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Short Paper

Quantitative evaluation of wind effect during emersion on *Porhpyra haitanensis* (Rhodophyta), a farmed species in southern China

KUNSHAN GAO,[1,2]* YAN JI[1] AND JIRO TANAKA[3]

[1]*Marine Biology Institute, Shantou University, Shantou, Guangdong 515063, China,* [2]*Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan, Hubei, China 430072,* [3]*Laboratory of Phycology, Tokyo University of Fisheries, Konan-4, Minato-ku, Tokyo 108-8477, Japan*

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Intertidal seaweeds encounter periodical exposure to air at low tide for hours, during which they are desiccated to varied levels associated with their zonation. Such a process of desiccation often significantly affects their physiological activities.[1–5] *Porphyra haitanensis* Chang et Zheng, is an intertidal red alga with high economic value, widely cultured in southern parts of China. The life cycle, morphology and distribution of this species differs in many ways from *P. yezoensis* and *P. tenera*, cultivated in Japan and other countries. During winter and early spring (December to March), it is usually found from middle to higher intertidal zones, experiencing several hours of daily desiccation at low tide. The farmed thalli, attached on pole-supported nets, also experiences daily desiccation. During such exposure to air, wind is an important factor in affecting the process of their desiccation. However, the effects of wind speed on its water-losing process have not been documented. This study aims to quantitatively evaluate the effects of wind speed on the desiccation of *P. haitanensis* by investigating its water loss and related photochemical efficiency at varied wind speeds while exposed.

The effects of wind speed on the water loss from the thalli of *P. haitanensis* were investigated in the laboratory. The thalli of *P. haitanensis* were collected in January 1999 from a laver culture field at NanAo Island near Shantou, Guangdong Province, stored in an icebox and transferred to the laboratory within 3 h. They were maintained in an aquarium at 15°C and 20 μmol photons/m^2 per s. Five individuals were spread on each transparent plastic sheet (10 × 10 cm) that was placed on an experimental table in air. A fan was stationed at a horizontal position to provide flat airflow above the table. Wind speeds were obtained by adjusting the distance from the fan to the sheets. The wind speed was measured by decline manometer (YYT-2000).

The relative water content (RWC) was calculated by the following formula:

$$RWC = (Wt - Wd/Wi - Wd) \times 100$$

where Wt (g) stands for instantaneous weight of the thalli measured at a certain time interval; Wd for the dry weight (dried for 24 h at 85°C); and Wi for the initial wet weight, measured after the surface water drops were shaken off. Natural indoor light intensity was about 10 μmol photons/m^2 per s during the exposure. Temperature was maintained at 30°C as high, 18°C as intermediate, and 8°C as low, which correspond to the temperature range that *P. haitanensis* experiences in nature or cultivation during winter and early spring seasons. Relative humidities were 70% at 30°C, 68% at 18°C and 56% at 8°C, respectively. Plant efficiency analyzer (PEA MK2, Hansatech Instrument LTD, Germany) was used to measure the ratio of variable (Fv) to maximal (Fm) fluorescence. The Fv/Fm ratio indicates photochemical efficiency, which has been shown to be proportional to the quantum yield of photochemistry.[6–7] Fv/Fm was measured according to Gao *et al.*[8] It was measured during the exposure for desiccation with 15 min dark adapted thalli.

*Corresponding author: Tel. 86-75-4290-3977.
Fax: 86-75-4290-3977. Email: address: ksgao@stu.edu.cn
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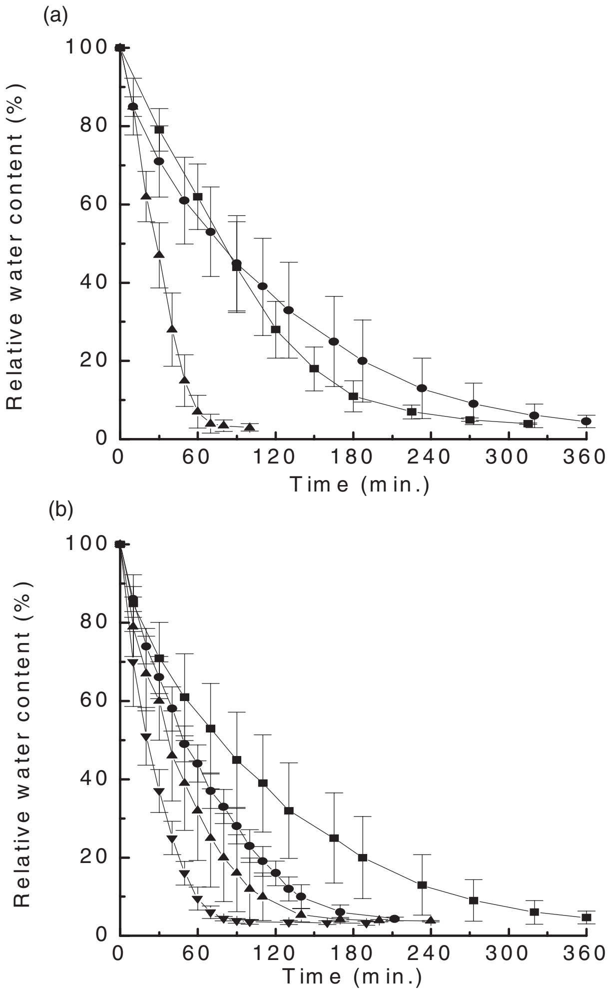

Fig. 1 Changes of relative water content in *Porphyra haitanensis* with time course in a still air at (a) various temperatures (■, 8°C; ●, 18°C; ▲, 30°C), and (b) different wind speeds (■, 0 m/s; ●, 2.0 m/s; ▲, 3.4 m/s; ▼, 4.3 m/s at 18°C. Means of five samples ± SD.

High temperature (30°C) resulted in a much higher water loss rate (Fig. 1a); 2.2–2.6 times that at 18°C and 8°C in still air (0 m/s). The time needed for the thalli to lose half of their water at 30°C was about 0.4 times those at 18°C or 8°C. There was no significant difference in the rates of water loss between 18°C and 8°C ($P > 0.1$). At 8°C, the relative humidity was 12% lower than that at 18°C, which must have compensated for the difference in temperature.

The higher the wind speed the faster the water loss; increased wind speed enhanced the water loss from the thalli (Fig. 1b). The water loss rate at the highest wind speed of 4.3 m/s was 2.3, 1.8 and 1.3 times those at 0, 2.0 and 3.4 m/s, respectively. The time needed for the thalli to lose half of their water at the wind speed 4.3 m/s was 0.3, 0.4 and 0.6 times those at 0, 2.0 and 3.4 m/s, respectively, indicating the higher water loss rate with faster wind at the initial phase.

The photosynthetic efficiency (Fv/Fm) of *P. haitanensis* decreased with enhanced desiccation (Fig. 2a). No clear correlation was observed between photosynthetic efficiency and the wind speed (Fig. 2b). The desiccation levels (relative water content) for reducing the Fv/Fm values by 50% were 24% at 8°C, 25% at 18°C and 36% at 30°C in still air, and were 41% at 2 m/s, 54% at 3.4 m/s and 36% at 4.3 m/s at 18°C, respectively.

From winter to spring, although air temperature seldom reaches 30°C, the temperature at the surface of the rock on which *P. haitanensis* sticks could reach even higher at noon on sunny days, and wind blows frequently at 4–5 m/s. While *P. haitanensis* is exposed to air at low tide, it experiences dramatic environmental changes different from those in water. The present study documented that the wind speed affects the water-losing process of *P.*

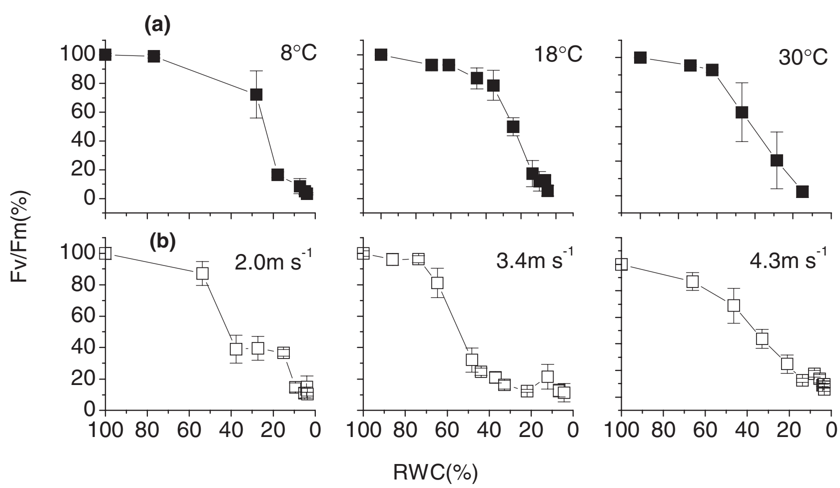

Fig. 2 Relationship of photosynthetic efficiency (Fv/Fm) to relative water content in *Porphyra haitanensis* in still air at (a) various temperatures, and (b) under different wind speeds at 18°C. Means of five samples ± SD.

haitanensis during emersion. *P. haitanensis* maintained nearly 80% of its photochemical activity at about 40–50% relative water content. Even when the alga was desiccated to less than 10% water content, it still maintained positive photochemical efficiency. It can be deduced that at a mild temperature (18°C) it takes about 6 h for *P. haitanensis* thalli to lose most of their water in still air, but only 1 h in moving air at 4.3 m/s. More accelerated water loss from *P. haitanensis* could be expected on windy and sunny days when it is emersed. However, it appeared that it was the desiccation levels rather than the desiccating velocities that significantly affected the photochemical efficiency of *P. haitanensis*, which has been suggested to be linked to the property of D1 protein.[9]

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