

The regulating effect of *S.trifasciatar.laurentii* on indoor environment



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Abstract

Purpose / Context - Indoor air pollution in China has become increasingly serious, which has aroused wide concern among the public. The purpose of this paper is to study the effect of *S.trifasciatar.laurentii* on indoor environment.

Methodology / Approach - An investigation in a house with two same bedrooms (experimental one and control one) was conducted during heating period in Jinan, Shandong, China. Indoor CO₂ concentration, indoor air temperature and humidity, PM_{2.5} and PM₁₀ concentration in two bedrooms were collected.

Results -The results showed experimental room with three pots of *S.trifasciatar.laurentii* was 1.6% higher in the room air relative humidity, 0.997 °C lower in temperature, 15.5% lower in PM_{2.5} concentration, 16.4% lower in PM₁₀ concentration than the control room without plants. Also, each 1m² leaf area of *S.trifasciatar.laurentii* absorbed 2039.96mg CO₂ per hour. For Chinese common housing, 15m² bedroom needs about 4-5 pots of *S.trifasciatar.laurentii*.

Key Findings / Implications - The quantitative data in this study are very promising for future indoor environmental management.

Originality - The possibility of reducing urban air pollution by lowering energy requirements of city buildings is also encouraging and nature's ability to cost-effectively mitigate urban pollution is impressive, and its development is urgently needed.

Keywords - *S.trifasciatar.laurentii*; indoor environment; indoor CO₂ concentration; indoor air temperature and humidity



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1. Introduction

In recent years, indoor air pollution has become a worldwide concern. Due to the need of building energy efficiency, the airtightness of modern buildings is improved and the indoor ventilation is reduced, which makes indoor air pollutants such as CO₂, dust, bacteria and so on are not easy to spread^[1]. The transpiration is the phenomenon that, moisture in gas state, through the plant's surface, loss out of the body. The transpiration and culture medium can release moisture into the air, thereby increase the indoor humidity. Photosynthesis is the physiological processes that plants convert carbon dioxide and water into organic material and oxygen, through the light reaction and carbon reaction under the irradiation of visible light. Crassulacean acid metabolism plant can absorb CO₂ at night because of the particularity of the stomatal.

Some literature demonstrated that *S.trifasciatar.laurentii* are net CO₂ absorbing state throughout all-weather^[2-3]. In order to further study the effect of *S.trifasciatar.laurentii* on indoor environment, in February 2016, an investigation in a house with two same bedrooms (experimental one and control one) was conducted during heating period in Jinan, Shandong, China.

2. Material and Methods

2.1 Materials

This investigation chosen 3 pots similar-sized, healthily-growing *S.trifasciatar.laurentii* with no pests and diseases. The plants were purchased at nursery market in Jinan. Before the experiment, the plants were watered for a week; and in experiment time, they were forbidden watering. In order to adapt the test environments, the plants were held in test room for one week and clean the leaves and dust.

The paper-cut weighing method were used, which means painted the leaf on the standard graph paper and cut the paper then weighing. According to the weight and the area is directly proportional: leaf area = area of the whole paper * the weight of the cut paper/ the weight of the whole piece of paper^[4].

2.2 Instruments

The investigation used PM2.5detector (CW-HAT200, the detection sensitivity is 0.001mg) to detect indoor PM2.5 and PM10 at 9:00 and 15:30 every day, used temperature and humidity instrument (testo 175H1) to detect indoor temperature and humidity peer 30 minutes, and used CO₂ concentration detector (Lutron MCH-383SD) to detect indoor CO₂ concentration peer 30 minutes during the experiment.

2.3 Study sites and time

The test was during 3-6th and 10-15th February, 2016, in Jinan, Shandong Province. The test room is brick structure and centrally heated without obvious pollution, and have no interior decoration and furniture replacement in the past five years. The net area of the two selected bedrooms is 17.11m², and the net volume is 43.63m³. Each of the bedrooms have 4 windows which size is 2.9m*1.3m.

During the experiment, door and windows were closed in the evening because of no ventilation, and people did daily life in test room. The number of air changes in the two rooms was detected by the method of carbon dioxide attenuation, before the start of the experiment. The air change of room A is 28.29% per hour, and room B is 28.31%. So it can be considered that the sealing performance of the two rooms is the same.

2.4 Methods

The room A which has two people living at night without any plant was taken as a control group. The room B which also has two people living at night, has 3 pots of *S.trifasciatar.laurentii* which placed in 1.2m distance from the balcony to ensure that the sun during the day. The data of two rooms were measured at the same time, and people movements of these rooms should be similar during the test time.

The PM2.5detector, temperature and humidity instrument 1, CO₂ concentration detector (data shows that the distribution of CO₂ is uniform in the closed room, and the CO₂ concentration is the same in any location of the room) were placed at the same position of the two rooms. with the same highly of people sit high breathing; placed the temperature and humidity instrument 2 and 3 at the same position in the two rooms respectively (i.e. near the plant placement in the room B and near the head of a bed in both rooms); placed CO₂ concentration detector, temperature and humidity instrument, PM2.5detector outside the window.

3. Results

3.1 Regulating effect of plants on indoor CO₂

The indoor CO₂ concentration was detected at 22:00 in the afternoon to 9:00 in the next morning during February 3 to 6 and February 10 to 15. People kept to entered both of the rooms at 22:00, and left at 7:00am on 4-5th February; at 8:00am on 6th February; at 8:30am on 10-15th February. As shown in Figure 1, on 3-5th February, the maximum CO₂ concentration of room A is 2291ppm, 2340ppm, 2445ppm respectively, and the Room B is 2035ppm, 1805ppm, 1887ppm respectively. In this three days, the average CO₂ concentration of room A is 1677 ppm, 1609ppm, 1987ppm respectively, and the room B is 1589 ppm, 1475ppm, 1667ppm respectively. The average CO₂ concentration of the three-days of room B is 180ppm lower than room A. Due to the door of both rooms remained closed after getting up in the morning on 5th February, the start concentration of CO₂ was significantly higher than the first two days.

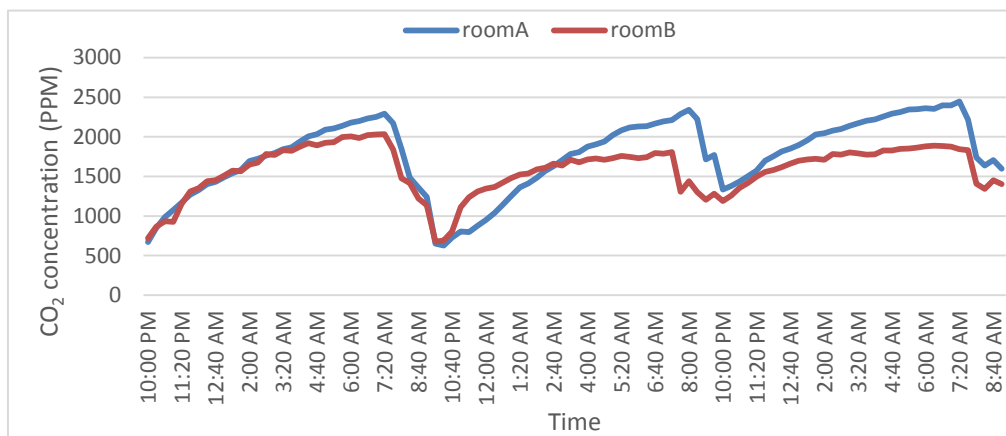


Figure 1 The CO₂ concentration of two rooms on 3-5th February

As shown in Figure 2, the maximum CO₂ concentration of room A is 2820ppm, 2790ppm, 2585ppm, 2375ppm, 2328ppm respectively, and the Room B is 2213ppm, 2019ppm, 1918ppm, 1920ppm, 1746ppm respectively on 10-15th February; the average CO₂ concentration of room A is 2248ppm, 2212ppm, 2146ppm, 1882ppm, 1898ppm respectively, and the room B is 1907ppm, 1622ppm, 1648ppm, 1678ppm, 1541ppm. The average CO₂ concentration of the five-day of room B is 398ppm lower than room A. The doors and windows remained closed expect of the access of people in the morning and afternoon during the experimental period.

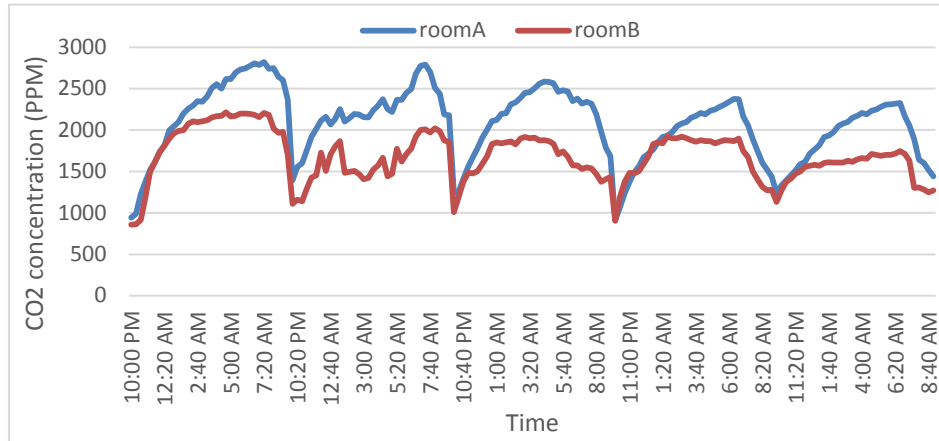


Figure 2 The CO₂ concentration of two rooms on 10-15th February

As shown above, the CO₂ concentration in the two rooms were at a peak at about 7:00am, and the people getting up at 7:00. Therefore, we selected 9 hours' data from 22:00 to 7:00 to analysis. The average CO₂ concentration of room A was increased by 1332.25PPM per day by two people (i.e. the average data of 7:00 minus the data of 22:00 the day before), so the average CO₂ emission of per people was 74.01PPM per hour, which was recorded as M1. Two people and 3 pots of *S.trifasciatar.lautentii* made the CO₂ concentration of room B increased by an average of 905.25PPM per day. Thus 3pots of *S.trifasciatar.lautentii* made the CO₂ concentration of room B decreased by an average of 427PPM compared to room A (i.e. the absorption of *S.trifasciatar.lautentii* on 9 hours at night). Because the total leaf areas of the selected plants is 1.8288m², so we can calculate the absorption of per unit time and per unit area of *S.trifasciatar.lautentii* is 25.94PPM/m²*h, which was recorded as M. According to M1 and M, the required leaf area to absorb the CO₂ emission by one people per hour is 2.84m². The volume of the tested room is 43.6305m³, so the required leaf area of one people in unit space is 0.065m²/m³.

3.2 Effects of plants on indoor temperature and humidity

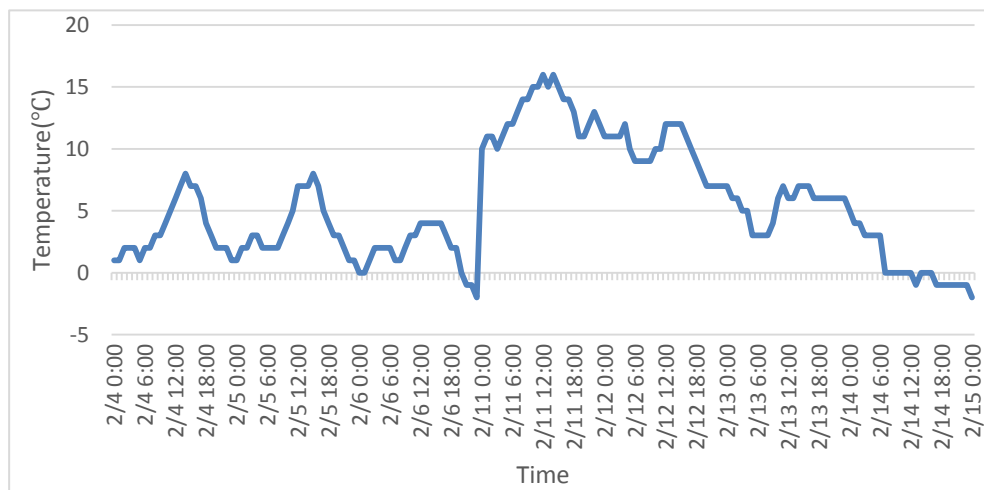


Figure 3 Outdoor temperature data during the experiment

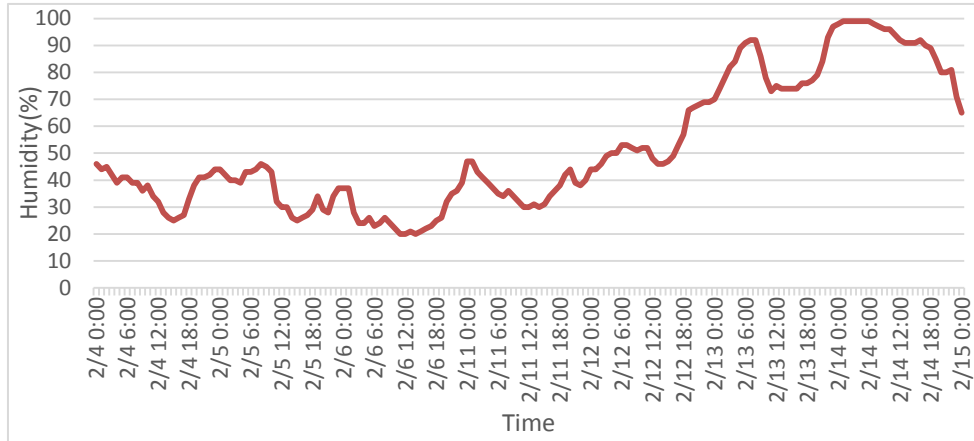


Figure 4 Outdoor relative humidity data during the experiment

Figure 3 and Figure 4 is the data of outdoor meteorological during the experiment. Except for the 12 and 13th February was rainy and snowy, the other time was sunny. During 4-6th February, the average outdoor temperature was 0 degrees Celsius, and the relative humidity was about 42%. The average outdoor temperature was about 6 degrees Celsius during 11-14th February. The outdoor average relative humidity was 45% during 11-12th February. The average relative humidity was about 80% during 12-14th February. During the experiment, the average wind speed was 2-3m/s.

In experiment time, the average temperature of the bedside of room A and B was 24.2 and 23.5 degrees Celsius respectively, and the average relative humidity was 28.54% and 29.38% respectively; the average temperature of the center of room A and B was 24.75 and 24 degrees Celsius respectively, and the average relative humidity was 27.45% and 28.24% respectively; the average temperature of the location next to the plant of room A and B was 24.18 and 22.64 degrees Celsius respectively, and the average relative humidity was 28.55% and 31.72% respectively.

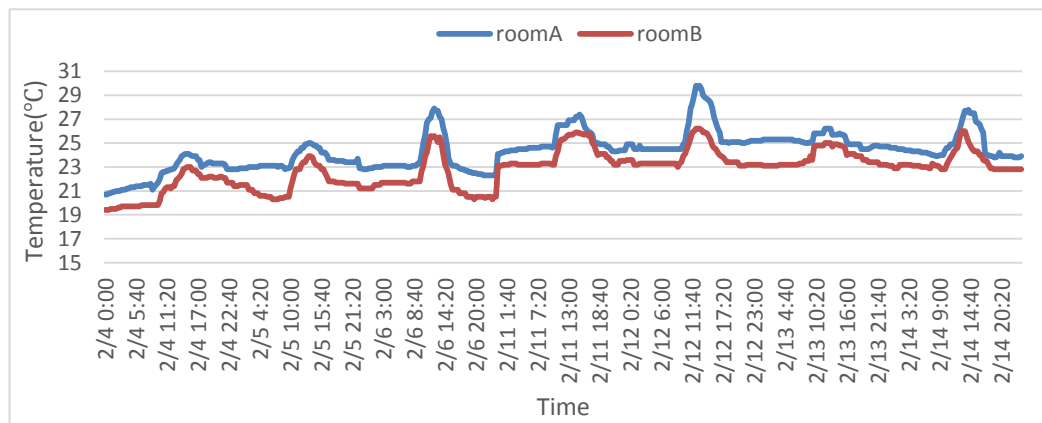


Figure 5 Indoor temperature data of the two rooms next to the plants

The location where nearby plants was chosen and analyzed data, because the temperature and humidity of the location of bedside and the center of the room had no obvious changes. As shown in Figure5, the trend of the temperature and humidity variation was consonant, and the change of indoor temperature and outdoor environment were related. When the room began to have sunlight, indoor temperature gradually increased, peaking in about 2 o'clock in the afternoon. It is the time that the outdoor temperature was highest and then gradually decreased. The change of the indoor temperature was not obvious, and tend to be gentle. As shown in Figure 5, the temperature of the location next to the plants of room B was 1.54 degrees Celsius lower than room A, which shows that the transpiration of plant has a cooling effect on the indoor environment.

As shown in Figure6, the change of indoor relative humidity is consistent, and the room B was 3.36% higher than room A. It shows that the transpiration of plant has a humidifying effect on the indoor environment. Because the external environment has a great influence on plant transpiration, so it also has a great influence on the cooling and humidity of plants. Due to sun exposure, the indoor temperature increased obviously and the relative humidity decreased at noon. Also because there were no personnel stay during the day, and people entering the room will also cause the increase in relative humidity, so the two rooms achieved the lowest value of indoor relative humidity at noon.

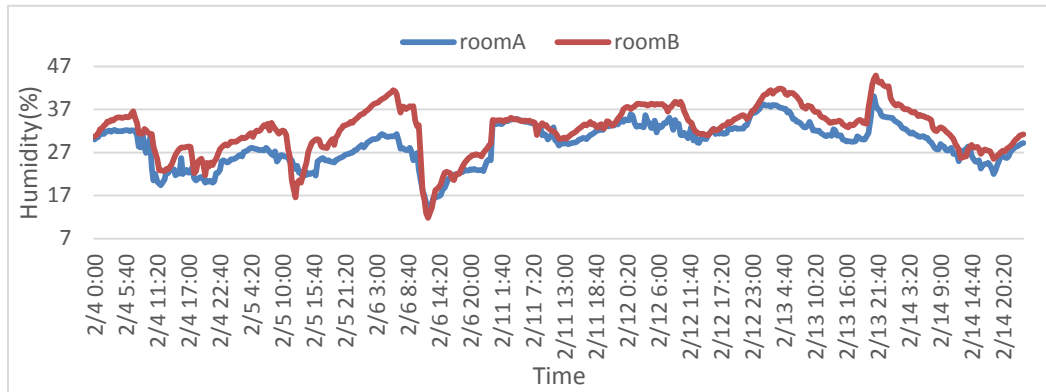


Figure 6 Indoor relative humidity data of the two rooms next to the plants

3.3 Regulating effect of plants on indoor PM2.5

In order to avoid the personnel activity influence of indoor PM2.5 values, the test time was selected at 9:00 and 15:30 (i.e. an hour after the people get up in the morning and at noon). The doors of two rooms remained closed before the detection started. Figure7 shows the data of PM2.5 of two rooms and outdoor during the experiment, and the Figure8 shows the data of PM10.

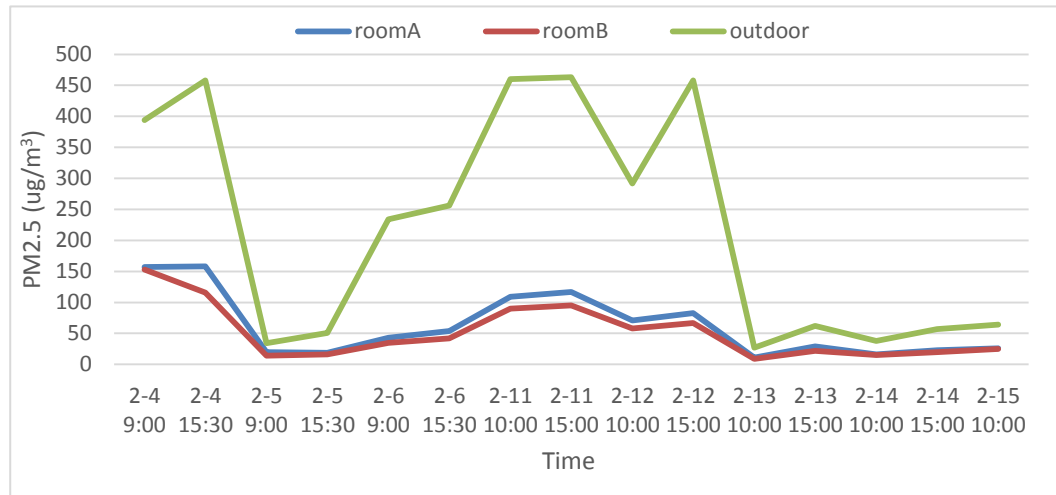


Figure 7 The value of PM2.5 of two rooms and the outside

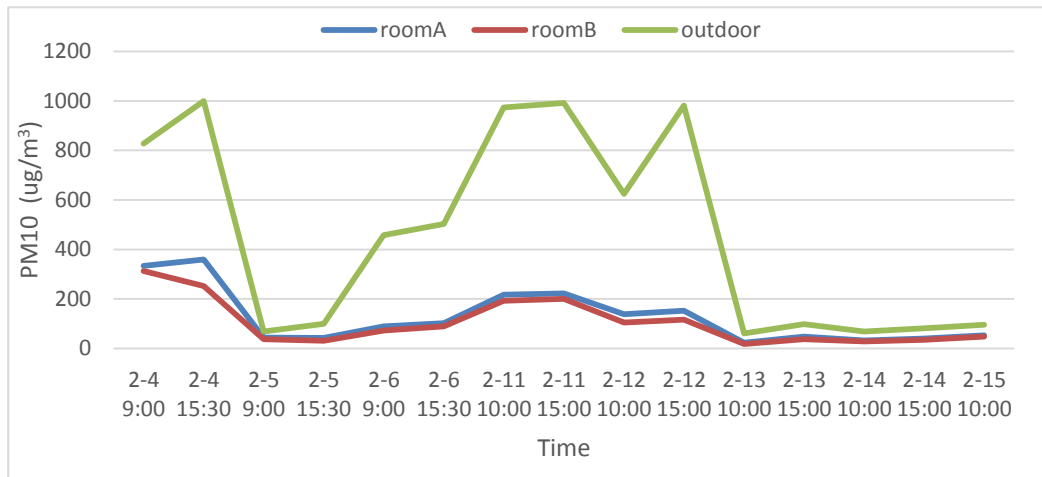


Figure 8 The value of PM10 of two rooms and the outside

As shown above, the data of PM2.5 and PM10 of the room B with plants were lower than the room A without plants. The value of PM2.5 of room B was 15.5% lower than room A, and the value of PM10 was 16.4% lower than room A. These proved that leaf has good effect of dust detainment. The value of indoor PM2.5 has a great related to the outdoor PM2.5, therefore, it's better to close the doors and windows to avoid the PM2.5 from the outside into the room.

4. Discussion

4.1 Indoor greening and building energy efficiency

The researchers had investigated the energy consumption of humidifier and air purify. It is found that the total power consumption was 1.6-2.2 billion degrees and 1.3-2.3 billion degrees respectively of annual winter by Beijing families which used the humidifier and air purify. The demand of humidifier and air purify were increasing year by year, thus the humidifier and air purify energy consumption will become an inseparable part of building energy consumption^[5]. This experiment proved that the plants can improve the indoor temperature、humidity and air quality. Therefore, if more and more comprehensive experiments will be done and the fixed quantify experimental conduction can be used to the design of the indoor environment, the energy consumption will be reduced significantly.

4.2 Problems in this experiment

In this experiment for the effect of plants on indoor air quality, we only collected the data of indoor CO₂ concentration but the O₂ concentration was not collected. The data collection was not comprehensive. In addition, we only used 3 pots of plants in the experiment, and didn't considering whether the effect of plants on indoor environment will reach a limit value or not with the increase of leaf area. Finally, the effects of plants on the indoor environment need longer time to comparison and observation, and the experimental period in this experiment should be extended.

5. Conclusion

- (1). *S.trifasciatar.lautentii* absorbed 2039.96mg (i.e. 25.94PPM) CO₂ per unit area and time in the night, has a certain role in the regulation of indoor CO₂ concentration.
- (2). In the circumstances that the frequency of ventilation is 0.28/h, the quality of CO₂ release of a person is same as the absorption by *S.trifasciatar.lautentii* with 0.065m² leaf area in the night. For Chinese common housing, 15m² bedroom needs about 4-5 pots of *S.trifasciatar.lautentii*.

(3). *S.trifasciatar.lautentii* can regulate indoor temperature and humidity, the average humidity of room B with 3 pots of *S.trifasciatar.lautentii* was 1.60% higher than room A with no plants, and the average temperature of room B was 0.997 lower than room A.

(4). *S.trifasciatar.lautentii* has good effect of dust detainment, the value of PM2.5 and PM10 of room B were 15.5% and 16.4% lower than room A respectively.

6. ACKNOWLEDGEMENT

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