

Nighttime Respiration Behavior of *Kandelia obovata* Sheue, Liu and Yong from Subtropical Okinawa Island, Japan

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Abstract

Aboveground nighttime respiration behavior of *Kandelia obovata* Sheue, Liu and Yong was measured from 10 sample plants growing in the mangroves of Okinawa Island, Japan. The dependence of the respiration on the tree size was successfully represented by a power function of $D_{0.1H}^2H$. The respiratory behavior of *K. obovata* was found dependent to size and the exponent was close to 3/4. The size-dependence of respiration could be successfully represented by a power function of $D_{0.1H}^2H$.

সারসংক্ষেপ

জাপানের ওকিনাওয়া দ্বীপের ম্যানগ্রোভ বনে জন্মানো দশটি *Kandelia obovata* Sheue, Liu and Yong (কেনডেলিয়া ওবোভাটা) এর নমুনা উদ্ভিদের ভূমির উপরিস্থিত অংশের রাত্রিকালীন শ্বসন পরিমাপ করা হয়। উদ্ভিদের আকারের উপর শ্বসনের নির্ভরতা $D_{0.1H}^2H$ এর পাওয়ার ফাংশন এর মাধ্যমে সফলভাবে উপস্থাপন করা হয়েছে। *Kandelia obovata* উদ্ভিদের পাওয়ার ফাংশনে এই সূচক 3/4 এর কাছাকাছি। *Kandelia obovata* এর শ্বসন নিশ্চিতভাবে এর আকারের উপর নির্ভরশীল। শ্বসনের আকার নির্ভরতা উদ্ভিদের $D_{0.1H}^2H$ এর পাওয়ার ফাংশনের মাধ্যমে সফলভাবে উপস্থাপন করা যায়।

Key words: Carbon release, enclosed standing-tree method, *Kandelia, obovata* mangrove, power function

Introduction

Kandelia obovata Sheue, Liu and Yong is a mangrove species, locally endemic and pioneer mangrove species of Okinawa Island, Japan. Mangroves are distributed in tropical, subtropical latitudes, notably southern Florida (USA), South Africa, Victoria (Australia), and Southern Japan (Saenger 2002, Tomlinson 1986). Mangroves in Japan are scattered throughout the Ryukyu Archipelago, reaching as far north as Kiire in southern Kyushu. These are the

northernmost mangroves in Asia and consist of small stands of *Kandelia obovata* (Sheue et al. 2003, Spalding et al. 2010). *K. obovata* is distributed in the Gulf of Tonkin north eastward to Kwangtung, Fukien, Taiwan, the Ryukyus and southern Japan (Sheue et al. 2003). As halophytes *Kandelia obovata* is well adapted to salt water and fluctuation of tide level. It has a homogenous canopy throughout the area.

Respiration is a major physiological process that influences the carbon balance of plant communities and ecosystems. It is commonly summarized that up to half or even more of the carbon assimilated by photosynthesis is eventually released through plant respiration (Amthor 1989, Ryan 1991). It is therefore important to consider the whole tree in determining the importance of respiration to forest productivity. Gross production can be defined as the sum of net production and respiration. The net production alone can not be a reliable measure of potential productivity of a forest stand. The significance of productivity can not be realized until the balance between the gross production (gross photosynthesis) and respiration can be analyzed. Hence, respiration measurement is fundamental to the primary production process.

Respiration of woody plants with different organs has been measured by different scientists (Wullschleger *et al.* 1995, Ryan *et al.* 1996, Paembonan *et al.* 1992, Paembonan and Hagihara 1994, Yokota and Hagihara 1995 and Adu-Bredu *et al.* 1996a, b). It has been shown that tree respiratory activity changes with time over the short term, and also dependence on tree size (Ninomiya and Hozumi 1983, Ogawa *et al.* 1985, Yokota *et al.* 1994). Most of the studies were restricted to terrestrial plant species. Despite potential importance, reports on the mangrove respiration are scanty. This study attempts to determine the nighttime respiratory behavior of *Kandelia obovata* grown in natural mangrove conditions of subtropical Okinawa Island of Japan.

Materials and Methods

This study was carried out at Manko Wetland, located in the southern part of Okinawa Island, Japan (26°11' N and 127°40' E) and the site has been registered under the

Ramsar Convention. The mean monthly minimum temperature is 17.3°C in January and maximum temperature is 28.9°C in July-August. Rainfall was over 100 mm month⁻¹ throughout the year and the mean annual rainfall was 2227 mm yr⁻¹.

Ten sample plants of *K. obovata* of different sizes were selected for the measurement of nighttime respiration in the field. The respiration of the sample trees was measured on non-destructively method with an enclosed standing-tree (Ninomiya and Hozumi 1983) shown in Fig. 1. The aboveground parts of a sample tree were enclosed in a chamber of 0.1 or 0.2 mm thick polyvinyl chloride film (Takafuji Chemical and Synthetic Co. Ltd., Japan). The skirt of the chamber was tied around the base of the stem and was well sealed with clay. The air in the chamber was mixed by a fan to keep CO₂ concentration uniform (air flow more than 0.1 ms⁻¹). Before starting measurement, leak test for 10 min was done to ensure the air tight of the chamber. CO₂ concentration within the closed air-circulation system was measured with an infrared gas analyzer (Carbon Dioxide Probe GMP343, Vaisala, Finland) every five seconds interval for maximum of 10 to 30 min. The CO₂ increment in a chamber is illustrated in Fig. 2. The measurement was carried out from May to July 2007. The mean air temperature inside the chamber during the measurement period was 27.8 ± 0.2 (SE)°C.

Respiration rate *r* was calculated from the mean CO₂ increment in a chamber following the formula,

$$r = V \cdot \frac{273.2}{273.2 + \theta} \cdot \frac{P}{1013} \cdot \frac{1}{22.4} \cdot \frac{\Delta C}{\Delta t} \dots\dots\dots(1)$$

where *r* is respiration rate (ppm CO₂ s⁻¹), *V* is chamber volume (L), *θ* is mean air temperature inside the chamber (°C), *P* is air pressure (hPa) and Δ*C*/Δ*t* is CO₂ increment rate (ppm CO₂ s⁻¹) in the chamber.

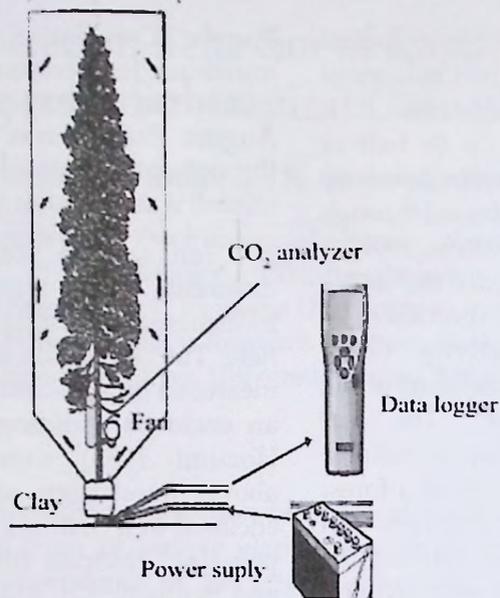


Figure. 1. Respiration measurement in a enclosed standing-tree (modified from Ninomiya and Hozumi 1983).

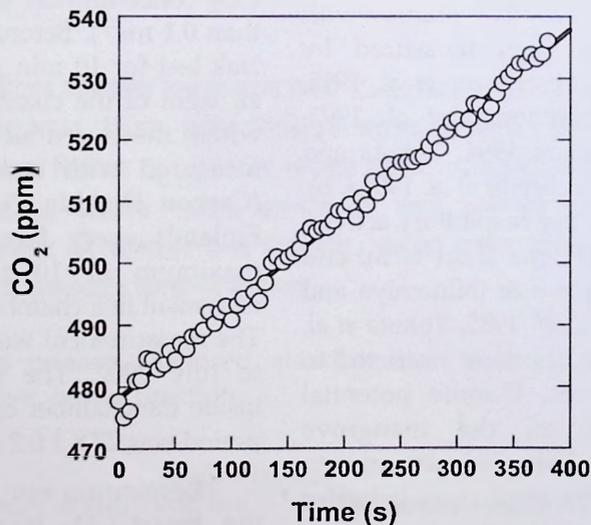


Figure. 2. CO₂ increment in a chamber.

Results and Discussion

The power equation was applied to express the relationship between respiration r of a tree ($\mu\text{mol CO}_2 \text{ s}^{-1}$) and $D_{0.1H}^2 H$ (cm^2m) of the corresponding tree:

$$r = g \cdot (D_{0.1H}^2 H)^h \text{-----} \quad (2)$$

where g multiplying coefficient and h is the scaling exponent. The values of g and h respectively were $3.37 \times 10^{-2} \mu\text{mol CO}_2 \text{ s}^{-1} (\text{cm}^2 \text{ m})^{-h}$ and 0.765 for *K. ovobata* (Fig. 3). This exponent of 0.765 was found to be

significantly lower than 1.0 ($R^2=0.946$; $P=0.668$), which was expressed by Reich *et al.* (2006), and significantly higher than $2/3$, which was expressed by Ninomiya and Hozumi (1983). But the exponent was not significantly different from $3/4$, which was claimed by West *et al.* (1997).

Von Bertalanffy (1957) stated 3 forms of size-dependence metabolism: the metabolic rate is (1) proportional to surface area $w^{2/3}$, (2) proportional to mass w_T and (3) proportional to one intermediate between surface area and mass. The scaling exponent $3/4$ in case of *K. obovata* could be attributed to the assumptions that the branching network is volume filling; the leaf and petiole size are invariant; biomechanical

constraints are uniform; and energy dissipated in fluid flow is minimized (West *et al.* 1999). Generally, the proportion of biomass allocated to transport systems is not strongly correlated with tree size. As a consequence, under optimal growth conditions when resource supply matches demand, metabolic rate scales to the $3/4$ power of biomass (Banavar *et al.* 2002). As organisms increase in size, their mass-specific metabolic rates decrease due to geometric constraints (West *et al.* 1997; Banavar *et al.* 2002). Specifically, larger organisms must allocate a larger proportion of their mass to their resource transportation systems or suffer a reduction in their mass-specific metabolic rates.

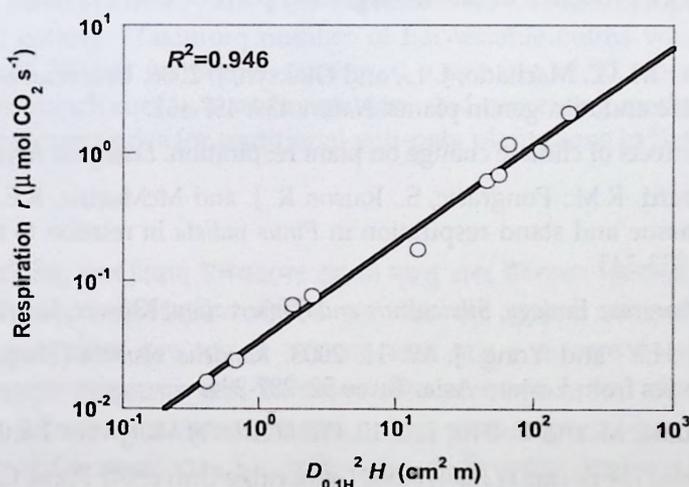


Figure 3. Relationship between respiration r and $D_{0.1H}^2 H$ in *K. obovata* trees.

Conclusion

The respiratory behavior of *K. obovata* was found clearly dependent to size. The size-dependence of respiration could be successfully represented by a power function of $D_{0.1H}^2 H$. The exponent was close to $3/4$ for *K. obovata*, supported by Enquist-group's theoretical model. So, real mass measurement

is prerequisite for estimation of stand respiration. Further respiration measurement on different growth conditions, and different seasons are needed for investigating long-term respiratory behavior in relation to environments.

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