DOI: 10.1051/matecconf/201710305004

Effectiveness of Indoor Plant to Reduce CO_2 in Indoor Environment

Mohd Mahathir Suhaimi [1,*], *A.M* Leman[1], Azizi Afandi[2], *Azian Hariri*[2], *Ahmad Fu'ad* Idris[2], *S.N. Mohd* Dzulkifli [3], *and Paran* Gani[3]

[1] Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[2] Faculty of Mechanical and Manufacturing Engineering, UTHM, 86400, Parit Raja, Batu Pahat,Johor Malaysia
[3] Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

Abstract. Modern country strongly emphasizes on indoor air quality (IAQ) because it can effect on human health and productivity. Numerous efforts were performed to make sure that sustainability of IAQ is guaranteed. In the last 4^{th} decade, researchers discover that indoor plants have abilities to reduce indoor air pollution. Generally, plants, carbon dioxide (CO_2), light, and temperature involve in the photosynthesis process. This paper intends to study the effectiveness of seven indoor plants (Anthurium, Dumb Cane, Golden Pothos, Kadaka Fern, Prayer Plant, Spider Plant, and Syngonium) to reduce CO_2 with different light level. This study was conducted in one cubic meter of chamber, and each plant was put into the chamber individually with CO_2 concentration in the chamber is set at 1000±50ppm, and light intensities is set at 300 and 700 lux, while temperature were fixed at 25 ± 1^0C. Based on the results, only the Spider Plant was not able to absorb CO_2 during the test at 300 lux of light intensity. Meanwhile, Prayer Plant performed well when tested at 300 or 700 lux of light intensity compare to other investigates plants. This study can conclude that light intensity play an important role for the plant to absorb CO_2 effectively. All the indoor plants absorbed more CO_2, when the light intensity is increased.

1 Introduction

IAQ issues are common in Malaysia. However there is lack of study, data and local regulation contributing toward health problem especially at Malaysian non-industrial sector [1]. IAQ must be preserved wisely because around 90% of the time people spent are at the indoor environment [2, 3]. Air quality significantly effect on human health and attributed

* Corresponding author: mohd_mahathir@rocketmail.com

the quality of life [4]. Thus, IAQ is essential to living environment [5].

There are many sources of pollutants like total volatile organic compounds (TVOC), even carcinogen (e.g. arsenic, benzene, formaldehyde, and vinyl chloride) that may have in the building which cause deterioration of IAQ [6]. In fact, CO_2 also contribute to indoor air pollution [7]. Generally, CO_2 come from human breathing during respiration process [8]. CO_2 is a IAQ problem when the concentration is increased above threshold limit [9]. At meantime, CO_2 limits that have been set in the building is below than 1000 ppm [10]. Effects of CO_2 on human are include respiratory and heart problems [7]

CO_2 gas is needed by plants to grow, survive, and propagate [11]. In other words, the more CO_2, the more the plant growth become effective [12]. Plants need CO_2 during photosynthesis process, where at the same time also react over the light and water, then produce the glucose (food for plants itself) and release the oxygen [13]. Without plants, humans simply could not exist, because sources of oxygen which is supplied by plants [14].

Human must take along plants to support their life in term of health especially at indoor spaces [15]. Extensive studies had been done on abilities of indoor plant to enhance IAQ for human benefit [16 – 21]. It is one of alternative method to sustain IAQ using non-mechanical or advance technology, and at the same time reduce cost.

Anyhow, plants originally come from outside the building, and of course the environment is different compare to the indoor in term of lighting and temperature. Light intensity and temperature is two factors that can effect plant growth [22 – 25]. Without the proper level of light and temperature that imposed on plant, growing proses will stunted [26, 16]. Nevertheless, certain plants are able to assimilated with different environment to keep on survive [27, 28]. Thus, there is need to conduct study to understand the effect of light intensity toward the effectiveness to reduce CO_2 by indoor plants.

2 Materials and Methods

Plants selected in this study is based on recommendation by former researchers [29, 30]. However, only seven plants were selected based on the availability of the plants at the local area of the study. The age for all indoor plants is one year, and has grown in pot of 17cm diameter and 25cm height with pot mix ration of 2:2:1 (garden soil, compost, and perlite). Indoor acclimated process has been carried out to all investigated plants by putting in indoor environment (25 ± 1^0C) for at least two weeks as suggested by Romanowska and Cavallero [31, 32]. Before the test in chamber is carried out, all indoor plants are watered every day and fertilized once a week.

The level of light intensity during acclimated process is 300 lux (minimum light intensity that specified by Industrial Code of Practice [10]. All plants were not be watered the day before the experimental conducted to avoid disruption value of relative humidity along experimental process [33]. Fig. 1 show all plants selected in this study. Main guideline methods for this study are based on report published by Horticulture Australia in 2011. Nevertheless, this study also refer others former researchers [34 – 38] as a guidance, to ensure accuracy results of the study.

Before the experiment is carried out, all plant selected were assimilated with indoor environment for two months. Assimilation process is important to familiarize the plant life in the building with different levels of temperature and light, as is done by other researchers [39]. During the experiment, chamber was seal with adhesive foam-plastic insulation tape to ensure no leaking. In this chamber consist of small fan (5V) for air circulation, and white fluorescent bulb for the plant live. The two white fluorescent bulbs placed inside the chamber, about 18 cm from the center of the plant. Meanwhile, value of light intensity is based on recommendation by Burchett [40]. Apart from that, a portable IRGA TSI IAQ meter also used to monitor CO_2 concentration in chamber, and was set to record CO_2 reading at 5 minute intervals.

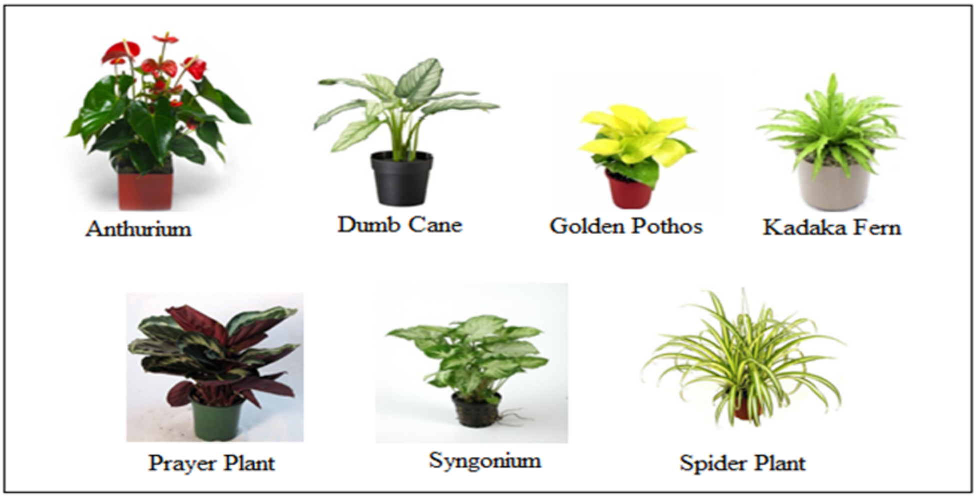

Fig.1. Plants selected that involve in this study

All indoor plants will be tested individually in small scale of chamber (one cubic meter). The concentration of light was taken from minimum and maximum rate (300 & 700 lux) of Malaysian Standard [41]. The temperature during the study is follow to Industry Code of Practice and Prime Minister Office [10, 42], where the reading is 25 ± 1^0C. Conversion process of inorganic carbon to organic compounds by plants was made under CO_2 concentration of 1000±10 ppm, because it is limit concentration permitted by ASHRAE [43]. Repeated experiment (three times at different plant) has been performed on every plants species, and time duration for every experiments take about eight hours.

3 Result and Discussion

Fig. 2 to Fig. 8 shows the results of CO_2 reduction by each of the investigated plants. Each of graph contain of two findings based on different light intensity (300 lux and 700 lux) that are imposed on every type of plant. CO_2 reading in the chamber is fluctuated, because apart of plants absorb CO_2 during photosynthesis, it also release CO_2 during respiration [26]. To facilitate the comparison between CO_2 reading by all plants at the chamber, correlation and fitting line by regression is used. The correlation analysis found that all data have strong relation to declare that CO_2 concentration is proportional with time, where the coefficient value is more than 0.5. Meanwhile, regression of fitting line analysis for all data have a statistically significant (all p-values is less than 0.05) [44].

Table 1 shows the total results of this study. According to the experiment that was conducted during 300 lux of light intensity, only Spider Plant is not capable to reduce CO_2 concentrations. While, other plants results that using the same light level (300 lux) shows that Prayer Plant is the most effective plant to reduce CO_2 followed by Symgonium , Kadaka Fern, Golden Pothos, Dumb Cane, and Anthurium with percent of CO_2 reductions is 7.0%, 6.72%, 6.5%, 6.1%, 5.5% and 2.2%. Respectively CO_2 that are reduced from 1000±10 ppm is 71.67 ppm (Prayer Plant), 66.67 ppm (Syngonium), 64.60 ppm (Kadaka Fern), 60.67 ppm (Golden Pothos), 55.4 ppm (Dumb Cane), and 23.67 ppm (Anthurium).

During all plants were tested with 700 lux light intensity shows that all plants are capable to reduce CO_2 concentration, however Spider Plant only reduce the CO_2 concentration with little amount of 0.1% (1.02 ppm) as shown in Fig. 7. At this light intensity, once again the Prayer Plant is the most effective plant to reduce CO_2 concentration followed by Kadaka Fern, Dumb Cane, Syngonium, Golden Pothos, Anthurium and Spider Plant with total reduction at 14.40% (154.63 ppm), 12.48% (123.33 ppm), 11.1% (111.33 ppm), 10.08% (104.00 ppm), 10.03% (101.33 ppm), 9.72% (100.67 ppm) and 0.1% (0.35 ppm) respectively.

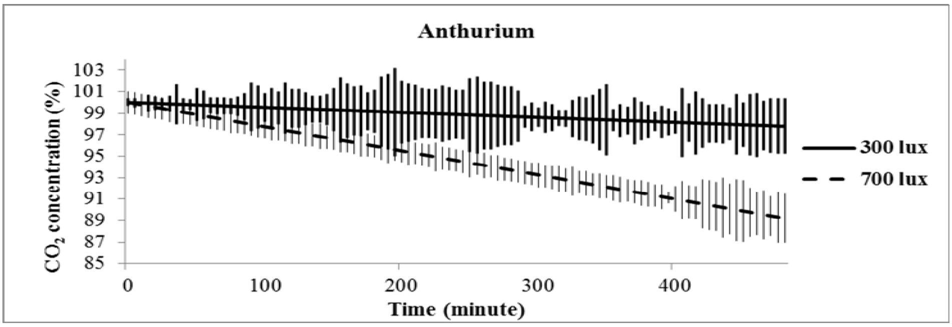

Fig. 2. Graph of CO_2 reduction by Anthurium using 300 lux and 700 lux light intensity

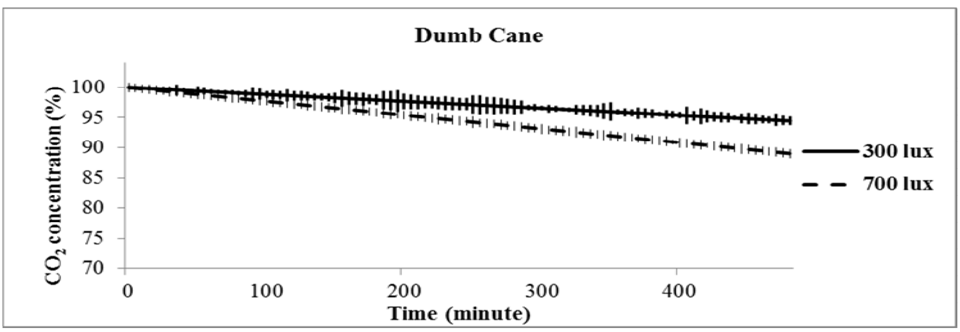

Fig. 3. Graph of CO_2 reduction by Dumb Cane using 300 lux and 700 lux light intensity

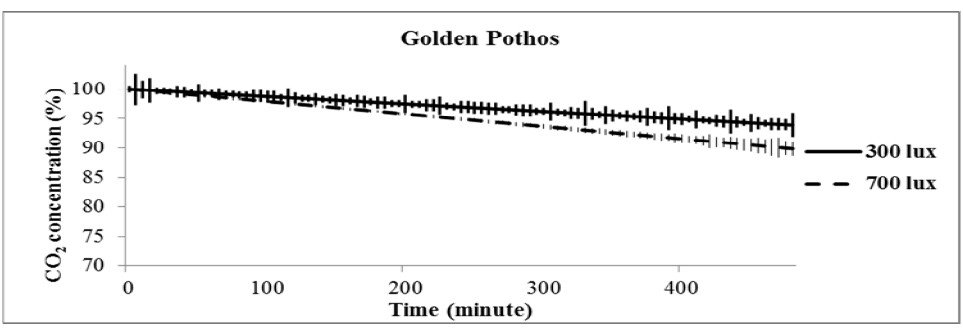

Fig. 4. Graph of CO_2 reduction by Golden Pothos using 300 lux and 700 lux light intensity

According to the all graphs (Fig. 2 to Fig. 8), CO_2 reduction is increased with the increased of the intensity of light. The investigated indoor plants absorb more CO_2 when the light intensity is increased. The results of this study is same agreement with others former researchers like David R. Holding, Torpy, and Wolverton [16, 26, 29]. Even Spider Plant did not show its capability to reduce CO_2 when exposed to 300 lux of light intensity, but CO_2 absorption still occurred when the light intensity increased to 700 lux; as shown in Table 1.

 DOI: 10.1051/matecconf/201710305004

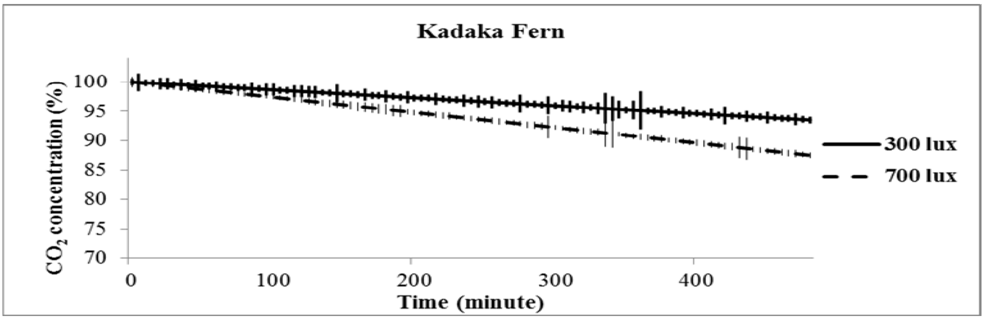

Fig. 5. Graph of CO_2 reduction by Kadaka Fern using 300 lux and 700 lux light intensity

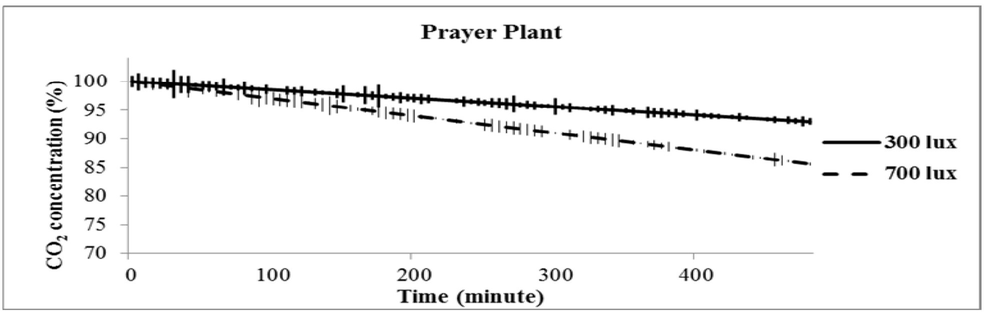

Fig. 6. Graph of CO_2 reduction by Prayer Plant using 300 lux and 700 lux light intensity

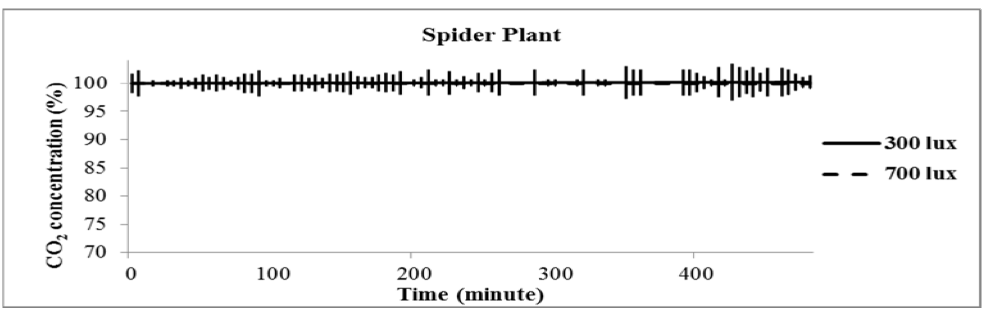

Fig. 7. Graph of CO_2 reduction by Spider Plant using 300 lux and 700 lux light intensity

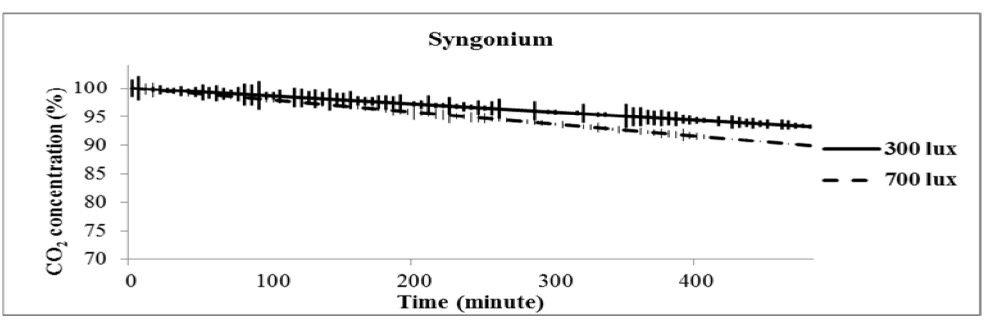

Fig. 8. Graph of CO_2 reduction by Syngonium using 300 lux and 700 lux light intensity

The most interesting in this study is the rate of CO_2 absorption by Anthurium, because the difference percentage of CO_2 absorption when the light level is changed from 300 lux to 700 lux is the highest value compare to others (7.52%). Even though, Anthurium just gave a moderate performance, but it may act as a great agent for CO_2 reduction when the right light imposed on this plant. Meanwhile, others plants like Dumb Cane, Golden Pothos, Kadaka Fern, Prayer Plant, and Syngonium also reduce more CO_2 when lighting level increased as show in Table 1.

Table 1. Rate of CO2 reduction by plants based on diffrent lighting

Plants	Light intensity	Percentage of CO_2 reduction (%)	Total CO_2 reduction (ppm)	Mean of standard deviation
Anthurium	300 lux	2.2	18.30	0.45
	700 lux	10.80	101.00	1.26
Dumb Cane	300 lux	5.50	55.4	0.45
	700 lux	11.10	111.33	0.18
Golden Pothos	300 lux	6.10	60.67	1.10
	700 lux	10.03	101.33	0.63
Kadaka Fern	300 lux	6.50	64.6	1.13
	700 lux	12.48	123.3	0.84
Prayer Plant	300 lux	7.00	71.67	0.64
	700 lux	14.40	154.63	0.62
Spider Plant	300 lux	*0.20	*0.67	1.32
	700 lux	0.10	1.02	1.17
Syngonium	300 lux	6.72	64.67	0.98
	700 lux	10.08	104.00	0.73

*Percentage of CO_2 increased

Table 1 also show the standard deviation (SD) and it is a measure to quantify the amount of variation or dispersion of a set of data values [45]. A low SD indicates that the data points tend to be close to the mean of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values [46]. Based on results, when all plants were tested (three plants for every species) using 300 lux, SD for Anthurium is the highest (1.9), while Prayer Plant have a smallest value (0.64). Besides that, SD for all plants that are used 700 lux found that the Anthurium also get the highest value where the value is 1.26, but this value is small if compare with value SD for Anthurium that are tested with 300 lux. In the case of Anthurium, lighting level seems play an important role to make sure that all plants in the same species acting at the same rate to absorb CO_2. Meanwhile, Syngonium get a smallest value (0.45) when 700 lux was imposed on plant during the experiment.

4 Conclusions

The finding of this study indicated that level of light intensity greatly influenced indoor plants to absorb CO_2 during the experiment. This study reveals that only Spider Plant not able to absorb CO_2 during the test using 300 lux of light intensity. Even light intensity was increase to 700 lux, Spider Plant just reduce small amount of CO_2 (0.35 ppm). It can be concluded that Spider Plant not suitable to use at indoor to reduce CO_2. However, Prayer Plant has total reduction of CO_2 being the highest, whether using 300 lux or 700 lux in this study. Nevertheless, standard deviation for Prayer Plant both 300 lux and 700 lux is quite small, that's mean data points for Prayer Plant tend to be close to the average of the set. Prayer Plant is good for commercialized and real-siuation study, because all finding may easy to expect based on SD value of Prayer Plant.

References

[1] S. H. Ismail, B. Deros, and A. M. Leman, Indoor Air Quality Issues For Non-Industrial Work Place, *IJRRAS*, **5**, 235–244, (2010)

[2] R. Jiang, Effects of Indoor Particulate Matter Pollution from Biomass Fuels Burning : A Case Study in Six Shenyang Households , Northeastern China in Summer Season, Bull. Yale Top. Resour. Inst., **26**, 47–55, (2007)

[3] Mahathir, Leman, and H. Shafii, Monitoring of Indoor Plants Application for Indoor Air Quality Improvement : Proposed Study, *3rd Scientific Conference on Occupational Safety and Health-Sci-Cosh 2014*, Skudai, Malaysia, (2014)

[4] J. Namieśnik, T. Górecki, B. Kozdroń-Zabiega ła, and J. Łukasiak, Indoor air quality (IAQ), pollutants, their sources and concentration levels, Build. Environ., **27** (3), 339–356, (1992)

[5] Y. Su and C. Lin, CO_2 Purify Effect on Improvement of Indoor Air Quality (IAQ) through Indoor Vertical Greening, *Proceedings of the World Congress on Engineering*, London, UK, (2013)

[6] T. Birgitta, Bert, *Helmut, Effects of Indoor Air Pollution on Human Health*, European Concerted Action, Environment lnstitute, Luxembourg City, Luxembourg, (1991)

[7] S. A. Rice , Human health risk assessment of CO2: survivors of acute high-level exposure and population sensitive to prolonged low-level exposure, *Third Annu. Conf. Carbon Sequestration*, Grass Valley, USA (2004)

[8] P. N. Bierwirth, *Effects of rising carbon dioxide levels on human health via breathing toxicity - A critical issue that remains unapprehended*, (2015), Retrieved on May 21, 2015 from https://www.researchgate.net/directory/publications

[9] R. Prill, *Measuring Carbon Dioxide Inside Buildings – Why is it Important ?*, Energy Proram, WSU, Washington, USA, (2013)

[10] ICOP, *Industry Code Of Practice On Indoor Air Quality*, Kementerian Keselamatn Pekerjaan dan Kesihatan Sumber Manusia, Kuala Lumpur, Malaysia (2010)

[11] B. P. Driessen, *Carbon Dioxide : The Gas of Life*, Committee For A Constructive Tomorrow, Washington, USA, (2013)

[12] J. Robertson, *Carbon Dioxide Feeds the World*, Robertson Science, Queensland, Australia (2011)

[13] D. Whiting, *Plant Physiology : Photosynthesis , Respiration , and Transpiration*, Colorado Master Gardener, Colorado State University, Colorado State, USA (2014)

[14] William Hopkins, *Photosynthesis and respiration*, Chelsea House, New York, USA, (2006)

[15] B.C. Wolverton, *Interior Landscape Plants For Indoor Air Pollution Abatement*, Final Report September, NASA, Washington, USA, (1989)

[16] F. R. Torpy, P. J. Irga, and M. D. Burchett, Profiling indoor plants for the amelioration of high CO2 concentrations, Urban For. Urban Green, **13**(2), 227–233 (2014)

[17] Z. Wang, *Dynamic Botanical Filtration System For Indoor Air Purification*, PhD Thesis, Syracuse University, New York, USA, (2011)

[18] U. Shome, *Comparative efficiencies of indoor plant-based biofilters in removal of selected volatile organic compounds*, Master Thesis, The University of Guelph, Ontario, Canada, (2004).

[19] H. Kim, J. Yang, J. Lee, J. Park, K. Kim, B. Lim, G. Lee, S. Lee, D. Shin, and Y. Lim, House-Plant Placement For Indoor Air Purification And Health Benefits On Asthmatics, Environ. Health Toxicol., **29**, 1–8 (2014)

[20] R. a. Wood, M. D. Burchett, R. Alquezar, R. L. Orwell, J. Tarran, and F. Torpy, The Potted-Plant Microcosm Substantially Reduces Indoor Air VOC Pollution: I. Office Field-Study, Water. Air. Soil Pollut., **175**(1–4), 163–180 (2006)

[21] Z. Wang, J. Pei, and J. S. Zhang, Experimental Investigation of the Formaldehyde Removal Mechanisms in a Dynamic Botanical Filtration System for Indoor Air Purification, J. Hazard. Mater., **7**, 1–22 (2014)

[22] J. P. Allewalt, M. M. Bateson, N. P. Revsbech, K. Slack, and D. M. Ward, Effect of temperature and light on growth of and photosynthesis by Synechococcus isolates typical of those predominating in the octopus spring microbial mat community of Yellowstone National Park., Appl. Environ. Microbiol., **72**(1), 544–550 (2006)

[23] R. V. Ribeiro, E. C. Machado, and R. F. De Oliveira, Temperature response of photosynthesis and its interaction with light intensity in sweet orange leaf discs under non-photorespiratory condition, Ciência e Agrotecnologia, **30**(4), 670–678 (2006)

[24] C. Hew, G. Krotkov, and D. T. Canvin, Effects of Temperature on Photosynthesis and CO_2 Evolution in Light and Darkness by Green Leaves, Plant Physiol, **44**, 671–677 (1969)

[25] B. V Pennisi, *Growing Indoor Plants with Success Table of Contents*. Extension Floriculture Specialist, Georgia, (2012)

[26] A. M. S. David R. Holding, *Plant Growth Processes : Transpiration , Photosynthesis , and Respiration*, EC1268 ed, University of Nebraska–Lincoln Extension, United States, (2013)

[27] J. Sun, X. Sui, H. Huang, S. Wang, Y. Wei, and Z. Zhang, Low Light Stress Down-Regulated Rubisco Gene Expression and Photosynthetic Capacity During Cucumber (Cucumis sativus L.) Leaf Development, J. Integr. Agric., **13**(5), 997–1007 (2014)

[28] E. Weston, K. Thorogood, G. Vinti, and E. López-Juez, Light quantity controls leaf-cell and chloroplast development in Arabidopsis thaliana wild type and blue-light-perception mutants., Planta, **211**(6), 807–815 (2000)

[29] B. C. Wolverton, *How to grow fresh air*, Weidenfeld & Nicolson, London, UK, (1996)

[30] K. Omar-Hor, *1001 plants in singapore*, National Parks Board, Singapore, (2006)

[31] A. Drozak and E. Romanowska, Acclimation of mesophyll and bundle sheath chloroplasts of maize to different irradiances during growth, Biochim. Biophys. Acta - Bioenerg., **1757**(11), 1539–1546 (2006)

[32] L. Cavallero, L. Galetti, D. López, J. McCargo, and I. Barberis, Morphological variation of the leaves of Aechmea distichantha Lem. plants from contrasting habitats of a Chaco forest: a trade-off between leaf area and mechanical, Rev. Bras. Biociencias, **9**(8400), 455–464 (2011)

[33] K. J. Kim, M. J. Kil, J. S. Song, E. H. Yoo, K.-C. Son, and S. J. Kays, Efficiency of Volatile Formaldehyde Removal by Indoor Plants: Contribution of Aerial Plant Parts versus the Root Zone, J. Am. Soc. Hortic. Sci., **133**(4), 521–526 (2008)

[34] Y.-J. Liu, Y.-J. Mu, Y.-G. Zhu, H. Ding, and N. Crystal Arens, Which ornamental plant species effectively remove benzene from indoor air?, Atmos. Environ., **41**(3), 650–654 (2007)

[35] B.C. Wolverton, Plants And Soil Microorganisms Removal of Formaldehyde, Xylene, and Ammonia from the Indoor Environment, J. Mississippi Acad. Sci., **38**(2), 11–15 (1993)

[36] Z. Xu, N. Qin, J. Wang, and H. Tong, Formaldehyde biofiltration as affected by spider plant., Bioresour. Technol., **101**(18), 6930–6940 (2010)

[37] D. Llewellyn and M. Dixon, *Comprehensive Biotechnology*, Elsevier B.V., Guelph, Canada, (2011)

[38] A. Aydogan and L. D. Montoya, Formaldehyde removal by common indoor plant species and various growing media, Atmos. Environ., **45**(16), 2675–2682 (2011)

[39] G. Forti, Biochimica et Biophysica Acta The role of respiration in the activation of photosynthesis upon illumination of dark adapted Chlamydomonas reinhardtii, BBA - Bioenerg., **1777**(11), 1449–1454 (2008)

[40] M. Burchett, *Indoor-plant technology for health and environmental sustainability*, Horticulture Australia, Sydney, Australia (2011)

[41] Malaysian Standard 1525, *Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings*, Department Of Standard Malaysia, Kuala Lumpur, Malaysia (2007).

[42] Malaysian Prime Minister Department, *Surat Perkeliling Am Bilangan 2 Tahun 2014*. Kerajaan Malaysia, Putrajaya, Malaysia, (2014)

[43] ASHRAE, ASHRAE Standard, *Thermal Environmental Conditions for Human Occupancy*, ASHRAE, Atlanta, USA (2010)

[44] K. M. Hasan, Simple Linear Regression, Am. J. Neuroradiol., **31**(9), 21–45 (2010)

[45] G. Smith, *Standard deviations : flawed assumptions, tortured data, and other ways to lie with statistics*, The Overlook Press, New York, USA, (2014)

[46] M. Centre, *Variance and standard deviation*, (2003), Retrieved on June 28, 2015 from http://www.lboro.ac.uk/media/wwwlboroacuk/content/mlsc/downloads/var_stand_deviat_group.pdf.