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Original Research

The Effect of Some Indoor Ornamental Plants on CO_2 Levels During the Day

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Abstract

The aim of the present study is to determine the effect of yucca (*Yucca elephantipes* Regel), dieffenbachia (*Dieffenbachia amoena* Gentil), and spathiphyllum (*Spathiphyllum* floribundum Schott) as common types of indoor plants on CO_2 levels in the environment. The study was conducted in a closed environment where air inlet/outlet was absent. As a result, the plants were found to affect the level of CO_2 in the environment to different extents; and while Dieffenbachia began to respire at around 13:00 hrs, yucca and spathiphyllum continued to photosynthesize until 19:00. While dieffenbachia and spathiphyllum could not lower the CO_2 level in the environment to below 500 ppm, yucca could decrease it to 475 ppm in a day. The results of the study demonstrated that CO_2 levels in photosynthesis during the day were 8.3, 5.8, and 1.4 times more in yucca, spathiphyllum, and dieffenbachia, respectively, in comparison with CO_2 levels released through respiration.

Keywords: indoor plants, CO_2, leaf area, ornamental plants, photosynthesis, respiration

Introduction

Due to increased construction and changes in recent living conditions, people spend at least 80% of their lives indoors [1-3]. This situation has led to many studies on indoor air pollution and increased of CO_2 levels in line with the metabolic activities of living things. As a result of the increased carbon dioxide level in the environment, fatigue, perception difficulty, and sleepiness are experienced. Carbon dioxide also causes various problems that lead to poor performance – the reason for which cannot be determined. When the CO_2 level in an environment increases up to 1,000 ppm, headache, vertigo, fatigue, concentration problems, and smell disorders are experienced, while itchy nose and throat, nasal discharge, cough, and eye discharge appear when it exceeds 1,500 ppm [4-6].

According to the U.S. Environmental Protection Agency (EPA), the maximum carbon dioxide level indoors should be 1,000 ppm – even in crowded environments such as schools and conference halls [5]. However, relevant studies determined that the carbon dioxide level indoors was higher than this maximum level in many

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environments and even exceeded 1,900 ppm in student residence halls [7]. It reached 3,700 ppm in exam rooms [5] and 5,400 ppm [8] in classrooms.

Indoor plants are living things and have several functions. For example, they reduce air pollution [9-13], increase work productivity [14], relax people psychologically, and reduce stress and negative feelings [5-6, 15-16]. Another reason why people want to grow plants indoors is that they have an effect on carbon dioxide levels. Plants are known to photosynthesize and thus reduce the level of CO_2 in an environment [5-6]. However, plants are living things and respire when the conditions are not suitable for them to photosynthesize, thus increasing the CO_2 level in an environment. However, the number of studies on how plants affect CO_2 levels depending on the conditions in the environment is limited.

This present study aims to determine how some indoor plants affect the CO_2 level in an environment at different times of the day.

Material and Methods

The present study aims to determine the effect of some indoor ornamental plants on the CO_2 level in a closed environment. Spathiphyllum (*Spathiphyllum* floribundum Schott), yucca (*Yucca elephantipes* Regel), and dieffenbachia (*Dieffenbachia amoena* Gentil) were used in this study. These plants have different ecological needs and physical characteristics (leaf area, type of stem, etc.) and are the most common indoor plants around the world.

The plants were placed in a glass wall (0.7 × 0.7 × 1 m) with a volume of about 0.5 m^3, which was not air-permeable, and the measurements were taken using the Extech Desktop Indoor Air Quality CO_2 Datalogger. The glass wall was placed in the south of the building so that it received plenty of daylight. It received direct sunlight between 07:00 and 11:00 and was illuminated until around 17:00. In the area where the study was conducted, the sun rose at around 05:05 and went down at around 20:30.

After the plants were placed in the glass wall, a CO_2 measuring device was set to measure the level of CO_2 every five minutes. The plants were placed in the glass wall between 13:00 and 14:00, and the CO_2 level within the glass was increased. Data were obtained from this time on; however, only those measurements taken after 04:00 were considered.

The plants were kept inside the glass wall for at least five days. This study was conducted June to July, when daylight is longer. The results obtained were evaluated using graphs.

Results and Discussion

To better evaluate the obtained data we used hourly values, and graphs showing the effect of dieffenbachia on the CO_2 level during the day are presented in Fig. 1.

Fig. 1 shows that the 1,868 ppm CO_2 level at 05:02 quickly decreased during the day, and this decline continued until 13:02. It went down from 1,868 to 766 ppm at 13:02. After this point, the CO_2 level kept increasing until 05:02 the next day and reached 1,506 ppm. The 1,506 ppm CO_2 level measured at 05:02 the second day declined to 670 ppm at 12:02 the same day. This situation indicates that dieffenbachia decreased the CO_2 level very quickly. The 1,868 ppm CO_2 level at 05:02 on the first day declined to 766 ppm at 13:02. In other words, it decreased by 1,102 ppm within eight hours. However, the increase in CO_2 level resulting from respiration during hours with insufficient daylight was also fairly high. The 766 ppm CO_2 level measured at 13:02 reached 1,506 ppm at 05:02 the next day. In other words, it increased by 740 ppm when the daylight was insufficient for photosynthesis.

When the results were evaluated, dieffenbachia was found to decrease CO_2 from 1,868 to 1,506 ppm within 24 hours. So the CO_2 level declined by only 362 ppm in total during the day. Out of the 1,102 ppm carbon dioxide used during the day, 766 ppm (nearly 69% of it) was used when daylight was insufficient for photosynthesis.

A graph showing the effect of spathiphyllum on CO_2 level during the day is presented in Fig. 2, which shows that spathiphyllum began to decrease the CO_2 level in the environment at 04:45, which continued until 18:45. During this time, the CO_2 level declined from 2,748 to 1,564 ppm; in other words, it declined by 1,184 ppm. After that, the CO_2 level initially took a horizontal course and then increased, which continued until 05:45 the next

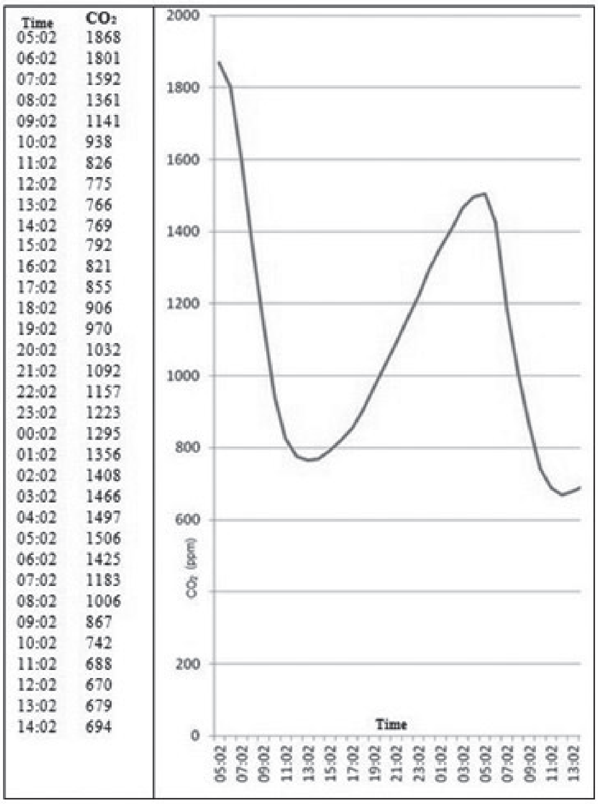

Fig. 1. Effect of dieffenbachia on CO_2 levels during the day.

Time	CO_2
04:45	2748
05:45	2746
06:45	2705
07:45	2590
08:45	2488
09:45	2310
10:45	2229
11:45	2138
12:45	2023
13:45	1912
14:45	1780
15:45	1699
16:45	1626
17:45	1580
18:45	1564
19:45	1565
20:45	1586
21:45	1615
22:45	1639
23:45	1663
00:45	1684
01:45	1705
02:45	1723
03:45	1743
04:45	1760
05:45	1769
06:45	1737
07:45	1624
08:45	1460
09:45	1314
10:45	1124
11:45	962
12:45	863
13:45	806

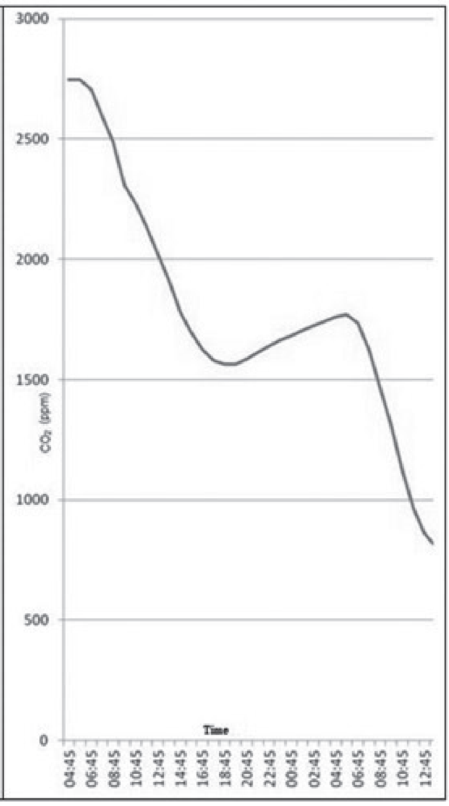

Fig. 2. Effect of spathiphyllum on CO_2 levels during the day.

Time	CO_2
04:10	3322
05:10	3310
06:10	3249
07:10	3052
08:10	2687
09:10	2380
10:10	2028
11:10	1768
12:10	1518
13:10	1273
14:10	1087
15:10	960
16:10	855
17:10	786
18:10	740
19:10	732
20:10	749
21:10	780
22:10	810
23:10	861
00:10	891
01:10	929
02:10	959
03:10	989
04:10	1016
05:10	1042
06:10	1036
07:10	984
08:10	822
09:10	679
10:10	558
11:10	488
12:10	471
13:10	455

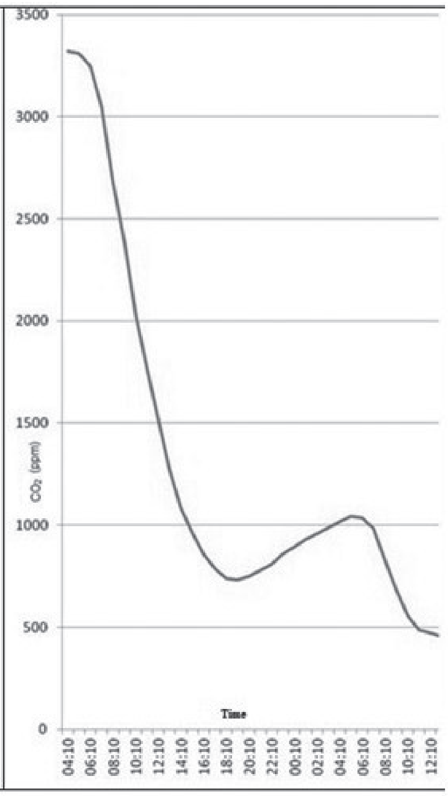

Fig. 3. Effect of yucca on CO_2 levels during the day.

day, reaching 1,769 ppm. A graph showing the effect of yucca on CO_2 level during the day is presented in Fig. 3.

The starting CO_2 level for Yucca was measured at 3,322 ppm at 04:10, which declined quickly and hit 732 ppm at 19:10. In other words, a decline of approximately 2,590 ppm was observed. The CO_2 level began to increase after 19:10 and continued until 06:10 the next day, reaching 1,036 ppm. Thus, the total increase was 304 ppm. Considering the 24-hour performance of the plant starting at 05:10, a decline from 3,310 to 732 ppm was seen and an increase from 732 to 1,042 ppm was observed within a day. The CO_2 level that declined by 2,578 ppm during the day because of photosynthesis increased by 310 ppm with respiration during hours when sunlight was insufficient.

Based on these results, all the plants were observed to photosynthesize between 06:00 and 12:00, when the daylight was sufficient, and thus they decreased the CO_2 level. However, each plant had a different effect on the decline of CO_2. Analysis of the relevant graphs could be misleading because CO_2 level is one of the factors affecting the rate of photosynthesis, and ensuring that all the plants were at the same CO_2 level when the experiment started was impossible. However, the graphs provide important results about certain aspects.

Results from the study show that the plants began to increase CO_2 levels at different hours during the day. Dieffenbachia began to increase the CO_2 level, or respire, at 13:00, while spathiphyllum and yucca did so at 19:00. All the plants were taken to the same place in the experiment, and all the experiments were conducted in a completely cloudless sunny weather. Thus, the duration of illumination and daylight in the environment can be considered the same (a difference of a few minutes was noted as days became shorter or longer). However, the durations of photosynthesis and respiration were fairly different. Under uniform light conditions, dieffenbachia respired while spathiphyllum and yucca photosynthesized.

Another striking point was the ratio of the CO_2 level used in photosynthesis during the day to the CO_2 level released during hours when daylight was insufficient. In the evaluations conducted on one particular day, dieffenbachia was found to cause a 1,102 ppm decrease in CO_2 level during the day but released 766 ppm when daylight was insufficient. Spathiphyllum caused a decrease of 1,184 ppm but released 205 ppm during hours when daylight was insufficient. Yucca caused a decrease of 2,578 ppm through photosynthesis during the day but released 310 ppm during hours when daylight was insufficient.

The ratio of the CO_2 level used in photosynthesis during the day to the CO_2 level released through respiration during hours when daylight was insufficient was 8.3 in yucca, 5.8 in spathiphyllum, and 1.4 in dieffenbachia. These figures demonstrate the importance of choosing plants according to the conditions in the environment.

One of the most important factors affecting the rate of photosynthesis is CO_2 level. In this regard, several studies have focused on agricultural plants [17]. In the present study, the CO_2 level was first kept at 2,000 ppm and not considered a determining factor. However, long-term measurements were performed on the plants to determine their behavior when CO_2 level declined.

As we made a general evaluation of the plant types used in the study, the CO_2 level for dieffenbachia, which was 1,868 ppm at 05:02, declined very quickly on the first day; however, it remained stable between 15:00 and 650 ppm during the last days. This indicates that the CO_2 level in the environment affects the rate of photosynthesis considerably. In spathiphyllum, the CO_2 level was 2,977 ppm at 15:45 on the first day and 1,699 ppm the next day at the same hour. The CO_2 level that continued to decline in a regular course remained between 600 and 1,100 ppm during the last three days. With Yucca, the 2,782 ppm CO_2 level at 10:30 on the first day declined to 502 ppm at 10:30 the next day, within 24 hours, and fell to its lowest level at 457 ppm. Then it remained at between 470 and 1,200 ppm. These levels indicate that yucca can make the CO_2 level much lower than other types of plants can.

Fig. 2 illustrates that the CO_2 level generally fluctuated within a certain range during the day. A striking point was the difference in the lowest CO_2 levels. Although they differed, the highest levels could be proportional to the amount of leaves in plants. However, the lowest CO_2 level indicates that plants do not photosynthesize under a certain level, depending on the type of plant. The graph shows that the lowest CO_2 level was that in yucca, followed by spathiphyllum and dieffenbachia.

The results from the study demonstrate that all the plants decreased the CO_2 level in the environment (depending on daylight conditions during the day) and increased it when light was absent. However, dieffenbachia was found to start increasing the CO_2 level, or photosynthesize, at 13:00, while spathiphyllum and yucca started at 1900. This indicates that dieffenbachia respires while spathiphyllum and yucca photosynthesize under the same light conditions, and the latter two could photosynthesize even in environments that have less daylight. Besides, the ratio of the CO_2 level used through photosynthesis during the day to the CO_2 level released through respiration differed, which was 8.3 in yucca, 5.8 in spathiphyllum, and 1.4 in dieffenbachia.

Similar results were obtained from studies that aimed to determine the effect of plants on the CO_2 level in an environment. Cetin and Sevik [6] indicated that *Ficus elastica* caused a decrease of 2,216 ppm, *Yucca massengena* 2,579 ppm, *Ocimum basilicum* 401 ppm, *Sinningia speciosa* 725 ppm, and *Codiaeum variegatum* 401 ppm. Another study found that *Schefflera arboricola* caused a decrease of 1,252 ppm, *Fuchsia magellanica* 252 ppm, and *Ficus benjamina* 657 ppm [18].

Cetin and Sevik [6] pointed out that *Codiaeum variegatum*, *Ficus elastica*, and *Yucca massengena* decreased the CO_2 level even with little light in the environment, while *Sinningia speciosa* and *Ocimum basilicum* increased the CO_2 level during the same time. Similarly, Sevik et al. [19] stated that *Fuchsia magellanica* started to respire at 15:28, while *Ficus elastica* and *Yucca massengena* continued to photosynthesize until around 17:00. This phenomenon could be associated with the anatomy of the plants [20-21]. Kacar et al. [22] indicated that the amount of light needed for photosynthesis changes according to type of plant. For example the rate of photosynthesis in *Asarum caudatum* reached its highest level when the light condition was 200 µmol $m^{-2}s^{-1}$, while the highest photosynthesis rate in *Atriplex triangularis* was reached with a light condition of 1,700 µmol $m^{-2}s^{-1}$.

The results from the study demonstrate that plants kept in the same environment react to conditions in the environment in different ways. While they cannot decrease the CO_2 level in the environment to below 500 ppm during the day, yucca can decrease it to lower degrees (up to 475 ppm) compared with other plant types. However, this number is above the CO_2 level in the atmosphere [6, 20, 23-24]. Nevertheless, a study found that a CO_2 level of around 391 ppm during the day and 422 ppm at night in the winter months remained at 148 ppm during the day and 229 ppm at night in the summer months [21, 23-25].

That plants affect the CO_2 level in an environment, besides being used for aesthetic purposes – especially in landscaping – is a known fact [25]. Relevant studies indicate that a beech tree with a leaf area of 1,600 m^2 can meet the oxygen needs of 10 people [18, 26]. Tarran et al. [27] stated that the presence of plants in the environment decreases the CO_2 level in offices with air conditioners by 10%, and in environments with natural ventilation by 25%. However, determining the plants to be utilized with respect to the conditions of the environment is necessary for more effective use. Studies on this subject are still very limited.

The present study aimed to find out the effects of certain plants on the CO_2 level in an environment. It is known that green plants photosynthesize with sufficient light and that the CO_2 level in an environment declines as a result of photosynthesis [27]. However, the effect of plants on the quality of air in an environment is not limited to regulation of CO_2 levels. Several studies have demonstrated that plants decrease the sulfur level in indoor air [28] and increase the quality of air by filtering pollutants that are harmful to living things, such as dust, ash, pollen, smoke, particles, and the like [29-30]. Nevertheless, increasing the number of studies on this subject and repeating the existing ones elaborately is necessary so that plants can be used effectively in decreasing indoor CO_2 levels.

Conclusions

The results from our study can provide significant clues on choosing plants according to the conditions of the environment and the amount of time these plants spend in the environment. For example, dieffenbachia starts to respire at a slight decline in the amount of light in the environment, while yucca and spathiphyllum can continue to photosynthesize even under poor light conditions. Considering that these plants are used indoors and that the amount of light is limited indoors for the majority of a day, dieffenbachia should not be chosen as an indoor plant. The results from the study also indicate that CO_2 levels during the day were 8.3, 5.8, and 1.4 times more in yucca, spathiphyllum, and dieffenbachia, respectively, compared with the CO_2 levels released through respiration. Accordingly, the most suitable plant for indoor use to reduce the CO_2 level is yucca. However, as mentioned before, studies on this subject are still very limited, and increasing the number of studies on this topic or elaborately replicating the existing ones is required so that plants can be used effectively to reduce the CO_2 level indoors. In this regard, studies on different plants should continue, and plants that can photosynthesize at a faster rate indoors should be searched. Another point that should be studied is the opportunity to increase the photosynthesis rate of plants by changing indoor conditions. Here, light intensity and type of light should be studied because the effect of plants on the quality of indoor air depends on photosynthesis, and light that comes in is one of the conditions that affect photosynthesis.

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