorescent illumination of 40 μE m^{-2} s^{-1}. Ultimately, mass cultivation was carried out in a greenhouse. The two separate inocula of 15 d cultivation were transferred into four raceway culture pools with paddle wheels, respectively. The cultures were harvested after about 12 d when the two cyanobacterial cells had achieved exponential growth phase.

2.3. Methods

2.3.1. Experimental design

The dunes at this research site are oriented West-east, and are separated by wide (100–150 m) interdune areas. An interdune area was selected as our experimental field site because the interdune was commonly flat, and abundant dew was found to occur in the interdune. Our experimental study was conducted for nearly an 8-week period at the area from August to October 2007. Twelve cross-sections of 1 m × 0.5 m were selected for cyanobacterial inoculation in the area. Six sections were randomly chosen as one inoculation plot (named PLOT a), and the remaining six sections as another inoculation plot (named PLOT b). *M. vaginatus* and *S. javanicum* were mixed at algal biomass ratios of 10:1 and 5:1 (i.e., 10 parts *M. vaginatus* to 1 part *S. javanicum* and 5 parts *M. vaginatus* to 1 part *S. javanicum*, and total chlorophyll *a* contents of the two mixtures were same), and inoculated evenly onto PLOT a and PLOT b, respectively. The ultimate biomass of the twelve cross-sections was approximately 4.26 μg Chlorophyll *a* cm^{-2} sand surface. Moreover, in order to determine the amounts of dew under the same circumstances, a nearby separate section was chosen for dew measurement in the interdune.

2.3.2. Cyanobacterial crusts culture

The cyanobacterial crust cultivation was based on the technical development of man-made biotic crusts and on the corresponding research achievements regarding the artificial crusts, which had long been conducted from 2000 to today in Hopq Desert, China (Liu and Ley, 1993; Liu et al., 2001; Hu et al., 2002b, 2003; Hu and Liu, 2003; Chen et al., 2006; Xie et al., 2007; Wang et al., 2008). The field inoculations were watered with an automatic sprinkling irrigation facility for the first 7d from 1 to 7 August 2007 after the inocula were inoculated onto the sand surface. During sprayings of the first 3 d, the time of 9:00–11:00 and 15:00–17:00 each day was chosen as sprinkling for 30 min every 2 h intervals at a flux of 50 ml m^{-2} min^{-1}. In the following 4 d, irrigation was reduced to half of initial amounts (all the above watering using BG-11 growth medium). During the subsequent days, watering was entirely ceased due to the need of the experimental investigation. So, on the third day after stopping irrigation, the relevant measurements were launched from 10 August to 7 October 2007.

2.3.3. Dew amount measurement

Owing to the fact that no standard method was accepted internationally for dew measurement (Zhangvil, 1996; Li, 2002), the amounts of dew were determined by the cloth-plate method