Study on Changes of Chlorophyll Content in plant under Indoor Benzene Stress

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Abstract. Benzene, as one of the “three stealth killers” of indoor air pollution, seriously threatens people’s life and health. The change of chlorophyll content is one of the important bases for selecting the resistance of indoor plants to benzene pollution. The experiment was carried out using simulated cabin airtight method, changes of chlorophyll content in 8 common indoor plants under different concentrations of benzene pollution, which revealed the resistance of indoor plants to benzene pollution. The results showed that: Among the 8 indoor plants, Sansevieria trifasciata was the most resistant to benzene pollution, followed by Kalanchoe blossfeldiana, and Chlorophytum capense var. Variegatum was the weakest.

1. Introduction
According to the official statistics of the World Health Organization, nearly half of the world's people suffer from serious indoor chemical pollution, and nearly 100,000 people die each year from diseases such as asthma due to indoor chemical pollution[1]. Among many indoor pollutants, benzene has a great toxic effect on the human body[2]. The restoration and treatment of benzene pollution in indoor air by indoor plants is closely related to its resistance[3,4].

Chlorophyll is one of the most important pigments in plant photosynthesis. The change of chlorophyll content in plant is an important index to evaluate its light and function[5,6]. Based on the analysis of chlorophyll content of indoor plants under benzene pollution stress of different concentrations, the resistance of 8 indoor plants to benzene pollution stress was comprehensively evaluated, thus providing a more scientific basis for residents to choose indoor plants.

2. Materials and methods

2.1. Materials
Chlorophytum comosum (X1), Chlorophytum capense var. Variegatum (X2), Calathea insignis (X3), Scindapsus aureus (X4), Sansevieria trifasciata var. laurantii (X5), Spathiphyllum floribundum (X6), Kalanchoe blossfeldiana (X7), Podocarpus nagi (X8), 8 common indoor plants were selected for the study. The plant size of experimental plants is basically the same, and the growth state is very good. They are placed in pots of the same material and size, and the same quality and quantity of soil. Before the experiment, plant leaves were washed and wiped and dried. The flowerpot and basin soil were covered with polyethylene film during the experiment.

2.2. Experimental method
In the experiment, the simulated cabin airtight method was used to set the concentration gradients of 25 mg.m⁻³, 50 mg.m⁻³, 100 mg.m⁻³, with three benzene concentration gradients, 8 experimental
plants were randomly divided into fumigation box and treated with benzene stress. After 24 hours, the leaves were collected and the chlorophyll content in the leaves was measured. The chlorophyll content in the leaves was measured and the experiment was repeated 3 times. The chlorophyll extract was a mixture of hexanol and acetone. The absorbance was measured with an ultraviolet spectrophotometer at A663, A645, and wavelength, and the chlorophyll content was calculated according to the formula. The variance analysis, multiple comparison analysis and difference significance test were carried out with SPSS17.0 software.

3. Results and discussion

After different concentrations of benzene were stressed to 8 indoor plants for 24 hours, the changes in chlorophyll content in plants were recorded and analyzed (Table 1).

Table 1. Different concentrations of benzene pollution under 8 plants the change of chlorophyll conten.

| Benzene concentration | Plants code | 25mg.m⁻³ | Change rate | 50mg.m⁻³ | Change rate | 100mg.m⁻³ | Change rate |
|-----------------------|------------|---------|-------------|---------|-------------|---------|-------------|
|                       |            | (mg.m⁻¹ FW) | (%)       | (mg.m⁻¹ FW) | (%)       | (mg.m⁻¹ FW) | (%)       |
| X1                    | 2.5012     | 2.2091  | 11.68      | 2.5116  | 2.0064  | 20.12      | 2.5065  | 1.6646  | 33.59 |
| X2                    | 2.6903     | 2.3542  | 12.49      | 2.7018  | 2.1229  | 21.43      | 2.7009  | 1.7577  | 34.92 |
| X3                    | 8.5958     | 7.6958  | 10.49      | 8.6959  | 7.1995  | 17.21      | 8.6828  | 5.0399  | 31.59 |
| X4                    | 3.8128     | 3.4896  | 12.49      | 3.8046  | 3.2685  | 14.09      | 3.8094  | 2.8060  | 26.34 |
| X5                    | 1.3864     | 1.3174  | 4.98       | 1.3929  | 1.2945  | 7.06       | 1.4012  | 1.2436  | 11.25 |
| X6                    | 6.3826     | 5.6912  | 10.83      | 6.3881  | 5.2581  | 17.69      | 6.3862  | 4.4184  | 29.82 |
| X7                    | 1.7533     | 1.6506  | 5.86       | 1.8068  | 1.6601  | 8.12       | 1.8056  | 1.5666  | 13.57 |
| X8                    | 3.3370     | 2.9928  | 7.26       | 3.4096  | 3.0182  | 11.48      | 3.3986  | 2.7281  | 19.73 |

Table 1 shows that the chlorophyll content of 8 experimental plants decreased in varying degrees after 24 hours of benzene stress. The plant species and benzene concentration were used as two factors, and the change rate of the chlorophyll content of the experimental plants was analyzed using the two-way analysis of variance in SPSS 17.0 data analysis software. (Table 2.)

Table 2. The variance analysis of different plant change rate of chlorophyll content under different benzene concentrations.

| Source             | Degree of freedom | Sum of squares of deviations | Mean square | F(Mean square ratio) | P(significance level) |
|--------------------|-------------------|------------------------------|-------------|----------------------|-----------------------|
| concentrations     | 2                 | 0.320                        | 0.160       | 2512.344 * *         | 0.000                 |
| Plants             | 7                 | 0.209                        | 0.030       | 468.138 * *          | 0.000                 |
| Plants * concentrations         | 14               | 0.045                        | 0.003       | 50.082 * *           | 0.000                 |
| Error              | 48                | 0.003                        | 6.369E-5    |                      |                       |
| Total              | 71                | 0.576                        |             |                      |                       |

Table 2 shows that the changes of chlorophyll content of 8 species indoor plants were significantly influenced by plant species, benzene concentration and their interaction. The F value was 2512.334>468.138, the results showed that the effect of benzene concentration on the foliage-plant chlorophyll content of shade tolerant was more significant than that of plant species.

3.1. Results and analysis of changes of chlorophyll content in indoor plant under 25 mg.m⁻³ benzene stress

After 24 hours of stress at 25 mg.m⁻³ benzene on the tested plants, the rate of change of chlorophyll content in the 8 species of plants was recorded. The change rate of the chlorophyll content of the experimental plants was analyzed using the multiple comparison in SPSS 17.0 data analysis software. (Table 3.)
Table 3. The multiple comparison of different plant change rate of chlorophyll content under benzene concentration of 25 mg.m\(^{-3}\).

| Plant code | \( \bar{x}_1 - \bar{x}_2 \) | \( \bar{x}_1 - \bar{x}_3 \) | \( \bar{x}_1 - \bar{x}_4 \) | \( \bar{x}_1 - \bar{x}_5 \) | \( \bar{x}_1 - \bar{x}_6 \) | \( \bar{x}_1 - \bar{x}_7 \) | \( \bar{x}_1 - \bar{x}_8 \) |
|------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| X2         | 0.1249          | 0.075167\(^{**}\) | 0.066367\(^{**}\) | 0.052367\(^{**}\) | 0.040167\(^{**}\) | 0.020000\(^{**}\) | 0.016600\(^{**}\) | 0.008133 |
| X1         | 0.1168          | 0.067033\(^{**}\) | 0.058233\(^{**}\) | 0.044233\(^{**}\) | 0.032033\(^{**}\) | 0.011867          | 0.008467          |
| X6         | 0.1083          | 0.058567\(^{**}\) | 0.049767\(^{**}\) | 0.035767\(^{**}\) | 0.023567\(^{**}\) | 0.003400          | 0.004300          |
| X3         | 0.1049          | 0.055167\(^{**}\) | 0.046367\(^{**}\) | 0.032367\(^{**}\) | 0.020167\(^{**}\) |                   |                  |
| X4         | 0.0848          | 0.035000\(^{**}\) | 0.026200\(^{**}\) | 0.012200\(^{*}\)  |                   |                  |                  |
| X8         | 0.0726          | 0.022800\(^{**}\) | 0.014000\(^{*}\)  |                   |                  |                  |                  |
| X7         | 0.0586          | 0.008800         |                   |                  |                  |                  |                  |
| X5         | 0.0498          |                   |                   |                  |                  |                  |                  |

As can be seen from Table 3, the changes in chlorophyll content of 8 species plants under the stress of 25 mg.m\(^{-3}\) benzene, it can be seen that the order of resistance to benzene pollution is: (X5) Sansevieria trifasciata var.laurentii > (X7) Kalanchoe blossfeldiana > (X8) Podocarpus nagi > (X4) Scindapsus aureus > (X3) Calathea insignis > (X6) Spathiphyllum floribundum > (X1) Chlorophytum comosum > (X2) Chlorophytum capense var. Variegatum.

3.2. Results and analysis of changes of chlorophyll content in indoor plant under 50 mg.m\(^{-3}\) benzene stress

After 24 hours of stress at 50 mg.m\(^{-3}\) benzene on the tested plants, the rate of change of chlorophyll content in the 8 species plants was recorded. The change rate of the chlorophyll content of the experimental plants was analyzed using the multiple comparison in SPSS 17.0 data analysis software. (Table 4.)

Table 4. The multiple comparison of different plant change rate of chlorophyll content under benzene concentration of 50 mg.m\(^{-3}\).

| Plant code | \( \bar{x}_1 - \bar{x}_2 \) | \( \bar{x}_1 - \bar{x}_3 \) | \( \bar{x}_1 - \bar{x}_4 \) | \( \bar{x}_1 - \bar{x}_5 \) | \( \bar{x}_1 - \bar{x}_6 \) | \( \bar{x}_1 - \bar{x}_7 \) | \( \bar{x}_1 - \bar{x}_8 \) |
|------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| X2         | 0.2143          | 0.143633\(^{**}\) | 0.133067\(^{**}\) | 0.099467\(^{**}\) | 0.073367\(^{**}\) | 0.042200\(^{**}\) | 0.037367\(^{**}\) | 0.013067 |
| X1         | 0.2012          | 0.130567\(^{**}\) | 0.120000\(^{**}\) | 0.086400\(^{**}\) | 0.060300\(^{**}\) | 0.029133          | 0.024300          |
| X6         | 0.1769          | 0.106267\(^{**}\) | 0.095700\(^{**}\) | 0.062100\(^{*}\)  | 0.036000\(^{*}\)  | 0.004833          |                  |
| X3         | 0.1721          | 0.101433\(^{**}\) | 0.090867\(^{**}\) | 0.057267\(^{**}\) | 0.031167\(^{*}\)  |                  |                  |
| X4         | 0.1409          | 0.070267\(^{**}\) | 0.059700\(^{**}\) | 0.026100\(^{*}\)  |                  |                  |                  |
| X8         | 0.1148          | 0.044167\(^{**}\) | 0.033600\(^{**}\) |                  |                  |                  |                  |
| X7         | 0.0812          | 0.010567         |                  |                  |                  |                  |                  |
| X5         | 0.0706          |                   |                  |                  |                  |                  |                  |

LSD\(_{a=0.05}\) = 0.011956
LSD\(_{a=0.01}\) = 0.016474
As can be seen from Table 4, the changes in chlorophyll content of 8 species plants under the stress of 50 mg.m\(^{-3}\) benzene, it can be seen that the order of resistance to benzene pollution is: (X5) Sansevieria trifasciata var. laurantii > (X7) Kalanchoe blossfeldiana > (X8) Podocarpus nagi > (X4) Scindapsus aureus > (X3) Calathea insignis > (X6) Spathiphyllum floribundum > (X1) Chlorophytum comosum > (X2) Chlorophytum capense var. Variegatum.

### 3.3. Results and analysis of changes of chlorophyll content in indoor plant under 100 mg.m\(^{-3}\) benzene stress

After 24 hours of stress at 100 mg.m\(^{-3}\) benzene on the tested plants, the rate of change of chlorophyll content in the 8 species plants was recorded. The change rate of the chlorophyll content of the experimental plants was analyzed using the multiple comparison in SPSS 17.0 data analysis software. (Table 5.)

| Plant code | \(x_i - x_j\) | \(x_i - x_5\) | \(x_i - x_7\) | \(x_i - x_8\) | \(x_i - x_4\) | \(x_i - x_6\) | \(x_i - x_3\) | \(x_i - x_1\) |
|------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| X2         | 0.3492         | 0.236700       | 0.213500       | 0.151900       | 0.085800       | 0.051000       | 0.033300       | 0.013300       |
| X1         | 0.3359         | 0.223400       | 0.200200       | 0.138600       | 0.072500       | 0.037700       | 0.020000       |                |
| X3         | 0.3159         | 0.203400       | 0.180200       | 0.118600       | 0.052500       | 0.017700       |                |                |
| X6         | 0.2982         | 0.185700       | 0.162500       | 0.100900       | 0.034800       |                |                |                |
| X4         | 0.2634         | 0.150900       | 0.127700       | 0.066100       |                |                |                |                |
| X8         | 0.1973         | 0.084800       | 0.061600       |                |                |                |                |                |
| X7         | 0.1357         | 0.023200       |                |                |                |                |                |                |
| X5         | 0.1125         |                |                |                |                |                |                |                |

As can be seen from Table 5, the changes in chlorophyll content of 8 species plants under the stress of 100 mg.m\(^{-3}\) benzene, it can be seen that the order of resistance to benzene pollution is: (X5) Sansevieria trifasciata var. laurantii > (X7) Kalanchoe blossfeldiana > (X8) Podocarpus nagi > (X4) Scindapsus aureus > (X6) Spathiphyllum floribundum > (X3) Calathea insignis > (X1) Chlorophytum comosum > (X2) Chlorophytum capense var. Variegatum.

### 4. Conclusions

The above study can be found in:

1. The effects of different plant species, benzene concentration and their synergism on the chlorophyll content of 8 species indoor plants were extremely significantly different; through the comparison of F values, the chlorophyll content of the plants can be determined by the benzene concentration. The effect is even more pronounced.

2. Under different concentrations of benzene stress, the chlorophyll content of 8 species indoor plants decreased in varying degrees.

The chlorophyll content of Sansevieria trifasciata (X5) changed the least after 24 h stress at 25 mg.m\(^{-3}\) benzene concentration, which was 4.98%, and its resistance was the strongest. Kalanchoe blossfeldiana (X7) was the second, decreased by 5.86%. The chlorophyll content of Chlorophytum capense var. Variegatum (X2) changed the most, decreased by 12.49%, which the resistance ability was the weakest.
The chlorophyll content of *Sansevieria trifasciata* (X5) changed the least after 24 h stress at 50 mg.m\(^{-3}\) benzene concentration, which was 7.06%, and its resistance was the strongest. *Kalanchoe blossfeldiana* (X7) was the second, decreased by 8.12%. The chlorophyll content of *Chlorophytum capense var. Variegatum* (X2) changed the most, decreased by 21.43%, which the resistance ability was the weakest.

The chlorophyll content of *Sansevieria trifasciata* (X5) changed the least after 24 h stress at 100 mg.m\(^{-3}\) benzene concentration, which was 11.25%, and its resistance was the strongest. *Kalanchoe blossfeldiana* (X7) was the second, decreased by 13.57%. The chlorophyll content of *Chlorophytum capense var. Variegatum* (X2) changed the most, decreased by 34.92%, which the resistance ability was the weakest.

(3) The changes of chlorophyll content in 8 experimental plants under the concentration of 25, 50 and 100mg. m\(^{-3}\) showed that *Sansevieria trifasciata* was the most resistant to benzene pollution, followed by *Kalanchoe blossfeldiana,* and *Chlorophytum capense var. Variegatum* was the weakest.

**Acknowledgments**

This work was financially supported by the Natural Science Foundation of China(20337010), Ministry of Housing and Urban-Rural Development of science and technology planning project(2012-K6-5), Shandong Provincial Department of Housing and Urban and Rural Construction of science and technology planning (2011 YK046).

**References**

[1] Organization W H and Europe R O F 2010 WHO guidelines for indoor air quality: selected pollutants. J.WHO.

[2] Lu M, Zhao J, Feng L D, Liu G S, Yan H M and Zhao X M 2013 Research progress of ecological plant rehabilitation technology of indoor benzene pollution J. Shandong. Jianzhu.U. 28(6):551-556 (In Chinese)

[3] Lu M, Zhao X M, Zhao J, Liu G S and Yan H M 2013 Research progress of plant resistance for indoor benzene pollution stress J. Shandong. Jianzhu.U. 28(5):457-463 (In Chinese)

[4] Zhou Q Q, Chen C G, Chen B, Chen Z Y, Wang Y and Cai Y Y 2013 Capability of purifying benzene by three indoor ornamental plants Guangdong.Agri. Sci. 40(16):143-146 (In Chinese)

[5] Lu M, Jing R R, Zhao J, Yan H M, Zhao X M and Ding Z 2016 Analysis of indoor plant chlorophyll content in benzene pollution stress J. Shandong. Jianzhu.U. 31(1):1-6 (In Chinese)

[6] Orwell R L, Wood R L, Tarran J, Torpy F and Burchett M D 2004 Removal of Benzene by the Indoor Plant/Substrate Microcosm and Implications for Air Quality Water.Air. Soil.Pollution. 157(1-4):193-207

[7] Wolverton B C. and Wolverton J D. 1993 Plants and soil microorganisms: removal of formaldehyde, xylene, and ammonia from the indoor environment J. MS. Aca.Sci. 38 (2): 11-15

[8] Lu C G, Sheng N and Zhang H F 2008 Study on Four Kinds of Indoor Ornamental Plants' Responses to Benzene Gas Stress J.Anhui .Agri 36(34):14869-14870,14884 (In Chinese)