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REVIEW/RESEARCH ARTICLE/SHORT COMMUNICATION

The Effectiveness of *E.aureum* in Reducing Carbon dioxide, Particular Matter and Sick Building Syndrome Among Office Workers in Private Hospitals

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Abstract

The Background: Indoor contaminant was higher than outdoor about 2 – 5 times because of activities of in the building. The activities that impacted to risk of contaminant included of copying and printing from either printers or photocopiers were a pollutant and potentially cause health problems. The particles less than 2.5 and 10 micrometers could get to lower respiratory tract and increase the incidence of pneumonia which more than two million people died from pneumonia every year and was the second most common cause of death in people with lung cancer.
The main aim of this research was an experiment to improving indoor air quality by used green energy of E.aureum (golden pathos plant) in reducing carbon dioxide, particular matters (PM) and sick building syndrome (SBS) among office workers in network hospitals of Bangkok Dusit Medical Services PLC (BDMS). It was a real-life setting study in multi-center of 4 areas.
Material and Methods: The research tools included the direct reading for collecting data of air quality in building and the questionnaire for gathering data of symptom of sick building syndrome. The duration of experiment was 18 weeks. The study used a quantitative approach with descriptive statistical analysis and general linear model repeated measure (Two-way ANOVA).
Result and Conclusion: This study revealed that E.aureum had an effectiveness in improving air quality. It reduced quantity of particular matter that smaller than 2.5 and 10 microns for a significance level of 0.05 and also decreased sick building syndrome among office workers in every area for a significance level of 0.01 within 18 weeks. In conclusion, the emplacement of E.aureum with 65 ± 5 leaves, average length between both sides of its leaves about 3.6 – 3.9 square meters, average height about 25 centimeters, in a 6-inch diameter pot with aluminum foil coverage, wall-type hanging at a plant per 2 cubic meters, 10 – 20 ml watering and yellow or dried leaves removing every 3 days could significantly decrease sick building syndrome among office workers and significantly improve indoor air quality.

Keywords: E.aureum, Carbon dioxide, Particular Matter, Sick Building Syndrome, Office Workers

Introduction

Recently, most people spent their time in building more than 90 percent (Gunnarsen et al., 2006). Indoor air quality had significantly impacted on health of office workers.(Jacek, Tadeusz, Bozena, Zabiega, & Jerzy 1992) A study of the U.S. Environmental Protection Agency had revealed that the indoor contaminant was higher than outdoor about 2 – 5 times because of activities of people in the building. The activities that impacted to risk of contaminant included of copying and printing from either printers or photocopiers. (Han, Kim, & Hong, 2011) The contaminants were carbon monoxide, carbon dioxide, formaldehyde, ozone and particular matters. There were many complaints from office workers about burning smell from printers and photocopiers during printing. Most of office workers had problems of stuffy nose, nasal congestion, eyes irritation, and dizziness during working. And their problems usually subsided when they escaped from the printing areas. These problems also named as sick building syndrome that was used to describe situations in which building occupant experience health effects that appeared to be linked to time spent in a building and get better after leaving. The data of workers' illness were gathered by group interview on sick building

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syndrome. The questions were adapted from the questionnaire for building occupants exhibited in the assessment of indoor air quality in office buildings guideline for the officers of Bureau of Environmental Health, Department of Health. The respondents from office workers who suffered from twice or more symptoms in any group of symptoms around 4 – 6 times per week or 1 – 3 times per week or suffered from one symptom in any group of symptoms but more than one groups around 7 days a week and such symptom occurred in the past week during working in building and subsided when escaped from it. The groups of symptoms included:

Group of stuffy noses: Sneezing, itchiness, stuffy nose, runny nose

Group of throats and respiratory: Dry cough, feeling dry, throat irritation, sore throat, shortness of breath, dyspnea

Group of eyes irritation: Burning eyes, dry eyes, eyestrain, itching eyes, conjunctivitis, eyes irritation

Group of headaches: Dizziness and tiredness such as headache, dizziness, nausea, exhaustion, drowsiness

The contaminants that usually met in building included of carbon dioxide and particular matter. Carbon dioxide was a pollutant and potentially cause health problems. Carbon dioxide was released from body by breathing and is the waste product of cellular respiration that human breathe out. High carbon dioxide level, generally over 1,000 ppm, could cause health problems.(Xu et al.) There was research revealed that the increase of carbon dioxide concentration in classroom influenced student attention level decrease.(Shaughnessy, Haverinen-Shaughnessy, Nevalainen, & Moschandreas, 2006) The particular matter was typically formed from incomplete combustion.(Kurniawan & Schmidt-Ott, 2006) The particular matter was a term represented all solid and liquid in air. This complex mixture includes SO4, NO3− , NH4+, carbon compounds, mineral, metal and others.(Wei et al., 2017) The particles less than 2.5 and 10 micrometers in diameter pose the risk to health because they could get deep into lower respiratory tract and increase the incidence of respiratory infections.(WHO, 2013) More than two million people died from pneumonia every year and pneumonia was the second most common cause of death in people with lung cancer. (Raquel et al., 2013)

There were many studies associated with indoor air quality improvement. Numerous research studied on various plants and the experiments carried out in laboratory or chamber. Few of studies carried out under field conditions.(Dela, Christensen, Thomsen, & Muller, 2014) The level of air quality improvement was depended on types of plants, soil and container material, light intensity, temperature, and air quality before the experiment. The plants that usually used in the experiment were wall type-plant rather than potted-plant because of space saving. The wall type-plant had leaf area index higher than potted-plant. The higher leaf area index increased the effectiveness of air quality improvement. The principal investigator had summarized the studies related with the particular matter removal capability as Table 1.

Contaminants	*D.deremensis* (Queen of Dracaenas)	*C.comomsum* (Spider plant)	*E.aureum* (Golden pothos)
CO_2			**++**
PM_{10} $PM_{2.5}$	**++**	**++**	**++**

Table 1: The summarization for particulate matter removal capability of each plant

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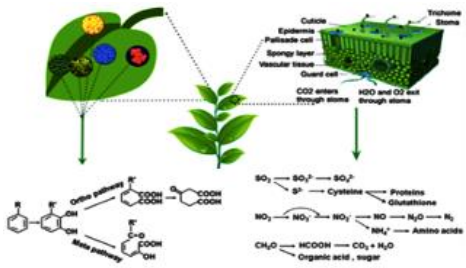
The wall type-plants that were effective and famous used on the architecture theory included of *E.aureum* (Golden pothos) and *C.comomsum* (Spider plant) because they were not affected with building structure. Both could equally decrease PM10 and PM2.5. (Fraser & Michael, 2018) The experiment on an effectiveness of reducing Carbon dioxides emission in building were conducted among 7 plants including golden pothos, spider plant, flamingo flower, fern, bilimbi and arrowhead plant. The average age for all plants was 1 year and had grown in pot of 7-inch diameter and about 25 centimeters height. The result showed that spider plant was not capable to absorb carbon dioxide emission. While there was no significant difference in carbon dioxide concentration reduction of the rest of two plants within 8 hours. The ability of carbon dioxide concentration reduction of bilimbi was strongest. While the rest of plants were able to reduce carbon dioxide concentration at 10.03 - 14.40%.(Mahathir et al., 2017)

The mechanism of particular matter (PM) captured by plants was not explicit. It was expected that the part of plants that could eliminate and reduce PM was Phyllosphere. Nitrogen fixation was carried out by the enzyme nitrogenase, which usually found in microbes. The PM were accumulated on leaf surface and chemical reaction of nitrogen fixation transformed particular matter into mineral and nutrient. The adaxial had more cuticular surface and trichomes than the abaxial so they could detect and covert more PM. Thus, the particular matter removal capability depended on plants, cuticular surface and trichome density (Wei et al., 2017) as Figurer (1).(Wei et al., 2017)



Figurer (1): Mechanism of particular matter removal (Wei et al., 2017)

Thus, growing of ornamental plants that were able to reduce carbon dioxide and particular matters emission for improving indoor air quality such as golden pothos was one of possible method to solve problems. The outcome of the study on "The effectiveness of *E.aureum* in reducing Carbondioxide, Particular matter and Sick building syndrome among hospital workers in Private hospital" Sadangrit K.(2019) revealed that the percentage of sick building syndrome among office workers was 89.4. After emplacement of golden pothos in the office for 4 weeks, the percentage of sick building syndrome among office workers decreased to 53.2. Therefore, the principal investigator had conducted an experiment in indoor air quality improvement with golden pothos emplacement based on documents and other related researches. It was a real-life setting experiment extended from previous one to study on the effectiveness of *E.aureum* in reducing carbon dioxide, particular matters and sick building syndrome among office workers from 4 areas in network hospitals of Bangkok Dusit Medical Services PLC.

Objectives

To investigate on an effectiveness of *E.aureum* in reducing carbon dioxide, particular matter and sick building syndrome among office workers in network hospitals of Bangkok Dusit Medical Services PLC.

To investigate and compare the carbon dioxide and particular matters concentration in air before and after golden pothos indoor emplacement.

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To compare the number of occurrences related with sick building syndrome among office workers before and after golden pothos indoor emplacement.

2. Materials and Methods

This research was an experimental study to investigate on the effectiveness of *E.aureum* in reducing carbon dioxide, particular matters and sick building syndrome among office workers in network hospitals of Bangkok Dusit Medical Services PLC. The sample of this study was selected from office workers that had working in the room equipped with air conditioners within 4 hospitals of Bangkok Dusit Medical Services PLC., including Bangkok Hospital Headquarters, Bangkok Hospital Rayong, Bangkok Hospital Chiang Mai, and Bangkok Hospital Khon-Kaen. The sample size was calculated by reference of the study of "The Effectiveness of *E.aureum* in Reducing Carbon dioxide concentration, Particular matter and Sick building syndrome among Office Workers in a Hospital in Rayong Province". The percentage of office workers suffered from sick building syndrome was 89.4. After golden pathos plant emplacement for 4 weeks, the percentage had decreased to 53.2. The principal investigator committed the type I error not exceeding 5% (α=0.05) and the power of a test was 80% (β = 0.20). The sample size was computed from the ratio of two dependent proportions that equaled to 84 office workers. To reduce the possibility of incomplete observation, the principal investigator added 10% more officer workers. Thus, the total volunteer of this study was 93.

Inclusion Criteria

- The officer workers that had work experience more than 3 months and had been registered as staff by Human Resource Department throughout the period of data collection.
- Age above 20 years old.
- Voluntary for disclosing information or being interviewed throughout the period of data collection.
- The office workers that had working in the room equipped with air conditioner.

Exclusion Criteria

- Office workers with underlying of respiratory diseases. Office workers that were undergoing a treatment of respiratory diseases, migraine, allergy and other diseases that may affect to the study. Office workers that experienced diseases during the study and unable to disclose further information or fulfill the obligated questionnaires.
- Office workers who resigned either before or at the period of data collection.
- Office workers who had been suspended from their works at the period of data collection.
- Pregnancy or breastfeeding mothers.

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Data Collection Method

Observe the location including floor plan, usable area, space, air conditioner system and environment before conducting an experiment.

The method of collecting data of sick building syndrome from office workers before golden pathos plant emplacement was a group interview. The questions were adapted from the questionnaire for building occupants exhibited in the assessment of indoor air quality in office buildings guideline for the officers of Bureau of Environmental Health, Department of Health. They were also reviewed by reliable experts and tested for content validity. Index of item objective congruence (IOC) was examined.

The interviews were conducted on the first time of air quality measurement and before golden pathos plant emplacement and every two weeks after emplacement for 3 times or on the 3rd and 5th time of air quality measurement. The interview was also conducted on the 18th week of the experiment as well as the 8th time of air quality measurement. The duration of experiment was 18 weeks. The questions were adapted from the questionnaire for building occupants exhibited in the assessment of indoor air quality in office buildings guideline for the officers of Bureau of Environmental Health, Department of Health. They were also reviewed by reliable experts and tested for content validity. Index of item objective congruence (IOC) was examined.

The method for measuring carbon dioxide concentration and particular matter was referred from the assessment of indoor air quality in office buildings guideline for the officers of Bureau of Environmental Health, Department of Health, 2012. The assessments that were carried out in compliance with the guideline of Bureau of Environmental Health, Department of Health were entitled to represent as the air quality of all experimental areas. Before golden pathos plant emplacement, the carbon dioxide concentration and particular matters were measured for 8 hours a day (7:00 - 16:00), once a week at the mid of week (Thursday) for 2 consecutive weeks. After emplacement, the carbon dioxide concentration and particular matters were measured again at the mid of week (Thursday) for 8 hours a day (7:00 - 16:00), once a week for 4 consecutive weeks (1 month) after that the air assessment would carried out every 4 weeks for 3 consecutive times. The duration of the experiment was 18 weeks. All data of carbon dioxide concentration and particular matters were calculated for its mean, frequency, maximum, minimum and standard deviation both before and after golden pathos plant emplacement.

Carbon dioxide (CO2) meter, Model AitThinx IAQ Monitor was a direct monitor through infrared light.

Particle counter (PM_{10}, $PM_{2.5}$), Dust Boy 2, was a direct monitor through dispersion of light. Its quality was equivalent to USEPA (United States Environmental Protection Agency). It was invented by Faculty of Engineering, Chiang Mai University.

The principal investigator used the mature golden pathos plant with 8 months to one year age. (Abbass, Sailor, & Gall, 2017; Fraser & Michael, 2018) The average number of leaves per plant was 65 **c**5, average length between both side of its leaves about 3.6 – 3.9 square meters, average height about 25 centimeters, in a 6-inch diameter pot with aluminum foil coverage to get rid of confounding variables. Each golden pathos plant was kept at 25 – 26 degrees Celsius for 2 weeks before the experiment. This study applied 1 plant per 2 cubic meters.(Abbass et al., 2017; Fraser & Michael, 2018) Before the experiment, the principal investigator grew each golden pathos plants in the same given area. They were graded their quality as the criteria mentioned above before using in the experiment. The principal investigator had developed a manual and discussed with 4 network hospitals to ensure that each golden pathos plant was grown under the same conditions including watering, removing yellow leaves off every 3 days. During the experiment, each golden pathos plants grew well without replacement. No water leak from the aluminum foil coverage. The plants

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were located as a designed plan and not disrupted the office worker's activities. The principal investigator had placed golden pathos plants for 16 weeks and tested the effectiveness of *E.aureum* in reducing particular matters, carbon dioxide emission and sick building syndrome among office workers in 4 areas.

This study had been approved by the Institution Review Board (IRB) of Bangkok Hospital Headquarters, Project code: BHQ IRB-2020-02-07, dated 22nd May 2020.

3. Results of the Study

The objective of study was to learn of the effectiveness of E.aureum in reducing carbon dioxide, particular matters, and sick building syndrome among office workers in private hospitals by using sick building syndrome questionnaire. The sample size was 58 respondents. However, owing to epidemic and economic recession, many officer workers that usually involved with printers and photocopiers were rotated to other units within the hospital (Job Rotation). Thus, the data were collected lesser than expected. The data of particular matter and carbon dioxide concentration were collected between 18th November 2020 to 18th March 2021. The principal investigator had analyzed, presented, and interpreted data as follows

Part 1: Demographic information about personal factors of respondents and 4 areas of experimental sites.

Part 2: Results of indoor carbon dioxide concentration and particular matters of each experimental site in each particular time.

Part 3: Results of assumptions of the comparison between indoor carbon dioxide concentration and particular matters before and after *E.aureum* emplacement in 4 experimental sites.

Part 4: Results of questionnaire about sick building syndrome of office workers before and after *E.aureum* emplacement in each experimental site.

Part 5: Results of assumptions of the comparison between sick building syndrome before and after *E.aureum* emplacement.

Part 1: Demographic information about personal factors of respondents and 4 locations of experimental sites.

From the questionnaire of 58 office workers, the respondents include of 50 females (86.21%) and 8 males (13.79%). The age range that had highest respondents was 20 – 29 years (66%). The range of work experience that had highest respondents was 1 – 3 years. The average working hours per day was 7.9 hours. Total officer workers without underlying disease were 57 people (98.27%). Total officer workers with underlying disease that did not involve with the experiment was 1 person (1.72%) as shown in Table 2. For Table 3, it showed the differences of each experiment location.

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Table 2: Percentage of office staff that was divided by respondents' demographic

Demographic Information (n=58)	**Quantity (People)**	**Percentage**
Male	8	13.79
Female	50	86.21
Age (Years) **Mean ± SD = 39.12 ± 1.09, Min = 24, Max = 47**		
Underlying		
Underlying and on treatment	1	1.73
No Underlying	57	98.27
Working Experience (Months) **Mean ± SD = 36.2 ± 41.5, Min = 3, Max = 180**		
Working hours that involved with printing per day (Hours per day) **Mean ± SD = 7.9 ± 2.7, Min = 1, Max = 12**		
Number of office workers		
Bangkok	31	53.45
Rayong	15	25.86
Khon-Kaen	6	10.34
Chiang Mai	6	10.34
Total	58	100.00

Part 2: Results of indoor carbon dioxide concentration and particular matters of each experimental site in each particular time.

The measurement of indoor air quality showed that average $PM_{2.5}$ before the experiment in Bangkok and Khon-Khaen exceeded standard that were 46.48 and 26.37 mcg/m^3, respectively. And all experimental locations in 18th week had average $PM_{2.5}$ microns exceeded standard.

The result from the measurement of average PM_{10} showed that before the experiment, Chiang Mai had indoor air quality 51.07 mcg/m^3, exceeded standard. And the experimental locations at Rayong and Khon-Kaen in 18th week had average PM_{10} at 51.77 and 51.91 mcg/m^3.

Average indoor carbon dioxide concentration in all locations during the experiment did not exceed standard except at Rayong in 3rd and 4th week showed 1,490.95 ppm and 1,433.95 ppm

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Part 3: Results of the comparison between indoor carbon dioxide concentration and particular matters before and after *E.aureum* emplacement in 4 experimental sites.

The comparison of the particular matters before and after E.aureum emplacement in 4 experimental sites by two-factors ANOVA (2-Way ANOVA) and used the value of air quality before E.aureum emplacement as reference value showed that $PM_{2.5}$ and PM_{10} at 8th time (after 7th time) before E.aureum emplacement and the value of air quality at 2nd, 3rd, and 6th time (after 1st, 2nd, and 5th) had a significance level of 0.05 (PM2.5: p = 0.006, 0.012, 0.022 and 0.039, respectively) (PM10: p= 0.008, 0.012, 0.021 and 0.031, respectively). However, the comparison betweenc$PM_{2.5}$ and PM_{10} before and after *E.aureum* emplacement at 1st time (before) to 7th time (after 6) showed that there was no significant different as Table (3). The results of average CO2 concentration in 4 experimental sites overall the period of the experiment was not different.

Table (3): The comparison of particular matter in 4 experimental sites before and after E.aureum emplacement (* p-value <0.05)

Measure		**Indoor Air Quality**		
		p-value		**95%CI**
$PM_{2.5}$				
After 7	Before	0.008	<0.05*	(3.22 - 45.21)
	After 1	0.012	<0.05*	(3.27 - 58.25)
	After 2	0.021	<0.05*	(1.55 - 56.53)
	After 5	0.031	<0.05*	(0.24 - 33.91)
PM_{10}				
After 7	Before	0.008	<0.05*	(4.02 - 44.40)
	After 1	0.012	<0.05*	(4.32 - 57.19)
	After 2	0.021	<0.05*	(2.61 - 55.48)
	After 5	0.031	<0.05*	(0.89 - 33.27)

Part 4: Results of sick building syndrome of office workers before and after *E.aureum* emplacement in each experimental sites.

The results of sick building syndrome showed that before emplacement there were 51 office workers (87.93%) suffered with sick building syndrome. After *E.aureum* emplacement in 3rd, 5th, 10th and 18th week, the number of office workers suffered with sick building syndrome decreased to 48, 45, 45 and 40, respectively. The number of office workers in each experimental site was shown in Table (4).

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Table (4): The number of office workers with sick building syndrome before and after *E.aureum* emplacement in each experimental site.

Timeline (Week)	**Before (0)**	**After 1 (3)**	**After 2 (5)**	**After 3 (10)**	**After 4 (18)**
Bangkok (n=31)	29 (93.54%)	29 (93.54%)	28 (90.32%)	28 (90.32%)	24 (77.41%)
Rayong (n=15)	11 (73.33%)	9 (60.00)	9 (60.00)	9 (60.00)	9 (60.00)
Khon Kaen (n=6)	5 (83.33)	4 (66.67)	3 (50.00)	2 (33.33)	1 (16.67)
Chiang Mai (n=6)	6 (100.00)	6 (100.00)	5 (83.33)	6 (100.00)	6 (100.00)
TOTAL (n=58)	51 (87.93)	48 (82.27)	45 (77.58)	45 (77.58)	40 (68.96)

Part 5: Results of comparison between sick building syndrome before and after *E.aureum* emplacement.

The results of percentage of office workers with sick building syndrome in 4 experimental sites showed that the office workers with sick building syndrome before and after *E.aureum* emplacement in the 2nd, 3rd and 4th survey had a significance level of 0.05 (p = 0.00, 0.01, 0.00, respectively). However, the results of office workers with sick building syndrome before and after *E.aureum* emplacement in the 1st survey were not different as Table (5).

Table (5): Results of assumptions of the comparison between sick building syndrome before and after *E.aureum* emplacement (* p-value < 0.05)

Measure	Sick Building Syndrome					
	Total(N=225)	No(N=56)	Yes(N=169)	Odds Ratio	95%CI	p-value
Before	45.0 (20.0%)	5.00 (8.9%)	40.0 (23.7%)	reference	-	-
After1	45.0 (20.0%)	8.00 (14.3%)	37.0 (21.9%)	0.40	(0.08-1.91)	0.25
After2	45.0 (20.0%)	14.0 (25.0%)	31.0 (18.3%)	0.10	(0.02-0.49)	0.00*
After3	45.0 (20.0%)	13.0 (23.2%)	32.0 (18.9%)	0.12	(0.03-0.59)	0.00*
After4	45.0 (20.0%)	16.0 (28.6%)	29.0 (17.2%)	0.07	(0.01-0.34)	0.00*

4. Conclusion and Discussion

The measurement of indoor air quality showed that average $PM_{2.5}$ before the experiment all had average $PM_{2.5}$ exceeded standard associated with the study (Han et al., 2011; Janis, 2011) that indoor air quality contaminated by copying and printing from either printers or photocopiers.

Average indoor carbon dioxide concentration in all locations during the experiment did not exceed standard except at Rayong in 3rd and 4th week showed 1,490.95 ppm and 1,433.95 ppm because human was also one of sources of carbon dioxide emission.(Xu et al.)

The study showed that E.aureum (golden pathos plant) was effective for air quality improvement. It enabled to reduce $PM_{2.5}$ and PM_{10} with a significance level of 0.05 in 18 weeks that associate with Torpy & Zavattaro (2018) that E.aureum could equally decrease PM10 and PM2.5. (Fraser & Michael, 2018) In addition, the number of office workers with sick building syndrome in 4 experimental sites reduced from 87.93 percent to 68.96 percent with a significance level of 0.01 associated with the study form S. Kawalee (2019) that golden pothos was one of possible method to solve indoor air quality improvement. Although the timing of survey and data analysis of sick building syndrome and indoor air quality measurement was not the same, it did not impact to the study because the effect of sick building syndrome usually took longer than 2 weeks and subsided after existing from the building or office so the number of office workers suffered with sick building syndrome would be slightly increased or decreased by air quality variation. Moreover, the innate human instinct usually bonded with nature or trees, namely “Biophilia”. It was an extraordinary relationship. Being around trees either at home, office or classroom was good for mental health and mood.(Golden, 2015)

In conclusion, this research suggested that the company with indoor air quality problems could combine the method of hanging on wall-type rack with 1 plant per 2 cubic meters and other methods for indoor air quality improvement. the emplacement of mature golden pathos plant with average leaves per plant was 65 **±**5, average length between both side of its leaves about 3.6 – 3.9 square meters,(Wei et al., 2017) and (Han et al., 2011) average height about 25 centimeters, in a 6-inch diameter pot with aluminum foil coverage, hanging on wall-type rack with 1 plant per 2 cubic meters, watering 10 – 20 ml and removing dried or yellow leaves every 3 days, was able to reduce sick building syndrome in office worker and to improve indoor air quality significantly.

This study had been carried out for 18 weeks while the previous study had been carried out in a single population group and a single experimental site for 6 weeks. The different factors caused some inconsistency. Growing plants indoor was different from outdoor. When the duration of experiment was longer, an effectiveness of indoor air quality improvement had also been decreased by the change of golden pathos plant. Although the golden pathos plant was grown and monitored under the same guideline, it was impossible to control all factors. Thus, if the golden pathos plant would to be used to reduced sick building syndrome for long-term, more studies should be conducted for finding the appropriate life span of golden pathos plant for air quality improvement and the appropriate time of new golden pathos plant replacement for the best effectiveness.

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