

A Study on Plant Selection for Green Building Design

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Abstract

Previous researches show that incorporating natural elements in design has proven a significant result in balancing building indoor environment. Using plant as part of the design has been widely accepted to contribute good thermal impact as shown in bioclimatic design, green roofing system and living wall elements. As there are so many species of plants for selection, this research was carried out to analyze types of indoor plants that have the potential to contribute thermal comfort to their surrounding. Based on the fact that plant leaves are the part where transpiration and guttation take place, plants are categorized into seven types based on their leaves architecture. They were then tested on their impact on surrounding temperature and humidity. Result shows that Linear, Lanceolate and Oblong shaped leaves categories are good in lowering the relative humidity while the categories that are good in lowering the temperature are Linear, Lanceolate, Cordate and Oblong shaped leaves categories. The study was carried out through series of relative humidity and air temperature monitoring of several room casings that consist with the plants. Both relative humidity and air temperature of the rooms with plants were recorded lower compared with the one without plant. Different categories of plants do give good result in relative humidity and air temperature. Thus, with a good combination of plant installation inside or onto building, it may contribute towards providing a good thermal comfort to the occupants.

Keywords: thermal comfort; air temperature; relative humidity

1. INTRODUCTION

Building is a major shading medium to human. Prevention of excessive increase in building internal temperature is very important to produce a comfortable indoor environment. With the growing concern about the climate change, there has been an increasing interest in using plant as part of sustainable strategy for building environment [1]. Previously, plant may be limited for the used of landscape element. In spite of beautifying the space, they also help to clean the air by filtering out toxins, pollutants and the carbon dioxide that we exhaled - replacing them with life sustaining oxygen [2]. Due to the potential, it is now used as part of the building itself as what we can see in Bioclimatic Designs, green roofing system and living wall elements [3]. This paper aims to show variety of plants' potential in giving impact to their surrounding environment. This may contribute to the process of plant selection in those building design approaches.

In the 1980s, NASA scientists had carried out studies on methods to reduce indoor air pollution. Their research found that houseplants, when grown in a closed, controlled environment, were able to extract volatile organic chemicals from the air. The scientists also found that there are varieties of plant efficiency in filtering out toxins than others when compared between few plant species. Philodendron species, spider plants and pothos were found to be the most efficient in the removal of formaldehyde. Thus, indoor plants are the most efficient and cost effective means of removing air pollution [2]. It is recommends that two plants per 100 square feet or two plants per a small office may keep the air pure and healthy [4,5]. Based on another study, one six-inch houseplant per 100 square feet of living area will do a good job of filtering out pollutants. Also, the more vigorous the plant, the more air it can filter [6]. Besides keeping the surrounding pure and healthy, plants may also helps in providing a good thermal for its surrounding. A well landscaped building surrounding shows a significant potential in keeping the indoor building air cool and less humid [7].

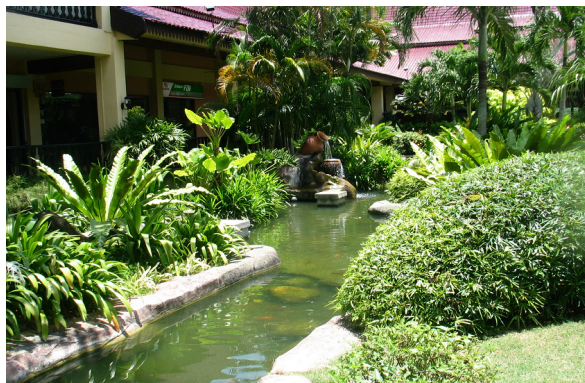


Figure 1: Incorporation of building and plant

The idea of common plants solving Indoor Air Quality problems is attractive. The findings of the two-year study by NASA indicate that plants provide a natural, cost-effective way to clean indoor air and combat "sick building syndrome" [3]. However, due to the different types of field study between architectural engineering and botany, the concept idea was just promoting the usage of plant in building. Further study on the plants potential in the aspect is still an issue. While there are so many species that able to stand the situation of being indoor plants, the selection has to function well in providing good thermal surrounding.

This research was focused on comparing the effect of type of plant towards their thermal surrounding. Considering the fundamental of plant botany, where transmission of air and water happened most at the leaves, this research classified plants based on the leaves architecture.

This research was done to meet the objective of comparing the plant potential to provide good thermal comfort in building space. Thus, the most potential type of plant may be identified due to the aspect. In term of thermal comfort, this research only focused on the effect towards air temperature and surrounding relative humidity (RH). Other variables of thermal comfort like air movement and human comfort variables may not be relevant.

2. METHODOLOGY

Photosynthesis is a major process of plant. It is a process of converting light energy to chemical energy and storing it in the bonds of sugar. The process takes place in the chloroplasts, specifically using chlorophyll, the green pigment involved in photosynthesis. The process primarily takes place in plant leaves.

One of the important components of leaf is stoma. Botanically, stoma is a pore, found in the leaf and stem epidermis that is used for gas exchange. Air containing carbon dioxide and oxygen enters the plant through these openings where it is used in photosynthesis and respiration. At the same time water vapor also released into the atmosphere through these pores in a process called transpiration. This process helps plant to maintain its desirable temperature.

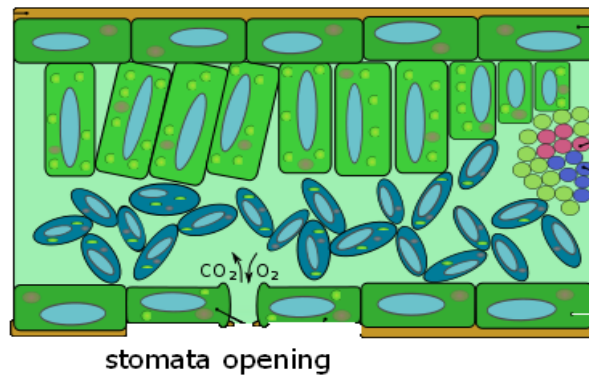






Figure 2: Cross section of leaf showing stomata opening underneath

Thus, when the processes take place, a slight effect on the plant surrounding is predicted. Hence, a number of plants may contribute to significant changes of the surrounding especially when dealing with indoor environment [9]. As most of the processes are mainly related to the leaves, hypothetically, different leaves' architecture may give different effect to the surrounding. As for this research, indoor plants are categorised into seven categories as follows;-

	<p>LINEAR Narrow with approximately parallel sides; a number times longer than wide.</p>
	<p>ELLIPTICAL Shaped like a football; broad at the center and sloping to a point at both ends.</p>
	<p>CORDATE Heart Shaped</p>
	<p>OBLONG Longer than broad, with side nearly parallel.</p>



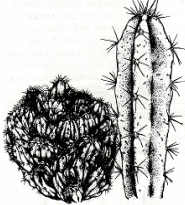
	<p>LANCEOLATE Lance-shaped. Widest about one-third the distance from the base with narrowed ends, several times longer than broad.</p>
	<p>SPATULATE Broadly rounded at tips but tapering to narrow base; narrower than obovate.</p>
	<p>CACTI</p>

Table 1: Type of plant based on leaves shape

8 room models were built using a brickwall with a see through perspex on top of it that act as the roof. Each of the room volume is at 0.729cub. meters. (0.9L x 0.9W x 0.9H). The indoor based of the space were laid with concrete as the flooring. Seven number of plants were then selected to represent each of the leaves category and placed inside the room models. This left a room empty that act as a reference indoor condition for such area. The plants chosen for the test were *Chlorophytum comosum* (spider plant) from Linear category, *Dracaena fragrans 'massangeana'* from Oblong category, *Aglaonema modestum* (Chinese evergreen) from Lanceolate category, *Philodendron domesticum* (Elephant ear philodendron) from Cordate category, *Ficus elastica* (Decora) from Elliptical category, *Peperomia obtusifolia* (Baby rubber plant) from Spatulate category and Melon Cactus (Column Cactus) from Cactus category.

Two sets of data were recorded. The first set consists of the air temperature and relative humidity data comparison between the room with and without the plant. Each plant was compared in the manner to see how significant the presentation of the plant may affect its thermal surrounding. The data were recorded using Hygro Thermo Anemometer for 10 days between 12pm to 2pm everyday.

Then, each of all seven plants were put in a room where the second set of data were taken. The air temperature and relative humidity for every each room were taken for every hour between 8.00am to 3.00pm for three continuous days. The mean for the data were plotted in graph to be compared and analyzed.

3. RESULT AND DISCUSSION

3.1 Relative Humidity Comparison

The relative humidity comparison between the room with plant and the room without plant is shown in Table 3.1 to Table 3.7 for each type of plant.

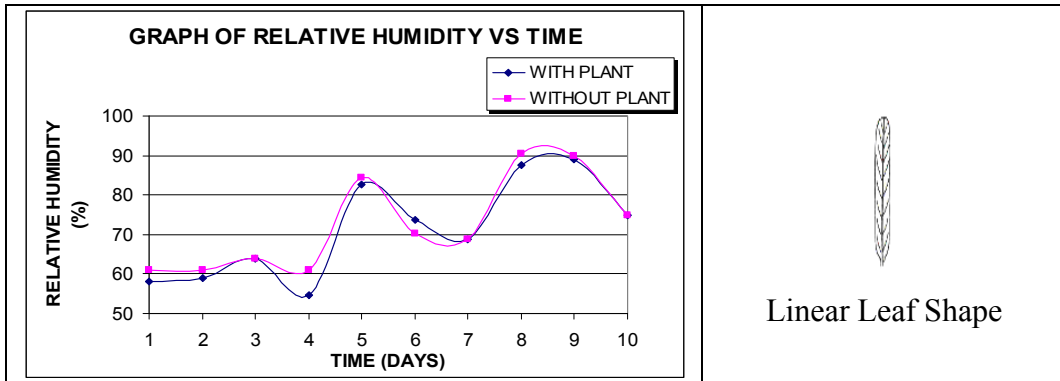


Figure 3.1: Relative Humidity of Linear Leaf Shape Plant Surrounding

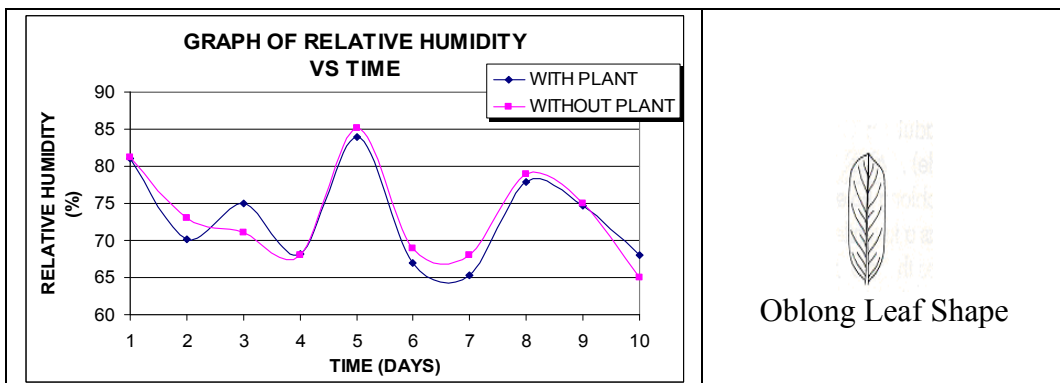


Figure 3.2: Relative Humidity of Oblong Leaf Shape Plant Surrounding

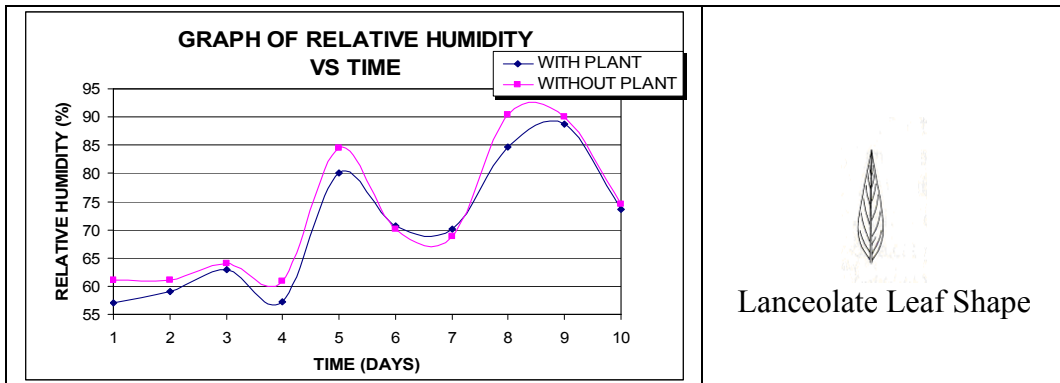


Figure 3.3: Relative Humidity of Lanceolate Leaf Shape Plant Surrounding.

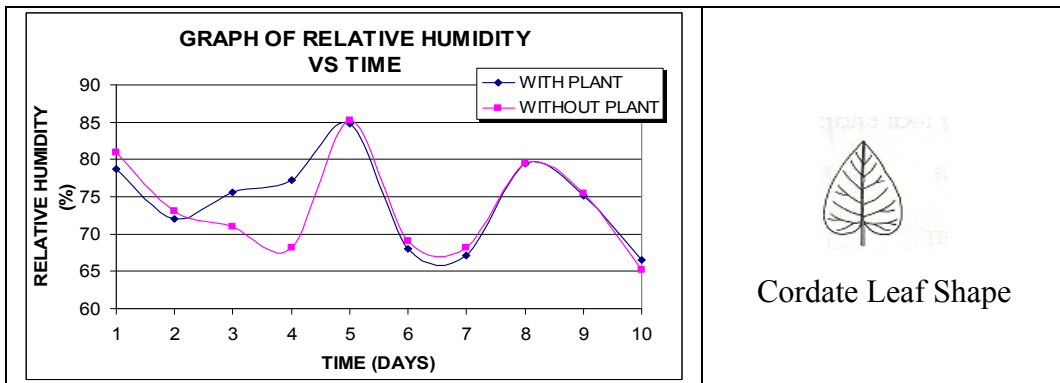


Figure 3.4: Relative Humidity of Cordate Leaf Shape Plant Surrounding.

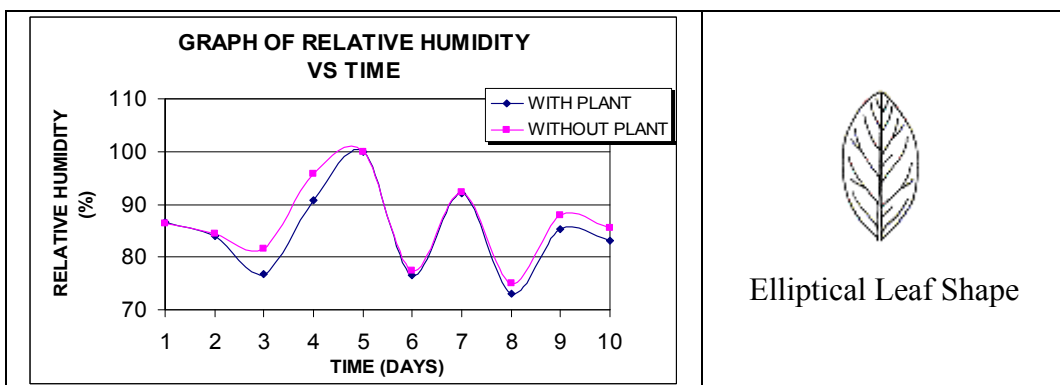


Figure 3.5: Relative Humidity of Elliptical Leaf Shape Plant Surrounding.

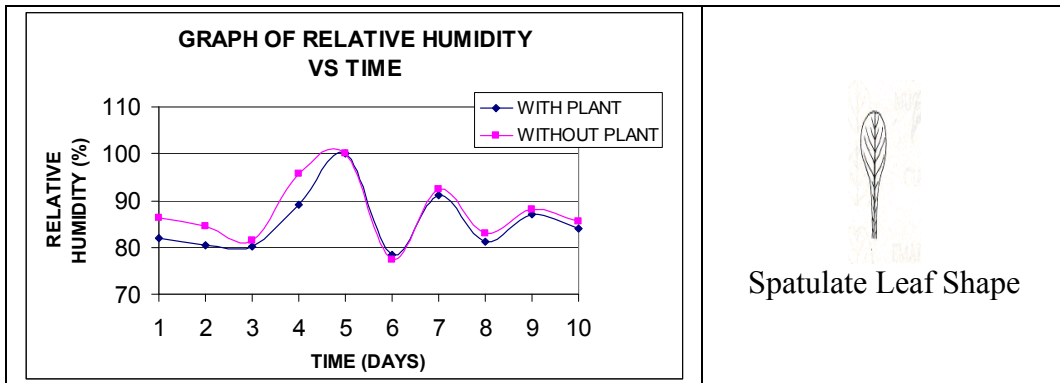


Figure 3.6: Relative Humidity of Spatulate Leaf Shape Plant Surrounding.

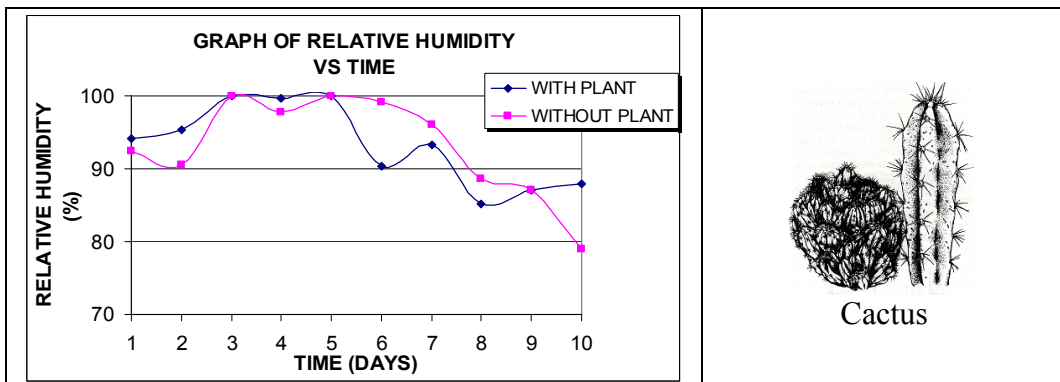


Figure 3.7: Relative Humidity of Cactus Leaf Shape Plant Surrounding.

Based on the figures above, most cases indicate lower relative humidity for rooms with plants compared to the rooms without plant although the graph shows irregular movement. Linear, Lanceolate, Elleptical and Spatulate shaped leaves plant show a consistant reduction of air humidity as shown in Figure 3.1, 3.3, 3.5 and 3.6. However, figure 3.7 shows that relative humidity of the room with Cactus indicate a slightly higher relative humidity than an empty room in 4 out of 10 days.

Basically the difference of relative humidity percent between rooms with plant and rooms without plant is about 0.1% to 7% in range.

3.2 Air Temperature Comparison

The air temperature comparison between the room with plant and the room without plant is shown in Figure 3.8 to Table 3.14 for each type of plant.

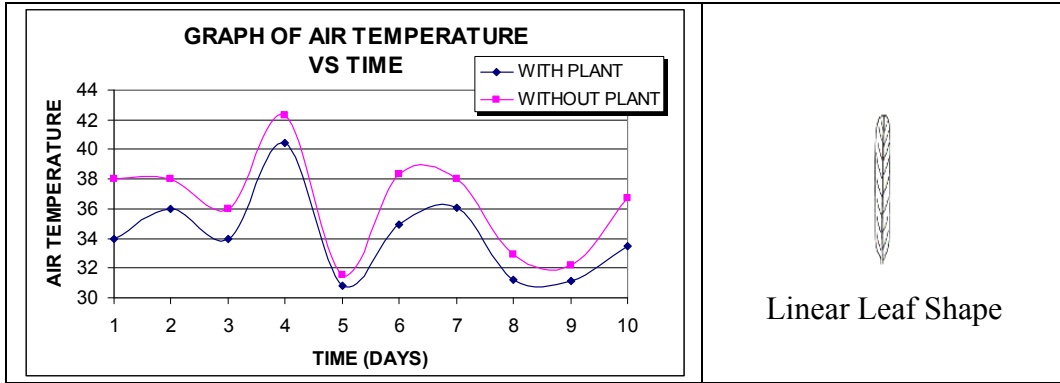


Figure 3.8: Air Temperature of Linear Leaf Shape Plant Surrounding.

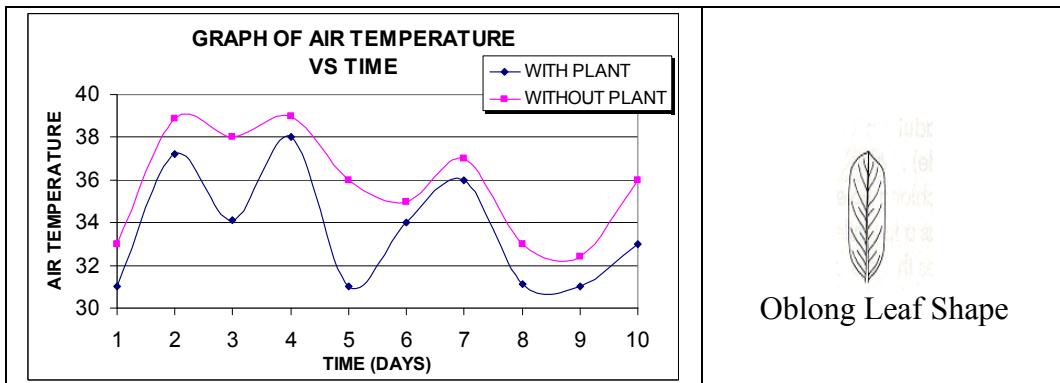


Figure 3.9: Air Temperature of Oblong Leaf Shape Plant Surrounding.

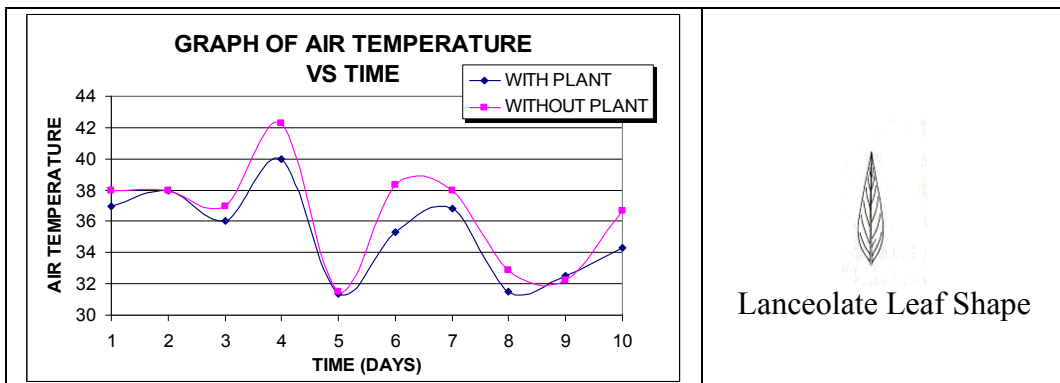


Figure 3.10: Air Temperature of Lanceolate Leaf Shape Plant Surrounding.

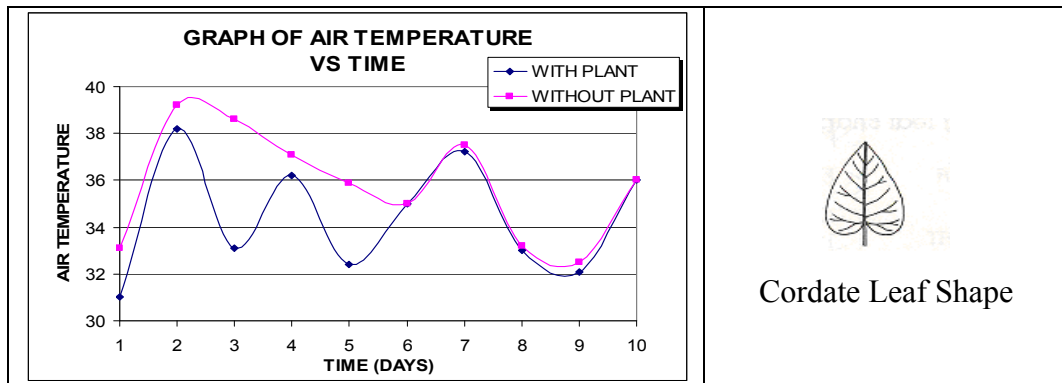


Figure 3.11: Air Temperature of Cordate Leaf Shape Plant Surrounding.

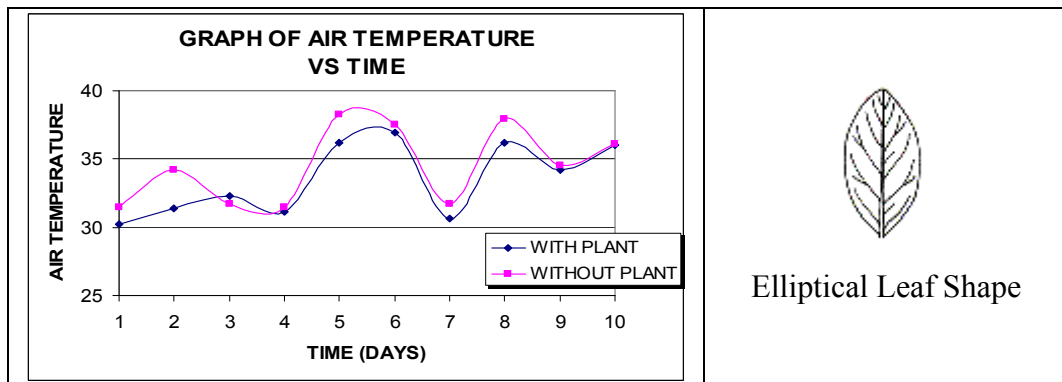


Figure 3.12: Air Temperature of Elliptical Leaf Shape Plant Surrounding.

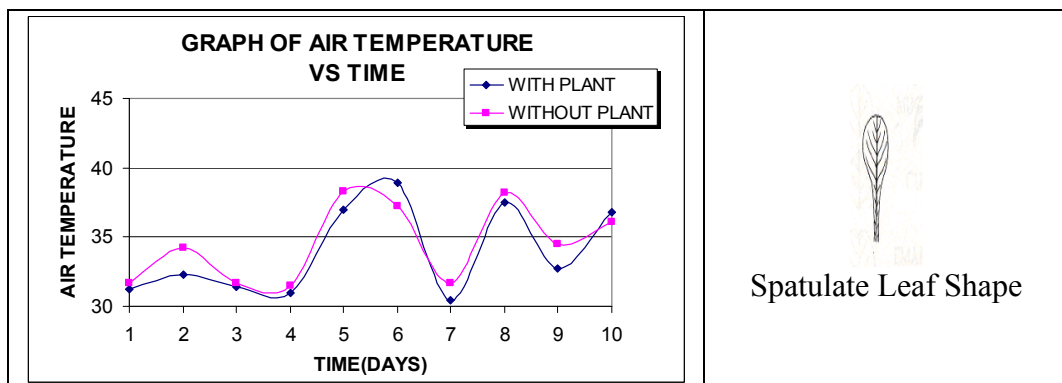


Figure 3.13: Air Temperature of Spatulate Leaf Shape Plant Surrounding.

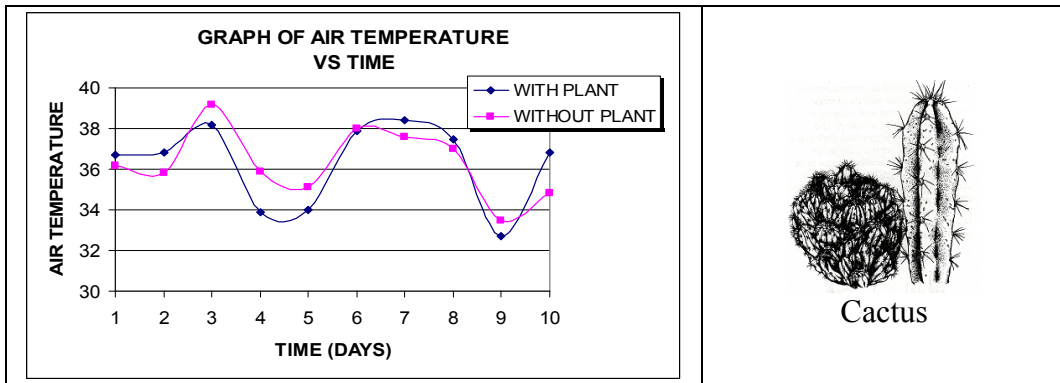


Figure 3.14: Air Temperature of Cactus Leaf Shape Plant Surrounding.

Based on the figure 3.8 to figure 3.14 show that the temperature for rooms with plants is recorded to be lower than rooms without plants besides its irregular pattern.

As the rooms were completely built with concrete blocks as the wall without any windows and come along with a see through perpex roofing, there were signs of green house effect happened in few cases. Figure 3.10 shows a maximum of air temperature level was recorded at 42.3°C for room without plant.. Anyway, as comparison on that particular day, the room with Lanceolate shaped leaves plant only recorded an air temperature at 40.0°C.

Figure 3.9 and figure 3.11 show an obvious air temperature reduction when empty rooms were compared to the rooms with plants with Oblong and Cordate shaped leaves. While again Linear, Lanceolate and Elleptical shaped leaves plants indicate a consistence reduction of air temperature as shown in figure 3.8, 3.10 and 3.12.

From all the graph analysis we can see that the differences of air temperature between rooms with plant and rooms without plan is about 0.1% to 5% in range.

3.3 Comparison Analysis Between Type of Plants

The rooms with plants indicate differences in the percentage of reduction and increment of relative humidity and air temperature when compared with empty rooms. Due to the result, another set of data were taken to compare the performance of relative humidity and air temperature of the plants surrounding simultaneously.

This data were taken for three continous days for all 7 rooms with each type of the 7 plants. Relative humidity and air temperature were taken at every hour from 8.00am to 3.00pm. The grapg shown below are the average of the data taken for three days at that particular hour.

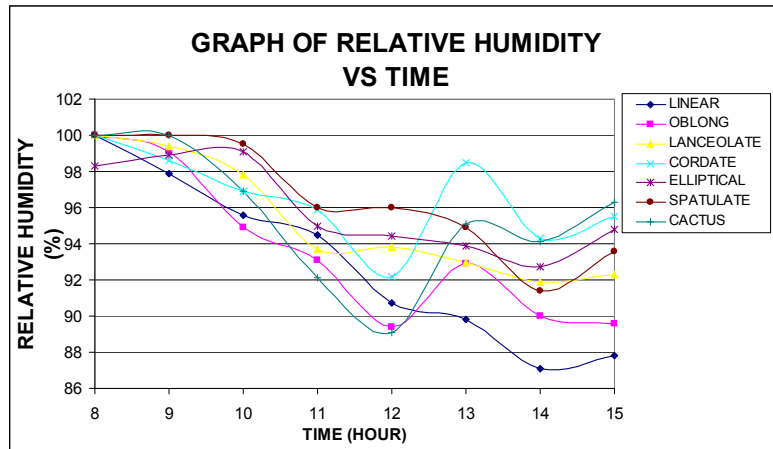


Figure 3.15: Analysis of Average Relative Humidity Comparison for Each Plant Category.

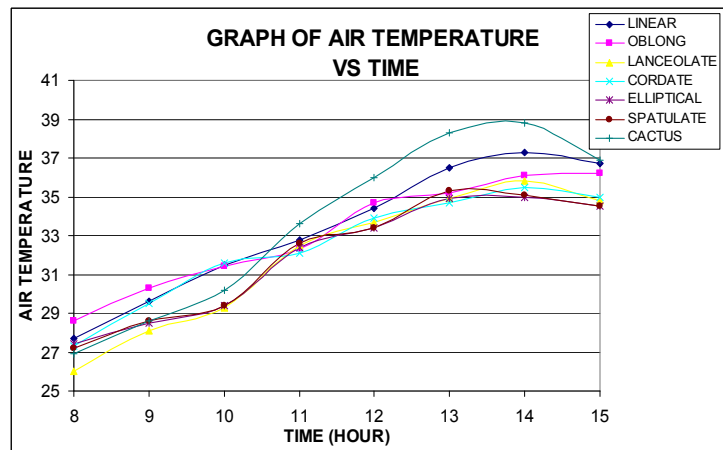


Figure 3.16: Analysis of Average Air Temperature Comparison for Each Plant Category.

Figure 3.15 shows an overall reduction of relative humidity from 8.00am to 3.00pm for all rooms. However rooms with Oblong, Cordate and Cactus shaped leaves plant indicate relative humidity increment at 1.00pm. Room with Linear shaped leaves plant shows a constant and significant reduction of air temperature compared to the rest with the minimum was 87.1% at 2pm.

Figure 3.16 shows an overall increment of air temperature from 8.00am to 3.00pm. As comparison, rooms with Lanceolate and Spatulate shaped leaves plant shows a consistence lower air temperature around 1°C to 2°C compared with other rooms. Room with Linear shaped leaves plant was also recorded with low air temperature during early hours but started to increase at noon.

3.4 Discussion

There are many reasons and factors that affect the increase and decrease of the relative humidity and air temperature. Surrounding weather is the biggest factor. The changes in weather may affect the data collection activity.

From the comparison among the 7 categories, small leaves plants like under category Lanceolate, Spatulate and Linear show a significant effect in lowering both the surrounding relative humidity and air temperature. Sizes of these leaves are small compared to other plants. Anyway, small areas do not guarantee that they cannot release oxygen in high quantity as they are depending on the amount of stomas action. These plants are actually capable in absorbing many types of pollutant like Formaldehyde at the rate of 560 microgram per hour, Xylene at rate 268 microgram per hour and Carbon monoxide gas at 96% [10]. The process may also rely on the quantity of stomas of the plant. Thus, with that significant quantity, it may also contribute in high respiration process in lowering the surrounding air humidity and air temperature.

On the other hand, wide leaves plants like Cordate and Elliptical categories show a significant effect in lowering the air temperature of its surrounding, but not its relative humidity, especially the Cordate type. Despite of having wide leaves that we thought will come with a high quantity of stomas, the Cordate type seems to be not efficient in lowering the humidity. This may be caused by the plant metabolism level which may not absorb the surrounding water rapidly compared to other plant. However, it shows potential in lowering the air temperature despite of inconsistency reduction of the temperature through out the day.

4. CONCLUSIONS

Overall, the result taken was influenced by the physical character of the plant where the shape of leaf has a very significant role in influencing the relative humidity and air temperature result. As the plants came under different species to represent the leaves potential, physically the plants themselves came in various sizes and architectural character. Some comes with bushy leaves while some may come with small quantity of leaves. This may also affect the result of the study. Besides that, the processes are also affected by the stomas number at other part of the plants such as the stems and branches. From the data analysis, the plants that are good in lowering the relative humidity may from Linear, Lanceolate and Oblong shaped leaves categories. While the plants that are good in lowering the air temperature may be from Linear, Lanceolate, Cordate and Oblong categories. Anyway the percentage of reduction in relative humidity and air temperature in this study may not be the same in a bigger and actual scale of room as the rooms used in the study are only with the size of 0.9m x 0.9m x 0.9m.

REFERENCES

- [1] Lokman Hakim, Magda Sibley and Izudinshah, (2011). Bioclimatic Technology in High Rise Office Building Design: A Comparison Study for Indoor Environmental Condition. *Journal of Science and Technology*, Vol. 3, No. 2. UTHM Publication, Malaysia.
- [2] Wolverton, B.C., Anne Johnson and Keith B. (1989). Interior Landscape Plants for Indoor Air Pollution Abatement-Final Report. *National Aeronautics and Space Administration* (NASA), Stennis Space Centre, USA.
- [3] Yeang, K., (1997). The Skyscraper, Bioclimatically Considered: A Design Primer. Academy Editions, London.
- [4] Wolverton, B.C. and John, D.(1993). Plants and Soil Microorganisms:Removal of Formaldehyde, Xylene,and Ammonia from the Indoor Enviroment. *The Mississippi Academy of Science*. Vol 38, No.2., USA.
- [5] Wolverton, B.C. and John, D. (1996). Interior Plants: The Influence on Airborne Microbes inside Energy Efficient Building. *The Mississippi Academy of Science*. Vol 41, No.2., USA.
- [6] Bill, H. and Sealey, A.(1992). Healthy Building. *1st ed.* Longman Group UK Limited, England. pp 21-22.
- [7] Abakr, Yousif A. (2005). Building performance assessment of an eco-house in Malaysia: A comparative analysis. *Proceeding 2005 World Sustainable Building Conference*, Tokyo, Japan.
- [8] Ismail, M.R. and Barber, J.M., (2001). A field study to determine inside design conditions for Malaysian air conditioning systems. *Architectural Science Review*, Volume 44, pp 83 - 99.
- [9] Briggs, G. and Calvin,C. L.(1987). Indoor Plants. *1st ed.* :John Wiley & Sons, Inc., Canada. pp 377-504.
- [10] Givoni, B., (1994). Passive and Low Energy Cooling of Building, John Wiley & Son. Inc., New York.