REMOVAL OF FORMALDEHYDE BY SOME AIR PLANT SPECIES IN EPIPHYTIC TILLANDSIA (BROMILIACEAE)

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Abstract- Air plants have an important role in the removal of air borne contaminants. In this study, epiphytic Tillandsia (Bromiliaceae) species have been applied in formaldehyde (FA) removal from the air environment .The removal rate of five plant species were tested in a glass chamber attached with real time indoor air quality (IAQ) gas sensor probe. The absorptive capacity of Tillandsiatrichomes were investigated and viewed by Scanning Electron Microscope. The removal formaldehyde efficiencies of high trichromesTillandsia species: flexuosa, T., capita, T. brachycaulos, T., 'cotton candy' (T. stricta× T. recuvifolia) with intact trichomes, were found less than in T. bulbosa leaf with less trichrome. All plants exposed to FA had a reduction in measured leaf chlorophyll with ranged from 14 to 35 %. In addition, plants in which trichomes had been removed increased the rate of FA removal more than plants with intact trichomes. This result indicated Tillandsia leaf trichomes protect the leaves from this toxin. Our finding demonstrated the application of air plant in the contribution of clean air environment which could be developed to plant-based remediation system for other toxic gases.

Keywords- formaldehyde,phytoremediation,air plant,epiphytic Tillandsia (Bromiliaceae),trichomes

I. INTRODUCTION

Formaldehyde (FA), an indoor air pollution, is used mainly to produce resins used in particleboard products and as an intermediate in the synthesis of other chemicals. Exposure to formaldehyde may occur by breathing contaminated indoor air, tobacco smoke, or ambient urban air. Acute (short-term) and chronic (long-term) inhalation exposure to formaldehyde in humans can result in respiratory symptoms, and eye, nose, and throat irritation. Limited human studies have reported an association between formaldehyde exposure and lung and nasopharyngeal cancer. Animal inhalation studies have reported an increased incidence of nasal squamous cell cancer. FA is considered as a probable human carcinogen Group B1, (USEPA 2016, IARC 2006). There have been many reports on FA removal by plants. (Wolverton et al., 1997; Wang et al., 2012; Li et al., 2015 Plant have been shown to uptake air pollutants via their stomata during normal gas exchangeduring normal (Schmit et al., 2000)and various pollutants have been found to be sequestered or degraded, transferred to other parts in the plant. (Giese et al., 1994; Son et al., 2000)

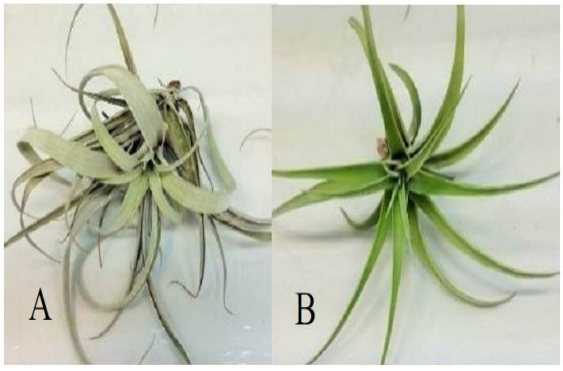
Epiphytic Tillandsia (Bromeliaceae) species, know as air plants, are very common in the American tripics(Benzing, 2000) They are also frequently used for biomonitor of airborne trace metals because they absorb nutrients directly from the atmosphere (Wannaz et al., 2006; Figueiredo et al., 2007; Vianna et al., 2011)Tillandsia spp. has been in the horticultural trade for a long time because its popularity is due to beautiful pink or red coloration when the plant flowers, and also its seemingly magic ability to live in the air. The absorptive capacity of Tillandsiatrichomesis well established but potential secondary effects of foliar trichomes on gas exchange remain unclear. Some species of Tillandsia can adsorption formaldehyde efficiently.

In this study five Tillandsia species: Tillandsia flexuosa, T. capita, T. brachycaulos, T. 'cotton candy' (T. stricta× T. recuvifolia) and T. bulbosa were selected for the study to investigate the following hypotheses: (1)the epiphytic plant Tillandsia spp can remove formaldehyde efficiently; (2) foliar trichomes of Tillandsia sppcan improve formaldehyde removal.

II. DETAILS EXPERIMENTAL

2.1. Study species

Tillandsia spp. are now grown commercially on a wide scale, is inexpensive, vendor via the internetand plant market. Selected five species have different morphological characteristics such as Tillandsiaflexuosa, T. capita, T. brachycaulos, T. 'cotton candy' (T. stricta× T. recuvifolia) and T.bulbosa in Figure. 1. Be cultured in the laboratory for one week before the plant is ready to experiment.



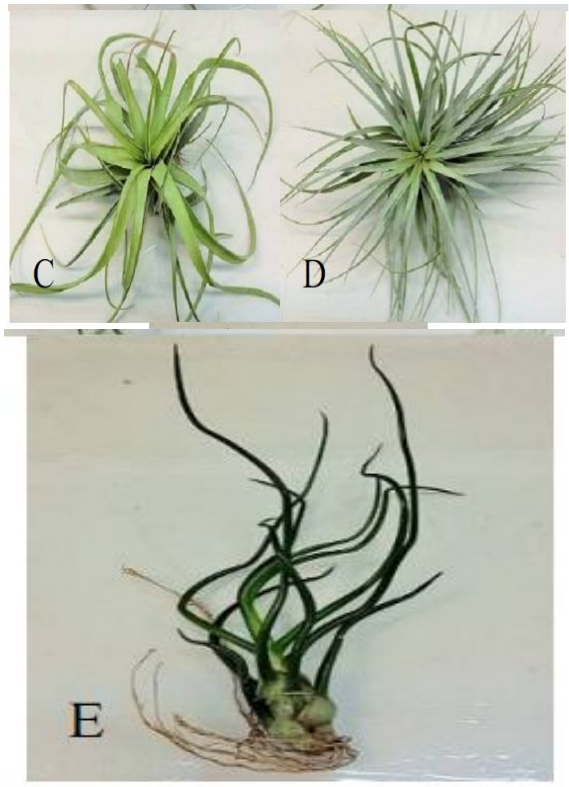


Fig.1. Epiphytic Tillandsia spp. plant samples: A. T. capitata; B. T. flexuosa;C. T. brachycaulos; D. T.'cotton candy'; E. T. bulbosa

2.2. Removal of foliar trichomes

Five Tillandsia spp. plants of similar size were randomly chosen for the trichomes removal study. 50 % of the trichomes were removed, with three replicates per species. Foliar trichomes were removed with adhesive tape method (Yamaura et al., 1992; Ohrui et al., 2007). The sticky side of adhesive tapes was lightly pressed onto the adaxial and abaxial surfaces of a leaf five times each to remove trichomes. Leaf anatomy of Tillandsia species was illustrated in Fig 2.

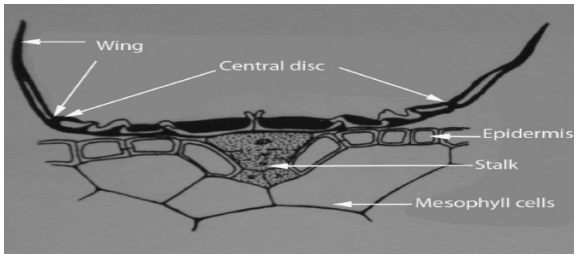


Fig. 2.Leaf anatomy of Tillandsia species (Li et al., 2015)

2.3. Analysis of leaf morphology by SEM

To investigate the effect of formaldehyde on the leaf of Tillandsia spp., leaf with and without formaldehyde treatment were observed and photographed after 30 min when the experiment ended. Scanning electron microscopy (SEM) was used to examine potential effects of trichomes on leaf surface morphology. Two mature leaves with and without formaldehyde exposure were evaluated. Two mid-leaf sections from each leaf were coated with a 30 nm layer of gold palladium (Papini et al., 2010), then examined with SEM (JEOL JSM-6400 Tokyo, Japan) at 10 kV.

2.4. Formaldehyde treatment and concentration measurement

FA absorption efficiency of five air plants, were tested in a sealed glass chamber (dimension 30 x40 x60 cm)with wall thickness 0.40 cm. A 6V DC fan was placed in the chamber to promote the air mixing. The designed glass chamber was tested before in previous work, Jinsart et al. 2011. The average temperature was 33.5$\pm$ 1.3 ^{o}C and relative humidity in the chamber was 45.3$\pm$ 7.0 %. Test plant was put in the middle of the chamber, in which a beaker with 1 ml FA solution (37%) was placed. The formaldehyde level in the chambers were measured during a 30 min period with gas sensor (IAQ RAE)The apparatus set up was shown in Fig. 3.

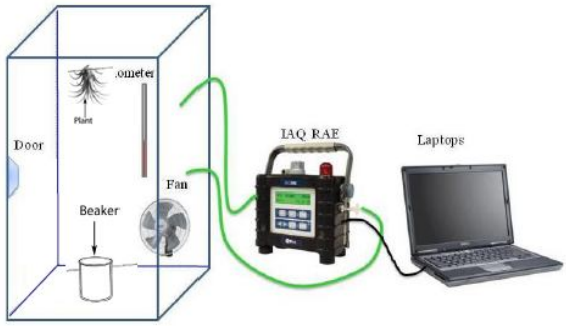


Fig. 3.Chamber and gas sensor IAQ RAE used in the experiment

2.5. Measurement of leaf chlorophyll content

After testing samples extracted leaves with acetone, cut the leavesinto small pieces 100 mg, extracted with 20 ml acetone until tissue turns white. Adjust the volume of the acetone to 30 ml.Chlorophyll solution to measure the absorbance at 645 and 663 nm by spectrophotometer. Chlorophyll content (Gross, 1991) in milligram per gram weight was calculated as:

$$[(20.2)OD_{645}\times v/1000 \times w] + [(8.02)OD_{663}\times v/1000 \times w]$$

Where OD is optical density measured at a wavelength of 645 and 663 nanometers (nm), v is volume of 80% acetone to extract the chlorophyll (ml), and w is weight of extract chlorophyll (g).

2.6. Data analysis

FA concentrations were expressed as micrograms per cubic meter (µg m^{-3}). Percent removal efficiency in each case was evaluated using the initial and final gas concentrations within the chamber and was calculated as:

$$(C_O - C_F)/C_O \times 100\%$$

The amount of FA removed per unit surface area of plant leaf was calculated as:

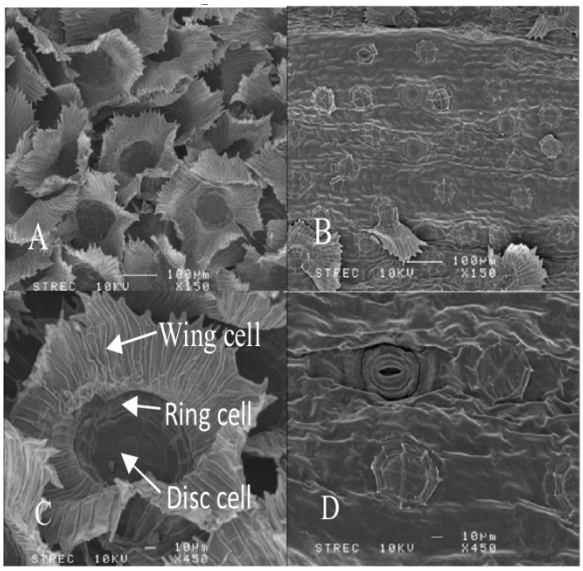
$$(C_O - C_F)/A$$

Where C_O is initial concentration (μg m^{-3}), C_F is final concentration (μg m^{-3}), and A is total leaf area (cm^2).

III. RESULTS AND DISCUSSION

3.1. Leaf surface morphology

The effect of trichomes removal on the FA exposure was viewed by SEM. Fig. 4. Showed the Leaf morphology with and without Trichomes, with and without FA exposure.



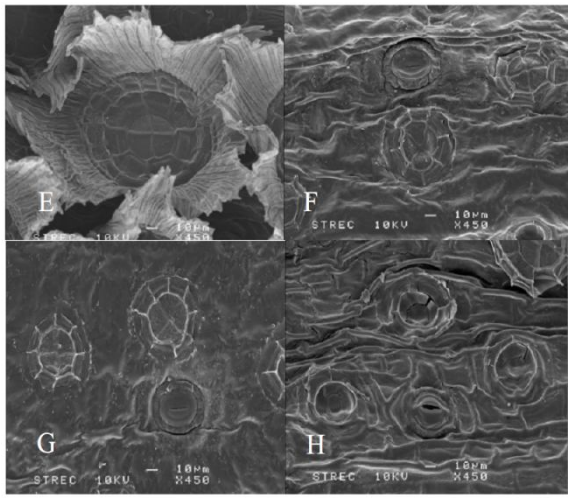


Fig. 4. Leave surface of Tillandsia capitata with SEM: A. Leaf surface before trichomes removal; B. Leaf surface after trichomes removal; C. trichome showing wing cells, ring cells and disc cell; D. trichome after wing cell removed; E trichome after 30 min FA exposured; F trichome after wing cell removed after 30 min FA exposure; G trichome after wing cell removed after 1 h FA exposure; H trichome after wing cell removed after 2 h FA exposure. Bar = 100 μm in A and B, bar = 10 μm in D to H

3.2 FA removal efficiency

All five plants could efficiently remove formaldehyde from air in the sealed chamber. A comparative of average concentration and % removal are summarized in Table 1.

Table 1: Characteristics of epiphyte Tillandsia spp. and formaldehyde absorption.

Treatments	FA concentration (μg m^{-3}± SD)	FA concentration after 30 min (μg m^{-3}± SD)	Percentage of removal efficiency (%) ± SD	Leaf area (cm^2) ± SD	Ability of absorbing formaldehyde (μg $m^{-3}cm^2$) ± SD
Control	2,787.30 ± 1.19	-	-	-	-
	Blank				
T. capitata	0.00 ± 0.00	2,404.25 ± 0.63	13.74 ± 0.94	20,139.41 ± 0.06	0.02 ± 0.06
T. flexuosa	0.00 ± 0.00	2,502.05 ± 0.77	10.23 ± 1.23	6,963.59 ± 0.05	0.04 ± 0.04
T. brachycaulos	0.00 ± 0.00	1,703.35 ± 1.69	38.89 ± 1.62	25,838.79 ± 0.06	0.04 ± 0.07
*T. 'cotton candy'	0.00 ± 0.00	2,363.50 ± 0.69	15.18 ± 1.10	7,914.51 ± 0.03	0.05 ± 0.04
T. bulbosa	0.00 ± 0.00	2,697.65 ± 1.32	3.19 ± 1.27	53.01 ± 0.04	1.69 ± 0.06

*slow removal process Each measurements n = 30

3.3 Chlorophyll content

Air Plants with trichomes exposed to FA, chlorophyll contents were reduced with ranged from 14 to 35 % as summarized in Table 2 .

Table 2: Changes of total Chlorophyll content of Tillabdsia spp. under formaldehyde stress.

Treatments	Chlorophyll content (mg g^{-1}± SD)		
	Before formaldehyde stress	After formaldehyde stress	Percent decrease
T. capitata	0.02 ± 0.99	0.01 ± 0.17	35.00 ± 0.94
T. flexuosa	0.02 ±0.50	0.01 ± 0.42	31.25 ± 0.32
T. brachycaulos	0.02 ±0.97	0.01 ± 0.25	23.53 ± 0.98
*T. 'cotton candy'	0.03 ±0.91	0.02 ± 0.49	14.29 ± 0.59
T. bulbosa	0.04 ±0.55	0.02 ± 0.94	31.43 ± 0.82

*Each measurements n = 3

CONCLUSIONS

All selected air plants have formaldehyde reduction capacity. The uptake rate depended upon the air environment and plant species. Plants exposed to FA, chlorophyll contents were reduced. The removal formaldehyde efficiencies of high trichromesTillandsia species: flexuosa, T., capita, T. brachycaulos, T., 'cotton candy' (T. stricta× T. recuvifolia) with intact trichomes, were found less than in T. bulbosa leaf with less trichrome.plants in which trichomes had been removed increased the rate of FA removal more than plants with intact trichomes. This result indicated Tillandsia leaf trichomes protect the leaves from this toxin.

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