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Physiological dynamic response of four potted plants under the stress of formaldehyde

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Abstract：The physiological dynamic changes for the four species indoor potted plants，*Neottopteris nidus*，*Dralaena fragrans*，*Sansevieria trifasciata* and *Aglaonema commutatum*，were studied respectively with these indexes such as the unit dry matter of Formaldehyde（FDH）absorption，the relative electric conductivity（REC），the malondialdehyde（MDA）content，and the leaf chlorophyll content，under the stress of FDH with the treatment concentration of 15 mg·m^{-3}. The results indicated that in four days of FDH intimidation，the unit dry matter of FDH absorption for both *Neottopteris nidus* and *Dralaena fragrans* reached to the peak at the third day，while *Sansevieria trifasciata* and *Aglaonema commutatum* increased slowly. Meanwhile，the most and least content of the unit dry matter for FDH absorption were *Neottopteris nidus* and *Dralaena fragrans* respectively. The REC and MDA contents for the four species increased with the raise of FDH stress time，the highest and lowest REC were *Neottopteris nidus* and *Sansevieria trifasciata* respectively，the highest and lowest MDA were *Dralaena fragrans* and *Neottopteris nidus* respectively. The leaf chlorophyll content for the four species decreased with the increasing of FDH stress time，the highest and lowest decreasing amplitude were *Aglaonema commutatum* and *Sansevieria trifasciata* respectively.

Key words：stress of formaldehyde；potted plants；physiological dynamic response

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甲醛胁迫下四种盆栽植物的生理动态反应

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摘 要：选择巢蕨（*Neottopteris nidus*）、巴西铁（*Dralaena fragrans*）、虎尾兰（*Sansevieria trifasciata*）和黑美人（*Aglaonema commutatum*）4 种室内盆栽植物作为典型的试验材料，以 15 mg·m^{-3} 甲醛分别进行熏蒸处理，测定单位干物质甲醛的吸收量、相对电导率、丙二醛含量和叶绿素含量等，以研究这些植物在甲醛胁迫下的生理动态反应。结果表明：在甲醛胁迫的 4 d 时间内，巢蕨和巴西铁的单位干物质甲醛吸收量均在第 3 天达到峰值，而黑美人和虎尾兰则一直在缓慢增加，其中以巢蕨吸收的量最多，巴西铁单位干物质甲醛吸收量最少；4 种植物的相对电导率、丙二醛的含量均随甲醛胁迫时间的增加而增加，以巢蕨的相对电导率最高，虎尾兰最低，但巴西铁的丙二醛的含量最高，巢蕨最低；4 种植物的叶绿素含量均随甲醛胁迫时间的增加而降低，其中黑美人降低幅度最高，虎尾兰最低。

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关键词：甲醛胁迫；盆栽植物；生理动态反应

Since formaldehyde (FDH) was excessively used in housing construction, reformation and decoration, the quality of the indoor environment has become a major health consideration in many cities of China (Yu *et al.*, 2005). FDH exposure has been associated with cancer of the nasal cavities, nasopharynx, prostate, lung, and pancreas (Hauptmann, 2004). During the past decades, much work has been done to purify the indoor FDH pollutants, such as physical adsorption, chemical adsorption, photocatalytic oxidation, combined adsorption and plants absorption (Ding *et al.*, 2003).

The first research for adsorption pollutant air with plants was carried out by NASA (Wolverton *et al.*, 1985). Then, many researchers from China focused on selection and sequence of plant species that are effective in absorbing FDH from indoor air in recent years, but a few plants species were tested currently (He *et al.*, 2014). In our past studies, 63 species plants from 7 families such as *Araceae*, *Agavaceae*, *Liliaceae*, *Marantaceae*, *Euphorbiaceae*, *Moraceae* and *Araliaceae*, and from Pteridophytes were tested for their abilities of removing FDH in the air respectively (Zhou *et al.*, 2011, 2012; Ou *et al.*, 2012). Very little work has been performed on the physiological dynamic reaction of the potted plants under the FDH stress. Therefore, in this present study, 4 typical potted plants were tested, in order to provide reference to the selection and utilization of plants for indoor FDH pollutant air purification.

1 Materials and Methods

Four indoor plant species, *Neottopteris nidus*, *Dralaena fragrans*, *Sansevieria trifasciata* and *Aglaonema commutatum* were used as experimental materials.

1.1 Experimental treatments

The tested potted plants were placed respectively in a glass box chamber with a wall 0.8 mm thick and inside volume of 0.8 m^3 (Wolverton, 1993). A small fan and a thermometer were placed inside the chamber. The probe of FDH inspector (Ke Ernuo trading Co., Ltd. of Shenzhen) was inserted into the chamber through a hole of 1 cm in diameter. The mouth of the hole was removable and fitted with a rubber gasket and clamps to provide an airtight seal. The initial concentration of FDH was set up to 15 mg · m^{-3}. The experimental temperature was controlled at (25 ± 1) ℃ (Zhou *et al.*, 2011). Three treatments were designed as below: (1) plant potted in the medium was placed in the chamber with 15 mg · m^{-3} FDH; (2) the pot with medium but without plant was placed in the chamber with 15 mg · m^{-3} FDH; (3) the chamber only filled with 15 mg · m^{-3} FDH as control. Each treatment was repeated for 3 times.

1.2 Measurement of leaf chlorophyll

Leaf chlorophyll was extracted with 95% ethanol. The concentration of the extracted chlorophyll was measured at 665 nm and 649 nm wavelengths by using an UV-Vis spectrophotometer (TU-1810 Model, General Analysis Instrument Co., Ltd. of Beijing) (Wang, 2006). Concentrations of chlorophyll a (C_A), chlorophyll b (C_B) and the total chlorophyll (C_T) were calculated using the equations as:

$$C_A = 13.7D_{665} - 5.76D_{649}$$

$$C_B = 25.8D_{649} - 7.6D_{665}$$

$$C_T = C_A + C_B - 6.10D_{665} + 20.04D_{649}$$

Where D_{665} and D_{649} were the optical density (OD) values of chlorophyll at 665 nm and 649 nm, respectively.

1.3 Measurement of leaf relative electric conductivity (LC)

The leaf sample was rinsed 3 times with deionized water, then drained the surface water with filter paper; 20 leaf discs each in 0.5 cm diameter taken with an hole puncher were immersed in 20 mL deionized water for 3 hours. The electrical conductivity (EC) (recorded as $C1$) of the water after the leaf immersion was measured. The leaf sample was boiled for 15 min and the EC ($C2$) was measured again after the water cooled down to the room temperature and replenished to 20 mL with deionized water (Huang *et al.*, 1990).

The leaf cell membrane permeability (LC) was calculated as:

$$LC\ (\%) = 100 \times (C1/C2)$$

Table 1 Change of FDH concentration per day in the chamber ($mg \cdot m^{-3}$)

Species	Days after being treated			
	1 d	2 d	3 d	4 d
Dralaena fragrans	15.00±0	13.98±0.072	8.87±0.062	5.45±0.049
Neottopteris nidus	9.56±0.296	4.05±0.056	2.06±0.026	0.75±0.032
Sansevieria trifasciata	15.00±0	13.83±0.071	9.23±0.052	4.29±0.036
Aglaonema commutatum	15.00±0	13.86±0.073	10.98±0.067	2.54±0.068
CK	15.00±0	14.12±0.021	13.56±0.038	9.57±0.057

1.4 Measurement of Malondialdehyde (MDA)

The leaf sample cut into pieces was to homogenizes with 10 mL 5% Trichloroacetic acid (TCA) and fewer silica sand, and then centrifuged 10 min at 4 000 $r \cdot min^{-1}$. The 2 mL supernatant extract was shook well added with 2 mL 0.6% Thiobarbituric acid (TBA), boiled 10 min after the small bubble arose in the tested tuber, kept cool, centrifuged 15 min at 3 000 $r \cdot min^{-1}$, then, the supernatant extract was measured at 450 nm, 532 nm and 600 nm wavelengths using an UV-Vis spectrophotometer (TU-1810 Model, General Analysis Instrument Co., Ltd. of Beijing) (Wang, 2006). The leaf MDA content was calculated as:

$$C\ (\mu mol \cdot L^{-1}) = 6.45\ (A_{532} - A_{600}) - 0.56\ A_{450}$$

Where A_{532}, A_{600} and A_{450} were the optical density (OD) values of MDA at 450 nm, 532 nm and 600 nm, respectively.

MDA content ($\mu mol \cdot g^{-1}$) = MDA concentration ($\mu mol \cdot L^{-1}$) × extracted volume (mL)/fresh weight (g)

1.5 Other measurements

After the experiment began, the FDA concentration in the chamber was measured for every day. The fresh above ground part taken from the plant was weighed as fresh mass. Then, these materials were dried in the microwave oven for dry mass determination (An *et al.*, 2010). The relative data were analyzed with SASS 16.0 statistical analysis software.

2 Results and Analysis

2.1 Change of FDH concentration by four potted plants

The concentration of FDH in the chamber showed a decreasing change, the quickest decrease was generally at the 2nd day and at the 3rd day. Although all species potted plants were effective purification on FDH, but there were difference among them, along with the stress time of FDH, the fastest absorption was found in *Neottopteris nidus*, followed by *Aglaonema commutatum* and *Sansevieria trifasciata*, while the lowest one was found in *Dralaena fragrans* (Table 1).

2.2 Absorption of FDH by potted plants

As it was shown in Fig. 1, 4 species potted plants all have the ability to purify FDH in the air. In 4 days stress of FDH, plants which had absorption peak of FDH at the 3rd day were *Neottopteris nidus* and *Dralaena fragrans*, while *Sansevieria trifasciata* had slowly increasing absorption, but *Aglaonema commutatum* had quickly increasing absorption after 3rd day. Among 4 species potted plants, *Neottopteris nidus* had the highest FDH absorption, but *Dralaena fragrans* had the lowest one.

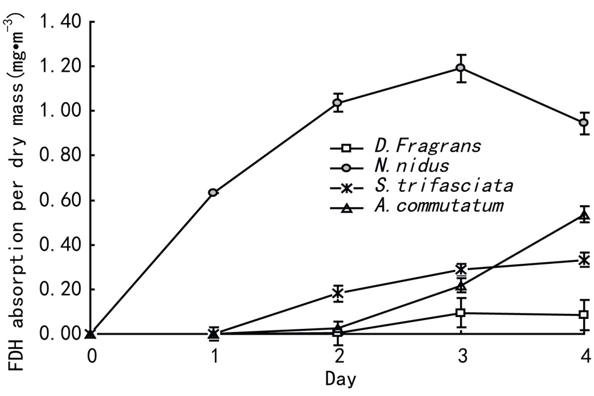

Fig. 1 Changes of FDH absorption per dry matter from four species

2.3 Changes in leaf relative electric conductivity (REC)

The cell membrane of plant maybe damaged and caused increasing of cell membrane permeability under the stress of FDH. The plant would has smaller degree of change of cell membrane permeability if there is a stronger resistance to FDH. Among the 4 days stress of FDH, *Dralaena fragrans*, *Sansevieria trifasciata* and *Aglaonema commutatum* had no obvious increasing of REC, but *Neottopteris nidus* had significant increasing. Therefor, it was indicted that *N. nidus* was the most sensitive to FDH stressing among 4 species potted plants (Fig. 2).

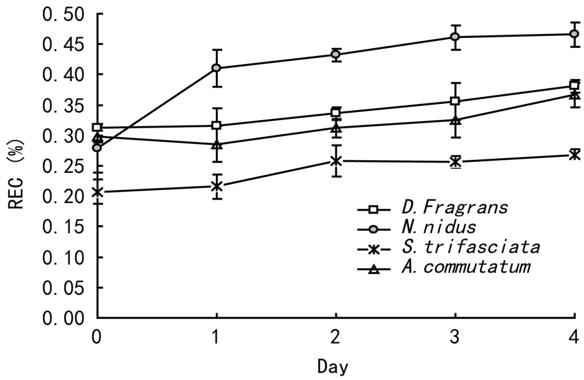

Fig. 2 Changes of leaf relative electric conductivity (REC) from four species

2.4 Changes in MDA content

As we know, plants often occurred membrane lipid peroxidation when being suffered injury under the stress conditions, MDA was just a lipid peroxidation product, the content of MDA was often used as an indicator of membrane damage, and can be described the resistant of plant to FDH. As it was shown in Fig. 3, among 4 species, *Dralaena fragrans* had the highest MDA content and increasing change, but *Neottopteris nidus* had the lowest one.

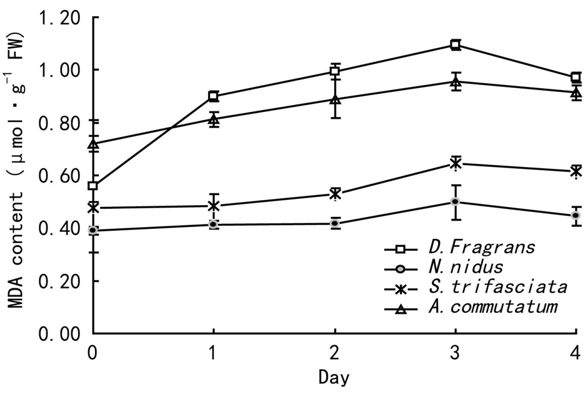

Fig. 3 Changes of MDA content from four species

2.5 Changes in total chlorophyll concentration

The plant wouldoccur blocking of leaf chlorophyll synthesis, accelerating decomposition, and finally lead to decrease the content of chlorophyll when it was stressed. In four days of FDH stress, all species had decreased the leaf chlorophyll content, and had the maximum reducing at the 1st day. Among the 4 species, *Aglaonema commutatum* had the highest leaf chlorophyll content and decreasing change, but *Sansevieria trifasciata* had the lowest one, the species which had the maximum decreasing rate of leaf chlorophyll content were *Neottopteris nidus* (Fig. 4).

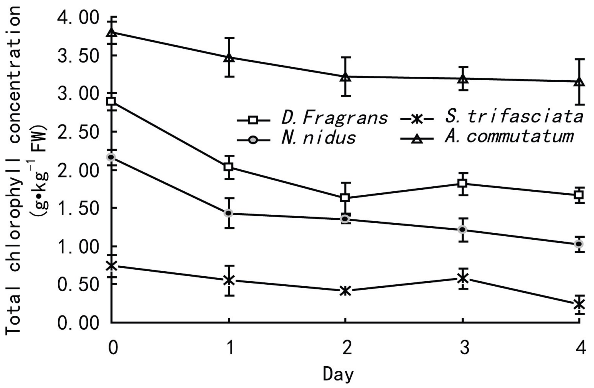

Fig. 4 Changes of total chlorophyll concentration from four species

3 Discussion

It has been demonstrated that many of indoor potted plants can absorb more or less FDH air pollutant in our earlier research (Zhou *et al.*, 2011, 2012; Ou *et al.*, 2012). The purification of FHD maybe included several aspects, such as assimilation by stem or by leaves of plants, transformation and metabolism by cells of plants, degradation by the microorganisms in the rhizosphere area (Ralph *et al.*, 2004), and by the others.

The results suggested that there maybe three ways for potted plants response to FDH stress. The first way showed obvious hurt morphology with high absorption but weak resistance, such as *Neottopteris nidus*, having the most content of the unit dry matter for FDH absorption, and the highest relative electric conductivity, and the lowest MDA. The second way showed weak absorption but strong resistance with normal morphology by taking avoidance strategy to protect itself, such as *Dralaena fragrans* , having the least content of the unit dry matter for FDH absorption and the highest MDA. The third way showed absorption and transforming ability with more or less hurt responses, such as *Aglaonema commutatum*, having moderate degree of these indexes. In this way, FDH gaseous absorbed by *Chlorophytum comosum* was found to be incorporated into organic acids, amino acids, free sugars, and lipids as well as cell-wall components (Giese *et al*., 1994). The light ^{14}C from ^{14}C-FDH maybe entered into the Calvin cycle after two-step oxidation process by FDH dehydrogenase and by formate dehydrogenase to become CO_2 and H_2O (Schmitz *et al*., 2000).

Therefore, only are these group plants which had lower resistance to FDH would have absorbed high content of high applying value. It still needs for further research on the mechanisms of FDH purification with potted plants.

4 Conclusions

The results indicated that in four days of FDH intimidation, the most and least contents of the unit dry matter for FDH absorption were *Neottopteris nidus* and *Dralaena fragrans* respectively. The relative electric conductivity (REC) and malondialdehyde (MDA) contents for the four species increased with the raise of FDH stress time, the highest and lowest REC were *Neottopteris nidus* and *Sansevieria trifasciata* respectively, the highest and lowest MDA were *Dralaena fragrans* and *Neottopteris nidus* respectively. The leaf chlorophyll content for the four species decreased with the increasing of FDH stress time, the fastest and lowest width degree were *Aglaonema commutatum* and *Sansevieria trifasciata* respectively.

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