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The Selection of Plants for indoor garden and the Environmental improvement effects

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Abstract

In this study, we built a mock-up of an indoor garden for private use and vertical gardens were installed on the walls of this indoor garden model. The purpose of this study is to examine the types of plants for best fit for growth and nurture in vertical garden and to identify the effects of indoor air quality improvement by these plants. As the result of the experiment, 22 species out of 32 species previously used for indoor garden was selected to be suitable for vertical gardens of a personal indoor garden. 10 species were found to be inappropriate for a personal indoor garden in terms of ornamental value, growth status and maintenance. The effect of plants on reducing CO2 has been proven by many studies. Also, through photosynthesis, plants combine CO2 with water and produce sugars and O2 (oxygen). Everyone accepts this fact. In nature, the production of oxygen is so important that without plants we would soon use it up and die. From the NASA Fact Sheet we know that air contains 20.95% O2 and 0.04% CO2. If you had enough plants in a room to use up all of the all of CO2 and convert it to oxygen, the oxygen levels would increase from 20.95% to 21%. This increase is difficult to detect and would have no effect on humans.

Keywords: *Vertical Garden, Suitable Plants list, Effect of Plants,* CO_2, O_2

1. INTRODUCTION

Environmental issues are no longer distant issues to any country around the global. As much of living conditions are directly impacted, social systems are being developed to cope with climate changes and to accommodate environmental changes leading many changes in our lifestyles and living patterns. Amid such changes, a city as a living space is where much of environmental issues have direct impact and is a special space with a need to evolve into environmental-friendly structure. Currently, modern cities suffer from climate change, desiccation, flood and fine dust due to dramatic decrease of green space.

In particular, there is a growing concern regarding indoor air pollution and more people are paying attention to substances that cause indoor air pollution. Indoor air pollutants are categorized into gas substances such as Cox, NOx, TVOCs and particles such as fine dust and PAHs [1]. Especially, fine dust, which is pollutant in particle form, has become nation-wide issue as fine dust situation is aggravated by yellow dust. In Korea, people are exposed to a number of find dust types including yellow dust from China, fine dust from automobiles and power plants [2]. These fine dust penetrate into indoor space through ventilation or infiltration having negative impact on people at homes.

Plants are known to have purification effects not just for fine dust, but for many other air pollutants plus

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psychological effects as well. As mentioned, many of researches conducted so far mainly to focus on fine dust reducing effects, but they do not include reviews on practical methods of utilizing plants such as greening methods, greening pattern or distribution. Therefore, there is a need to quantify and systematically organize air purification methods using various plants, greening methods and patterns.

With hosting of International Garden Exposition Suncheon Bay Korea 2013, there is a growing interest on gardens in Korea along with more people taking interest in owning a garden and doing gardening activities [3-4]. Growing plants and arranging flowers in a vase at one's home reflects human's basic instinct to own a garden and be close to nature. But considering the fact that more than 50 % of residence type in Korea is apartments/condominiums, there is much constraint on space for owing a garden at home. However, recent development of various technologies such as LED technology, watering system and planting media technology is making greening more possible on indoor space, rooftops or walls at home which were spaces limited in the past for landscape planting. Especially, vertical gardens can also be constructed indoor like in apartments which are the most popular form of residence in Korea and with the development of various types of vertical gardens, installation has become easier.

In this study, we built a mock-up of an indoor garden for private use and vertical gardens were installed on the walls of this indoor garden model. The purpose of this study is to examine the types of plants for best fit for growth and nurture in vertical garden and to identify the effects of indoor air quality improvement by these plants.

2. RESEARCH METHOD

2.1 Selection of Plants Suitable for Indoor Garden

32 plant species were selected for the experiment of an indoor garden based on the result of studies in the past [5]. 20 units of each species were purchased from flower markets and were transferred to ebb and flow sub-irrigation flowerpots for adaptation which were then installed on indoor vertical gardens. Vegetation environment for these plants consisted of 5~15 PPFD (300~900lux), 20~25℃ of temperature, and circulating irrigation system for 2 times per day using water tanks and underwater pumps. Hyponex was diluted 1:2000 for fertilization once a month [6]. Plant growth was measured once a month. The overall width of a plant was measured for plant species with clear growth points such as Ardisia pusilla. For species that have petiole lengths for growth points instead of plant width, a distance from the ground to the end of petiole was measured for plant width. For the number of leaves, if a plant had one branch, then a total number of leaves of the plant was counted. If a plant had more than one branch, then one branch was selected as a standard branch and the number of leaves of the standard branch was counted. The width and length of a leaf were measured based on a full-grown leaf from 3rd to 5th bottom ranking growth points. Chlorophyll content was measured from 5-6 full-grown leaves with SPAD–502 plus (Konica, Japan) and an average score was taken. Growing point index of plants growing domestically in Korea before and after installation on greening walls was also prepared using growth data measured at the time of installation and 2 months after the installation. Adaption of plants into an indoor vertical garden was evaluated based on growth point index and visual observation of growth status.

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Figure 1. Selection Experiment of Plants

2.2 Building Mock-up for experiment

As a part of experiment of the study, indoor vertical gardens were constructed in a closed cubicle shape with woods. The size of the cubicle is approx. 4m^2 and vertical gardens of 2*1.5*m* are built on 3 surrounding walls. For one side, glass doors were installed to lessen the feeling of being in a closed space. Machines to keep temperature and humidity consistent were installed in the ceiling of the cubicle. At the center of a garden, a table and a chair for resting were installed.

2.3 Experiment on the Impact of Indoor Garden on Air Quality

Hobo data loggers (HOBO Pro v2, Onset, USA) were used to measure changes in the environment. 13 Plant species growing domestically in Korea selected for indoor gardens are *Nandina domestica, Eunymus japonica , Ardisia pusilla 'Variegata', Dracaena sanderiana, Epipremnum aureum ʻLimeʼ, Fittonia verschaffelti 'White Star', Begonia, Ponerorchis graminifolia Chamaedorea elegans, Spathiphyllum, Dracaena deremensis 'Virens Compacta', and Aglaonema*. 20 units of each species were purchased from flower market and were installed into felt type, pocket exchange type and unit type of indoor gardens for 1 week adjustment period. After a week, changes in vegetation environment of indoor gardens were measured using Hobo data loggers (HOBO Pro v2, Onset, USA)

After measuring changes in vegetation environment, changes in air quality of indoor garden were also measured according to % of plants area (on vertical walls) installed. Indoor garden with 0% of plant area, 65% of plant area and 100% of plant area were measured for the concentration level of oxygen, CO^2, NO_2 and Volatile Organic Compounds (*VOCs*) with a portable gas measurement device (MultiRAE, RAE systems, UOS). For volatile organic compounds, 5ml of Iso-propyl alchol was placed in 10 different points for gasification and absorption by plants 5 minutes after was measured.

3. RESULTS

3.1. Selection of Plant Species Suitable for a Personal Indoor Garden

For selection of suitable plant species for a personal indoor garden, growth index of plant species was studied and recorded for 2 months. There were 3 criteria for selection of plant species which are growth status, ornamental value and maintenance. For growth status, an observation was made for how stable a plant would grow within a personal indoor garden system, how big it would grow, whether a plant would wilt and die out and lastly, whether the color of plant would change or fade out. For ornamental value, the shape of a leaf, the color of a plant and whether the bloom of flower or fruit be problematic or not were observed. For maintenance, how much leafs would fall out and any special conditions would be required for watering or lighting was evaluated.

Based on the evaluation of 32 plant species selected from previous experiments, 10 species were evaluated to be inappropriate for use in a personal indoor garden as the following. For *Nandiain domestica*, leaves fell out and the number of leaves shrank. The length of petiole increased notably along with leaves changing color from red to green which lessened ornamental value of the plant. For *Eunymus japonica*, the overall growth of the plant was not good. The number of leaves reduced largely during 2 months of observation and the length of petiole and leaf width also decreased. Also, when installed at the bottom of a vertical garden where lighting was not sufficient due to distance of the ceiling, then many fallen leaves were observed. For *Mandevilla Sander*, if planted on high level near lighting, the stem or branches of a plant grew long and thin and the plant wilted when planted at the middle or bottom level. Also, the flower of the plant fell quickly reducing the ornamental value of the plant. For *Hedera Helix "Ceridwen" and "Yellow star Jasmin"*, the overall growth was not robust as these plants died out quickly with a notable reduction in the number of tillers. For *Kalanchoe blossfeldiana 'Calandiva'*, the number of leaves decreased, and the leaves grew thicker. In the early stage, flowers were observed, but as time passed by, the number of flowers decreased sharply. For *Ficus pumila*, the color of leaves changed to brown along with many fallen leaves. For *Codiaeum variegatum. 'Van Oosterzee'*, the overall growth was good. However, some fallen leaves were observed and the level of chrolophyll increased from 41.4 to 54.9 changing the color of brown and yellow patterns in the leaves to greenish patterns which reduced the ornamental value of the plant. For *Peperomia clusiifolia*, the leaves grow thicker which reduced ornamental value. For *Heteropanax fragrans*, the plant showed steady growth during 2 months of the experiment, but it grew dramatically afterwards. There was a possibility of chemical treatment for controlling growth from the vendors and the plant was deemed inappropriate for a personal indoor garden due to its growth pace and difficult maintenance.

On the other side, the experiments concluded that 22 species were appropriate for use in a personal indoor garden system based on growth stability, ornamental value and maintenance. All *Ardisia pusilla, Hedera helix "Sagittifolia", Rhapis excelsa, Annona muricata, Nematanthus gregarius, Asplenium antiquum, Euphorbia milii var. splendens, Alocasia×amazonica, Calathea insignis Calathea concinna 'Freddie', Fittonia verschaffelti 'White Star', Hoya carnosa* showed stable and solid growth status along with steady increase in the lengths of the leaves and the number of branches and leaves. For Ardisia, no change in the number, or length or width of leaves was observed. It showed steady growth and bore fruit well serving its ornamental value. For *Aglaonema 'SiamAurora'*, the overall growth status was good. Newly grown leaves developed wax layer which reflected light and presented bright and healthy image. For *Sansevieria trifasciata 'Laurentii Compacta'* and *Sansevieria stuckyi* which are known to grow in dry environment, they showed solid adaptability in the personal indoor garden where certain level of water is provided. For *Codiaeum variegatum 'YellowBanana'*, no change in the number and lengths of leaves was observed, but some leaves in the bottom of the plant fell out. There was a slight decrease in the number of leaves, but the overall growth status was good with high ornamental value from vivid yellow leaves.

3.2 Building Mock Up of a Personal Indoor Gardens for the Experiment

A personal indoor garden was built with wood in a shape of a cube. The size of the garden is approximately $4m^2$ and vertical gardens of 2*1.5m are built on 3 surrounding walls. Glass doors were installed on the remaining side of the indoor garden to lessen the feeling of being in a closed space. Machines were also installed in the upper area to maintain consistent temperature and humidity. In the center of a garden, a table and chairs for resting were installed.

Figure 2. Mock Up of Personal Indoor Gardens

3.3 The Experiment to examine the impact of an indoor garden on air quality

As shown in Figure. 3, temperature change of the environment after the indoor garden was built was not significant with a range from the lowest of 20°C to the highest of 24°C. This is probably due to the indoor environment of a garden and the temperature range is considered appropriate for plant growth. Change in the humidity (Figure. 4) was expected to occur depending on plant species used and irrigation interval. However, the difference in the humidity was big due to day and night. Humidity remained high at night which is thought to have been caused by circulating fan not working at night. Such high humidity can lead to plant disease or decay of plant roots so operating ventilation fan for 24 hours a day would be required to maintain 50-60% humidity.

The luminous intensity varied greatly depending on planting species and the height of plants installed, and this is because the lighting of the indoor garden was placed in the ceiling. The luminous intensity was measured to be quite high between 300-500 *PPFD* with the felt type, unit type and pocket exchange type. This implied that adequate lighting environment with supplement lighting is needed to promote growth and maintenance of herbs, leafy vegetables, helophytes, and etc. However, at the medium or lower level of the indoor garden, the lighting declined proportionately to the distance from ceiling which implied that plant species must be selected carefully depending on how high on the wall plants are to be installed.

Changes in air quality based on area of plants of a personal indoor garden was measured and the result is shown in Figure.5-8. The lager the plant area, the better the air quality improved.CO_2 concentration level change was measured which is shown in Figure. 5. Before installation of plants, the concentration level of CO_2 in the air was 1000ppm which was reduced by 300ppm as the plant area increased to 65% and 100%. The reduction of CO_2 is the result of plants observing CO_2 through photosynthesis. On the other hand, the concentration level of Oxygen did not change much as plant area increased (Figure. 6). The level of Oxygen occurrence in 0% plant area and 100% plant area did not change which implied that the photosynthesis of plant did not have effect on producing Oxygen. This calls for a technical review on the introduction of oxygenator for an indoor garden to cover the current technology gap. NO_2 level changed which was 50% reduction (Table. 1) as plant area increased.

For changes in the level of volatile organic compounds concentration (Figure. 7), the speed of *VOCs* spreading was controlled as time passed by from emission points. With no plant installed, *VOCs* started to spread quickly throughout the indoor garden from the points of emission. But, with plants installed and as plant area increased, the speed and volume of *VOCs* spreading deceased dramatically. Looking at the overall changes in the air quality of the indoor garden due to plant implementation is that as the plant area increased, the level of CO_2 concentration and NO_2 decreased dramatically plus *VOCs* spreading and absorption in the air were much controlled. This suggests that the indoor garden has positive effect on improving the air quality of indoor space.

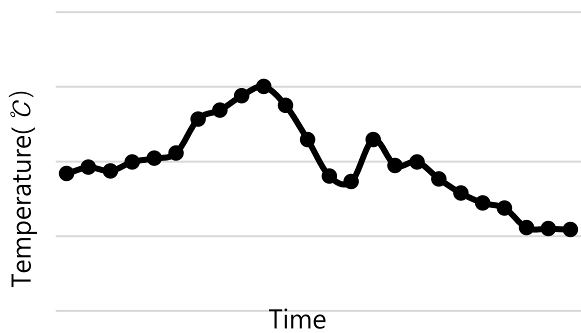

Figure 3. Temperature change

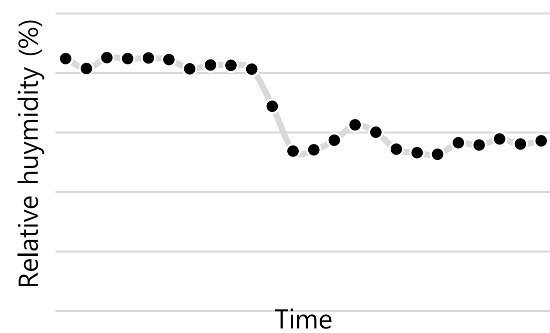

Figure 4. Relative humidity change

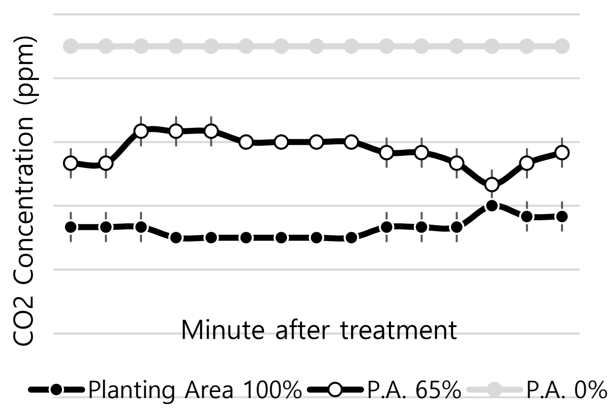

Figure 5. *CO_2* Concentration level change

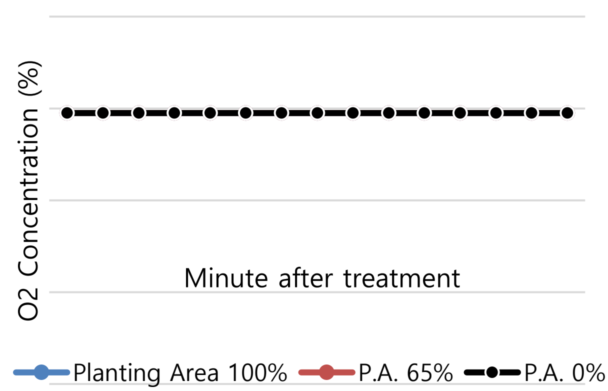

Figure 6. *O_2* Concentration level change

Planting area (%)	NO2 Concentration (*ppm*)
100	0.048
65	0.057
0	0.100

Table 1. *NO_2* Concentration level change

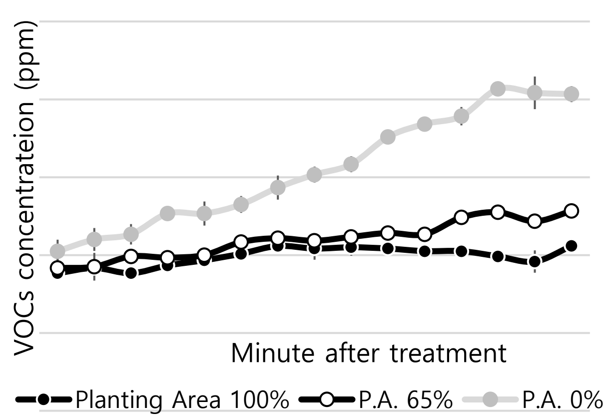

Figure 8. *VOCs* Concentration level change

4. DISCUSSIONS

As a result, an indoor garden for personal use was built in a cubical shape of $4m^2$ in size which has 3 surrounding walls constructed with vertical gardens. This indoor garden is for personal use and equipped with a chair, lighting, air-conditioning system and sound system. Out of 32 plant species previously known as appropriate for indoor growth, 22 species were confirmed to be appropriate for use for a personal indoor garden and 10 species were confirmed to be not appropriate due to declining ornamental value, unsteady growth and difficult maintenance. An experiment on plant growth was conducted to select suitable plant species for use in a personal indoor garden. As the result of the experiment, 22 species out of 32 species previously used for indoor garden was selected to be suitable for vertical gardens of a personal indoor garden. 10 species were found to be inappropriate for a personal indoor garden in terms of ornamental value, growth status and maintenance. The effect of plants on reducing CO_2 has been proven by many studies. Also, through photosynthesis, plants combine CO_2 with water and produce sugars and O_2 (oxygen). Everyone accepts this fact. In nature, the production of oxygen is so important that without plants we would soon use it up and die. From the NASA Fact Sheet we know that air contains 20.95% O_2 and 0.04% CO_2. If you had enough plants in a room to use up all of all of CO_2 and convert it to oxygen, the oxygen levels would increase from 20.95% to 21%. This increase is difficult to detect and would have no effect on humans.

5. CONCLUSIONS

In short, plants growing indoor do not produce oxygen sufficiently for humans to use. But, one famous NASA experiment, published in 1989, found that indoor plants can scrub the air of cancer-causing volatile organic compounds like formaldehyde and benzene. (Those NASA researchers were looking for ways to effectively detoxify the air of space station environments.) Based on this research, some scientists say house plants are effective natural air purifiers. And the bigger and leafier the plant, the better. “The amount of leaf surface area influences the rate of air purification,” says Bill wolverton, a former NASA research scientist who conducted that 1989 plant study. However, precisely measuring how much of leaf surface area is needed is difficult through an experiment. This study confirmed the effects of plants in reducing CO_2 level, but increasing oxygen level was again proven to be impossible even with supplemental lighting.

There was no significant variance observed from the experiment in the correlation between the number of plant species and the total quantity of planting installed in a personal indoor garden. Also, the result of this study is based on one-time experience of vertical gardens, thus further study is needed to examine the effects of vertical gardens after experiencing the gardens on a consistent basis and for multiple times. Plus, more comprehensive study covering various sizes of an indoor garden would be needed along with a review on an appropriate number of subjects of an experiment.

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