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Uptake of the natural radioactive gas radon by an epiphytic plant

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HIGHLIGHTS

- *Tillandsia brachycaulos* can absorb natural radioactive gas radon efficiently.
- Foliar trichomes of the leaves play a major role in the uptake of Rn.
- Epiphytic *Tillandsia* plants can be applied widely in Rn removal systems.

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ABSTRACT

Radon (^{222}Rn) is a natural radioactive gas and the major radioactive contributor to human exposure. The present effective ways to control Rn contamination are ventilation and adsorption with activated carbon. Plants are believed to be negligible in reducing airborne Rn. Here, we found epiphytic *Tillandsia brachycaulos* (Bromeliaceae) was effective in reducing airborne Rn via the leaves. Rn concentrations in the Rn chamber after *Tillandsia* plant treatments decreased more than those in the natural situation. The specialized foliar trichomes densely covering *Tillandsia* leaves play a major role in the uptake of Rn because the amplified rough leaf surface area facilitates deposition of Rn progeny particles and the powdery epicuticular wax layer of foliar trichomes uptakes liposoluble Rn. The results provide us a new ecological strategy for Rn contamination control, and movable epiphytic *Tillandsia* plants can be applied widely in Rn removal systems.

1. Introduction

Radon (^{222}Rn), with a half-life of 3.825 days, is a colorless, odorless and tasteless noble gas, and the natural radioactive gas decays to form a series of radioactive particles, including ^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po and ^{210}Pb (Majumdar, 2000; Ramola et al., 2016). It has been estimated that Rn and its progeny are the major contributors to human exposure from natural radiation sources (UNSCEAR, 2008), constituting more than 50% of the dose equivalent received by the general population from all sources of radiation, both naturally occurring and manmade (Little, 1997). The World Health Organization has recognized the exposure to Rn and its progeny as the second most important cause of lung cancer, after smoking (WHO, 2009).

At present, the most effective way to reduce Rn is ventilation, and this technology has been applied widely in mines (Mudd, 2008). Since the strong ability of activated carbon to adsorb Rn was discovered by Rutherford in 1906, activated carbon has also been considered for many applications (Gaul and Underhill, 2005; Karunakara et al., 2015), including Rn sampling (Nagarajan et al., 1990; Tommasino, 1998) and Rn removal systems (Bocanegra and Hopke, 1989).

However, knowledge of the biological migration chains of Rn is still insufficient. In particular, for plants, experimental data are limited on the behavior of Rn isotopes in soil-plant systems (Mitchell et al., 2013). Although plants are supposed to trap airborne Rn by diffusion, adsorption and permeation (Tavera et al., 2002; Vives i Batlle et al., 2011) and enhancement of Rn release from vegetation can occur during times of peak transpiration (Jayaratne et al., 2011), above-ground plant organs are believed to be negligible in trapping Rn because the emanation ability of the plant tissues approaches nearly 100% (Taskayev et al., 1986) and the non-reactive inert characteristics of Rn. Considering the importance of finding new ways to reduce airborne Rn and that more than 3×10^5 species occur in nature, it's useful to explore whether any plant can trap airborne Rn effectively.

The epiphytic *Tillandsia* (Bromeliaceae) species, known as air plants, are very common in the American tropics, and are now cultivated worldwide (Benzing, 2000). They absorb water and nutrients directly from the atmosphere by wet or dry deposition (Nowak and Martin, 1997; Ohrui et al., 2007). Therefore, they can absorb air pollutants at the same time and have been frequently used as biomonitors of many

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air heavy metals (Cd, Cr, Pb, Cu, Zn, Hg, Co, Ba, V, Mn, Fe, Ni, Zn, Pb, etc.) (Brighigna et al., 1997; Calasans and Malm, 1997; Pignata et al., 2002; Cortés, 2004; Wannaz et al., 2006; Figueiredo et al., 2007; Vianna et al., 2011), organic pollutants (formaldehyde, PAH, PCB, PCDD, PCDF, etc.) (Pereira et al., 2007a, 2007b; Li et al., 2015) and nuclides (mainly Cs and Sr) (Cortés, 2004; Li et al., 2012; Zheng et al., 2016b; Zheng et al., 2017). Foliar trichomes covering the stem and leaves presumably promote absorption of air pollutants (Filhoa et al., 2002; Li et al., 2015).

If any plant could trap airborne Rn, the epiphytic *Tillandsia* species would seem to be a strong possibility due to the strong absorption capability of their leaves. Therefore, *Tillandsia brachycaulos* (Fig. 1), one common species in *Tillandsia*, was chosen to investigate (1) whether any plant can trap airborne Rn efficiently and (2) whether the foliar trichomes of *T. brachycaulos* can improve Rn uptake.

2. Materials and methods

2.1. Plants treated with Rn

The experiments were carried out in the standard radon chamber (Fig. 2) of Peking University, China. The closed chamber method is commonly used for the measurement of Rn concentrations because Rn concentrations can be measured easily in the chamber. The Rn chamber is a perspex barrel with an effective volume of 1 m^3. The stainless steel inlet and outlet are located on the side of the chamber with the inlet tube extending down to the bottom of the chamber. The lid of the chamber is wrapped with a gasket and then pinned by eight bolts. A small 24 V circulation fan is placed at the bottom to keep Rn mixing fully in the chamber.

To test the Rn absorption with plants, a control experiment was first carried out to measure the Rn concentration changes in the natural situation due to the decay and leakage in the Rn chamber. Then, forty *T. brachycaulos* plants of similar size were randomly chosen from the green house for the experiments. They were divided into four groups of ten plants per group. Before the plants were put into the chamber, they were watered thoroughly with de-ionized water, then dried out for 30 min to give them a standard fresh weight, which was determined by electronic balance. After the plants were suspended in the chamber with a string (Fig. 1A), the experiment started with a supply of Rn from a ^{226}Ra source, which created a high Rn concentration of approximately 5000 $Bq \cdot m^{-3}$ in the chamber. The Rn concentrations of the control and exposed plant groups, duration time, plant characteristics and experimental conditions are listed in Table 1.

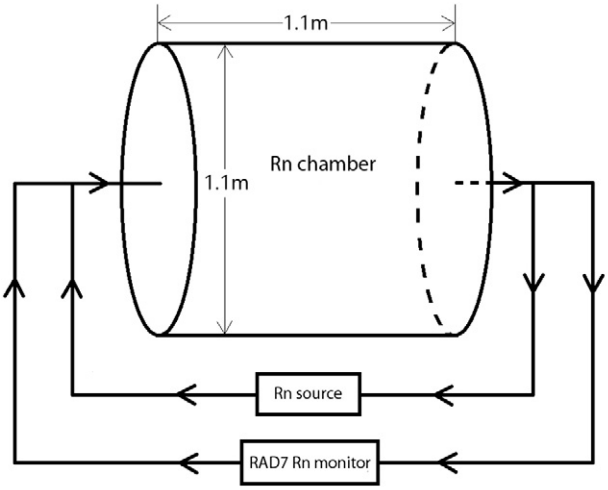

Fig. 2. Rn chamber used in the experiment.

The Rn concentration reached a dynamic equilibrium after 2 h, in balance with the decay of the daughter products and any losses of aerosol through walls. Then, the Rn source was closed and Rn concentrations in the chamber were measured by a RAD7 continuous radon monitor (Durridge, USA), which also recorded the temperature and humidity of the chamber. Considering that the error would be large if the initial Rn concentration was too low, the lowest Rn concentration exposed to the plants was approximately 2500 $Bq \cdot m^{-3}$, and the highest Rn concentration exposed to the plants was approximately 4500 $Bq \cdot m^{-3}$ (Table 1).

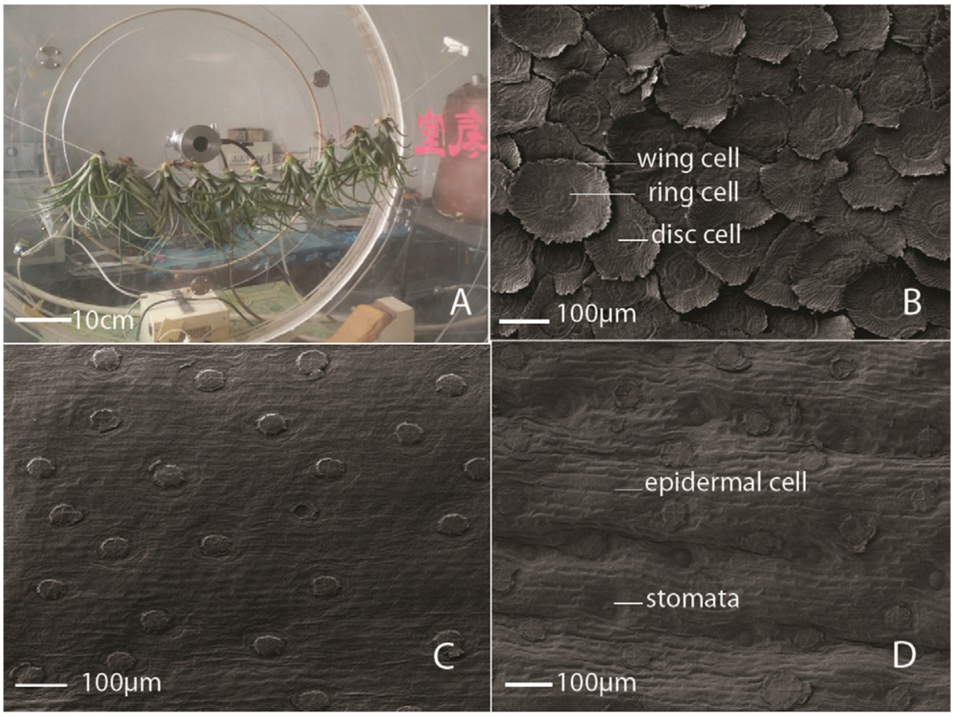

Fig. 1. *T. brachycaulos* and its leaf surface with SEM A, *T. brachycaulos* suspended in the Rn chamber; B, Leaf surface before foliar trichomes removal; C, Leaf adaxial surface after foliar trichomes removal; D, Leaf abaxial surface after foliar trichomes removal.