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Effect of wind speed on loss of water from *Nostoc flagelliforme* colonies

Kunshan Gao[1,2,*], Baosheng Qiu[1], Jianrong Xia[2], Aijun Yu[1] & Yunguang Li[1]
[1] *Institute of Hydrobiology, The Chinese Academy of Sciences, Wuchang, Wuhan, Hubei, 430072 China*
[2] *Institute of Energy and Environmental Sciences, Science Center, Shantou University, Shantou, Guangdong, 515063 China*

(* *Author for correspondence; e-mail ksgao@public.wh.hb.cn)*

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Abstract

The effects of wind speed on loss of water from *N. flagelliforme* colonies were investigated indoors in an attempt to assess its ecological significance in field. Wind enhanced the process of waterloss; the half-time of desiccation at wind speeds of 2.0 and 3.4 m s^{-1} was, respectively, shortened to one-third and one-fifth at 20 °C and, to one-sixth and one-eighth at 27 °C that of still air. Photosynthetic efficiency was not affected before the wet alga lost about 50% water.

Introduction

Nostoc flagelliforme is a terrestrial blue-green alga of economic value as food or herbal ingredient in China. However, the resource is being over-exploited and is diminishing, while the market demands are increasing with the economic growth (Gao, 1998). *N. flagelliforme* is distributed in arid or semi-arid steppes or bare lands in the northern and north-western parts of the country, where temperature is marked by great daily and yearly variance and wind is frequent. The alga has been shown to be ecologically drought-adapted and physiologically heat-resistant; drought is not simply an environmental stress, but of physiological and ecological significance for its survival in these environmental extremes (Gao, 1998). Excess water either reduces photosynthetic production (Sheng et al., 1984) or leads to its disintegration, as shown in culture (Wang et al., 1992). *N. flagelliforme* posseses a higher surface to mass ratio than *N. commune*, which is distributed at places with more moisture (Scherer et al., 1984). A large surface to mass ratio is usually associated with rapid water absorption and water loss. Being able to absorb water and loose water rapidly may be ecologically and physiologically important for *N. flagelliforme* to sustain its life (Gao, 1998). The balance of gain and loss of water is obviously important for the alga. In addition, the rate at which *Nostoc* colonies are dried in air can be critical to cell survival (Potts, 1994). Since *N. flagelliforme* is distributed in the areas of frequent wind, wind speed is an important factor affecting its water status. The aim of this study was to quantify how this factor affects to loss of water from *N. flagelliforme* colonies.

Materials and methods

The effects of wind speed on loss of water from *N. flagelliforme* colonies were investigated in laboratory. *Nostoc flagelliforme* (Berk. & Curtis) Bornet & Flahault was collected at Siziwangqi, Inner Mongolia, in 1995 and stored under dry conditions before use for experiments in 1997. The sample had been wetted with distilled water for 5–8 h before the wind experiments. Wet mats (8 cm in diameter) of the alga were laid on transparent plastic sheets that were then placed on an experimental table. A fan was stationed at a horizontal position to provide flat air flow above the table. Various wind speeds were obtained by adjusting the distance

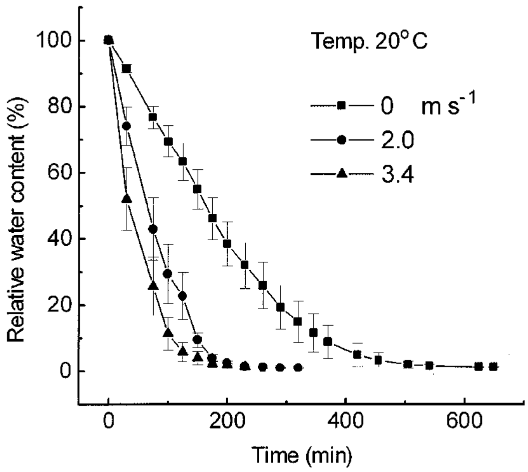

Figure 1. Time course of relative water content of *N. flagelliforme* exposed to still air (0 m s^{-1}) and moving air (2.0 and 3.4 m s^{-1}) at 20 °C. Means of 5 mats ± SD.

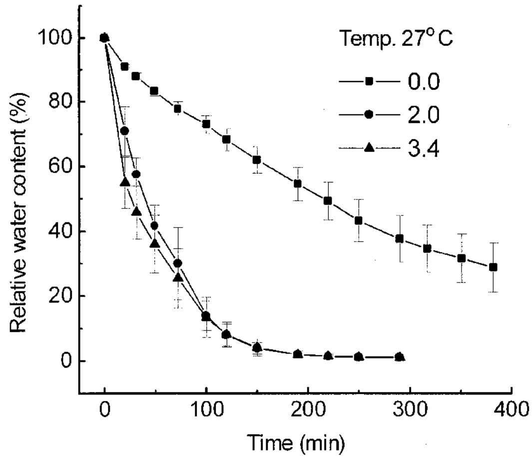

Figure 2. Time course of relative water content of *N. flagelliforme* exposed to still air (0 m s^{-1}) and moving air (2.0 and 3.4 m s^{-1}) at 27 °C. Means of 5 mats ± SD.

from the fan to the mats. At the beginning of the experiment, the wet weight was determined after the wet mats of *N. flagelliforme* had been shaken or tapped to remove excess water drops. The relative water content (RWC) was calculated as follows:

$$RWC = \frac{W_t - W_d}{W_w - W_d} \times 100,$$

where W_t is the weight of a mat measured at certain time intervals; W_d is the dry weight (85 °C, 12 h); W_w, the initial wet weight. Samples were weighed to the nearest mg value with an Ohaus balance (TS400D). Relative water contents were determined at various wind speeds, at 20 and 27 °C in an air-conditioned room. Wind speed was measured by a decline manometer (YYT-2000). Light irradiation was about 4 μmol m^2 s^{-1} during the exposure provided. Relative humidity was 57 and 66% for the experiments at 20 and 27 °C, respectively.

The ratio of variable to maximal fluorescence (F_v/F_m) of the dark adapted samples was used as a measure of photosynthetic efficiency, which has been showed to be proportional to the quantum yield of photochemistry (Krause & Weis, 1991; Hanelt, 1992). Photosynthetic recovery after rewetting was made at 40° μmol m^2 s^{-1}; F_v/F_m was measured according to Gao et al. (1998). The filaments of *N. flagelliforme* were spread on plastic sheets and exposed to 40 μmol m^2 s^{-1} at 20 °C while the relative water content and F_v/F_m were determined.

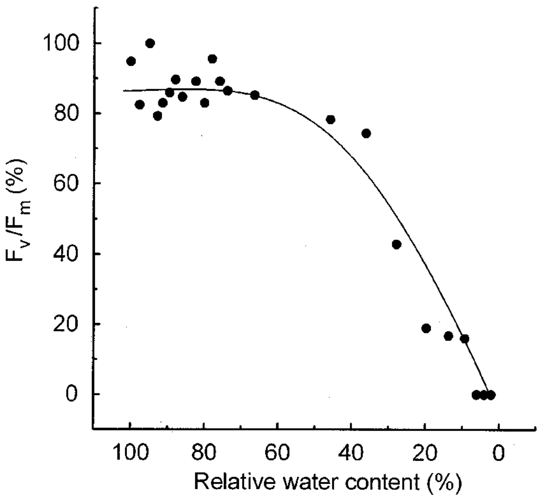

Figure 3. Relationship of relative photosynthetic efficiency (F_v/F_m, %) to relative water content in *N. flagelliforme.* Means of 15 samples ± SD.

Results

Water-loss from the mats of *N. flagelliforme* was faster at higher wind speeds (Figures 1, 2). At 20 °C, the alga had lost almost all of the water in 440, 180 and 150 min and the half-period for desiccation was 165, 60, and 34 min at 0, 2.0 and 3.4 m s^{-1}, respectively. The algal mats lost water 2.4–2.9 times faster in the moving air than in the still air in terms of loosing all the water; however, in terms of the half-period for desiccation, the water loss at 2.0 and 3.4 m s^{-1} was 2.8 and 4.9 times faster, respectively, than in the still air. This indicates that wind effect on the water loss is more profound at the initial phase of water-loosing process of the alga. At 27 ˚C, the algal mats became dry in moving air in about 140 min; however, it required more than 1000 min for the algal mats to get dry in still air. The half-period for desiccation was 220, 40 and 28 at 0, 2.0 and 3.4 m s^{-1}, respectively. With regard to the half-period for desiccation, water loss from the mats was 5.5 and 7.9 times faster than in the still air at 2.0 and 3.4 m s^{-1}, respectively. Comparison of the results at 20 ˚C with those at 27 ˚C shows that the half-period for desiccation was less at the higher temperature in the moving air. However, the high temperature did not result in faster water loss in the still air, this probably being due to the effect of humidity. The relative humidity was about 10% higher at 27 ˚C than at 20 ˚C. In the still air, humidity may be more important than temperature in controlling loss of water by the alga.

Figure 3 shows the relationship of photosynthetic efficiency (F_v/F_m) of *N. flagelliforme* to relative water content. The photosynthetic efficiency was not affected before the relative water content declined to 48%. The relative water content for half of the initial efficiency was about 24%.

Discussion

The balance of gain and loss of water is important for *N. flagelliforme* to grow in a dry environment. Excessive water is physiologically negative to *N. flagelliforme*. Immersion leads to cellular damage (Mei & Cheng, 1989); watering in the field results in negative daily production of the alga (Cui, 1985). Therefore, it is important for *N. flagelliforme* to loose water rapidly after rain. Wind speeds selected for this study are common in the northern or northwestern parts of China. The ecological implication of our results is that wind after rain is positive for the alga to keep itself from being damaged, since it accelerates water loss. It has been estimated that 5 to 10 h was needed for rewetted *N. flagelliforme* to loose water and become dry under windy and dry conditions in the field (Chen et al., 1987). Based on the present study, it takes about 3–4 h at wind speeds of 3.4–2.0 m s^{-1} and 9–16 h with no wind for the rewetted alga to become dry at a temperature range of 20–27 ˚C, which corresponds to summer conditions at habitats where *N. flagelliforme* occurs. On the other hand, wind can affect *N. flagelliforme* negatively, because it enhances water loss when its physiology is water-critical.

In its natural habitats with a relative humidity of 37 ∼ 91%, *N. flagelliforme* usually contains 4–30% water (Dai, 1992). Such a range of water content can bring about 3–55% photosynthetic efficiency of *N. flagelliforme* under moderate light irradiation (Figure 3). Water for *N. flagelliforme* to maintain its life and growth has been suggested to come from the dew that forms at night (Gao, 1998). In the northern and north-western parts of China, the temperature shows a very marked day-night shift, leading to dew formation at night. The relative humidity may be 80–90% at night (2200–0800) (Hong, 1987). It is reasonable to expect *N. flagelliforme* to hold 20–30% water in the early morning. On the basis of the relationship of water content with photosynthetic efficiency, the photosynthetic efficiency of *N. flagelliforme* can be expected to be as high as 50% of its maximum. The length of the period, during which *N. flagelliforme* can maintain relatively high photosynthetic efficiency, depends on its water content associated with wind, temperature, humidity and solar radiation. Wind accelerates water loss, so can shorten the period and give rise to enhanced water stress.

Water molecules play a critical role in structure-function relationships of proteins; fast water loss and the consequent water stress may bring about physiological damage to *N. flagelliforme*. However, this can be counteracted by the protective roles of certain sugars, which have been found in other prokaryotes to contribute to the stability of proteins, membranes and whole cells when water is removed from them (Potts, 1994). The extracellular sugars of *N. flagelliforme* colonies may play an important role in protecting the intracellular components when it is dried. Further studies are needed on this aspect.

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