Biofacade for Urban Development: Pest and Diseases, Its Control and Prevention

Atikah Fukaihah Amir
School of Housing, Building and Planning, Universiti Sains Malaysia
11800, Penang, Malaysia
Tel: 60-19-440-6580 E-mail: idealism_85@yahoo.co.uk

Foong Swee Yeok
School of Biological Sciences, Universiti Sains Malaysia
11800, Penang, Malaysia
Tel: 60-12-552-9694 E-mail: foong_sy@yahoo.com

Aldrin Abdullah
School of Housing, Building and Planning, Universiti Sains Malaysia
11800 Penang, Malaysia
Tel: 60-12-410-4715 E-mail: aldrin@usm.my

Abdul Malek Abdul Rahman
School of Housing, Building and Planning, Universiti Sains Malaysia
11800, Penang, Malaysia
Tel: 60-19-448-0205 E-mail: malik@usm.my

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Abstract

Biological façade (biofacade) is an ecological friendly building design. Biofacade represents a new idea that is beneficial in reducing carbon in the atmosphere and provide food or medicine, benefiting both the environment and people. There obstacles such as pests and diseases which attacked the plants, causing loss of productivity and photosynthesis system on plants. Without proper prevention, these plants cannot survive until the end of their life span, which and this is one of the main problems for biofacade in the tropical environment. This paper discusses the maintenance of biofacade, including the prevention of pests and diseases that attack wall-climbing legume plants such as *Bemisia tabaci* and fungi. Four types of legume, namely the *Pisum sativum, Vigna unguiculatasesquipedalis, Psophocarpus tetrogonobulus* and *Phaseolus vulgaris* were studied. The plants were allowed to overgrow on a chain-fence attached to a typical brick wall at Desasiswa Tekun, Universiti Sains Malaysia. The plants were grown from January until May 2010. Every legume species were grown from seedlings. There were three pots for each species; altogether there were 12 potted plants. In the first month of growth, the seedlings were grown under 50 % of shade and were subsequently transferred under open sunlight after its maturation. All potted plants received direct afternoon sunlight from 1 pm until 5 pm. The dry weight of the pods was taken during the observations. *Pisum sativum* and *Vigna unguiculatasesquipedalis* was recorded on the average of 58.1 g and 18.8 g, respectively. Dry weight and carbon sequestration were become the sub-topic. In addition, control and prevention study were listed on the end of discussion.

Keywords: Legume, Biofacade, Pest and disease

1. Introduction

Cultivar selection is important in order to compare the benefits of different plants. Recommendations for cultivar selection based on the photosynthetic productivity in legume as biofacade were scanty. Furthermore, a tropical country like Malaysia enjoys year long growing for its plants. This brings about maintenance challenge to uphold the biofacade on a twelve-monthly basis. Our research included a study of four common types of legume, which were *P. sativum, V. unguiculatasesquipedalis, P. tetrogonobulus* and *P. vulgaris* to select the best species to be used as biofacade for tropical environment. However, *P vulgaris* was excluded from further studies due to its poor growing performance.

We have chosen leguminous plant in this study in view of its symbiotic nature with the Nitrogen fixing Rhizobium in its root nodules. This symbiotic association could help lower maintenance costs in terms of fertilization and also for ensuring long-term sustainability of the biofacade. Furthermore, drought tolerance in legumes can be acclimatized to suit different growing conditions in most urban areas of Malaysia. However, growers have to be aware of the drought tolerances in legumes that are parallel with its salinity tolerance in the soil component (Graham, 2003). According to Sponchiadoa (1988), if the legume were deeply rooted, it may reduce the leaf size with thickened cuticles, which in turn would reduce the water loss. In 1988, there was an experiment performed in Colombia at two locations with *Phaseolus vulgaris L.* under different soil conditions to compare the root growth (Sponchiadoa, 1988). Roots of drought tolerance lines grew as deep as 1.3 m, whereas drought sensitive lines only reached 0.8 m. according to this study, our research group paid attention to our pot size to make sure it would be able to enhance the ability of legume plants to survive in limited spaces, with harsh sunlight in hot and humid urban tropical climate. Overall, the objectives of this research were to investigate:

- The variation in photosynthetic rates and dry weight productivity among three legume cultivars in a tropical climate
- Options for sustainable pest and disease management
  The risk and impacts of biofacade in a tropical climate

2. Method and Materials

This research was conducted at Universiti Sains Malaysia (Latitude 5°21'20.39"N, Longitude 100°17'30.03"E) which is situated in Penang Island, the northern part of Peninsular Malaysia. Plants were propagated in 0.02 m^3 pots (2-3 seedlings per pot) on December 29, 2009. Potted plants received 50% daylight for the first month. The type of soil used was mixed soil and on top was 3 inches of compose. The plants were regularly watered on a daily basis, depending on the soil moisture. One month later, all the plants were moved to an open space where they received 100% afternoon sunlight. Afternoon sunlight was chosen to measure the highest possible risk of plant stress condition.

The site is located at the solid walls on the ground floor of a high rise building (2.5 m height x 3.67 m wide). A diamond fence was used to help plants climbing on the wall with 15 cm gap from the walls of the building. The four species were planted side by side. It took nearly three months for the plants to reach the targeted height and maturity. More plants were planted to incorporate possible loss due to plant stress during the dry season (i.e. from January to February). Regular watering was applied twice daily after plants were moved into the open space. The plants were fertilized with compound chemical fertilizers monthly (N8+P8+K8+3.3MGO+TE) and leaves were sprayed bi-weekly with the liquid organic/synthetic pesticide (*Cymbopogon nardus*), Mapa Malathon 57. Besides this, treatment, a water-based aerosol to control insects and fungicide (Dithane* NT) for disease controlling was used, depending on the condition of the plants. Disease infected parts of the plants, especially leaves, were removed immediately to avoid spreading.

It was observed that for the five months of planting duration, *Phaseolus vulgaris* recorded the slowest growth when compared with the rest of the species. The leaves were retarded and this could be due to soil mixture used was not suitable for the plants. *Psophocarpus tetrogonobulus* and *Phaseolus vulgaris* did not produce flowers until the late fruiting season. Most likely, this was caused by strong wind and turbulence on site. Another two species *Vigna unguiculatasesquipedalis* and *Pisum sativum* were well grown and bore flowers and fruits after three months.

The research focused on *Photosynthetic Assimilation Rate* and *dry weight* of the three legume plants. There were limitations during plant selection based on the size of the leaves. The leaves need to have at least an area of 6 cm^2 (2 cm x 3 cm) to fit into the clamp of LICOR 6400 (Nebraska, USA) leaf cuvette for photosynthesis assimilation rate measurement. The photosynthesis assimilation rate measurements were carried out on April 26, 2010 from 2 pm to 4 pm on the three selected legume plants. The time period was selected to capture direct afternoon sunlight from 13:00 to 17:00. Measurements were taken twice daily, i.e. at 14:00-14:50 and

15:00-15:50 p.m. A total of sixty leaves were logged with twenty leaves on each of the three species respectively.

Legumes were harvested from May, 17 to May, 30 2010. Fruit harvested for the five months of growth were recorded weekly on a phase by phase basis. Legumes were put on the oven (105° C) for at least three days to collect dry weight measurements as a way to compare biomass productivity (Figure 1).

3. Results

Figure 2 shows the bio-façade wall with four species of legume plants. Based on our observation, species of *P. sativum, V. unguiculatasesquipedalis* and *P. tetrogonobulus* seem to be growing well. However, *P. vulgaris* plants developed poorly. Many of *P. vulgaris* leaves size were less than 6 cm^2 and couldn't fit into the Photosynthesis Machine leaf cuvette. Therefore, we only make the comparison was only made in terms of photosynthetic assimilation rate and dry weight on *P. sativum, V. unguiculatasesquipedalis* and *P. tetrogonobulus.* Graph 1 shows the variation of photosynthetic assimilation rate and dry weight comparison.

The air temperature ranged from 29 ^oC to 39 ^oC, relative humidity of 40% to 65%, and CO_2 concentration (ambient) was 400 mmol l^{-1} to 430 mmol l^{-1} in photosynthetic assimilation rate study. Photosynthetic Assimilation Rate averaging over the two measuring period were 10.0 µmole m^{-2} s^{-1}, 13.4 µmole m^{-2} $s^{-1}$and 11.8 µmole m^{-2} s^{-1} for *P. sativum*, *V. unguiculatasesquipedalis* and *P. tetrogonobulus* respectively (Figure 3). The highest photosynthesis rate on both sampling periods amongst the three species was recorded on *V. unguiculatasesquipedalis*. In the second sampling, (12:00 pm – 15.50 pm), all photosynthesis rates of species were higher due to higher PAR for that period.

During the five months plantation, pest and disease were common. According to Dickson (1956), weather conditions are the main factors that influence the spread of disease on plants. As defined by Hill (1975), pest that can be in a form of animal or other plant can gives harm or causes damage to man, his animals, crops or possessions or even an annoyance. Figure 4 shows the legume plant disease and pest identification commonly occurred.

4. Discussion

As stated by Rosenberg (1983), there are several factors that are affecting photosynthesis rate. The main factors are light, water, wind and turbulence, temperature and carbon dioxide concentration.

Legume biofacade on external building walls could help to solve limited space of plantation in urban areas. Long term observation on food production is another important aspect when comparing the productivity. However, the five months period duration of harvesting was choosen to look into the overall productivity of these legume species. Basically, this research investigates on how far those plants are durable under such conditions and how the plants' survive. Farmers will usually plant the legume facing the morning sunlight as this is the best radiant for food production. However this study that focuses on the ability of plant as biofacade has shown that planting the legumes on the wall that faces the evening sun helps to absorb heat energy from the harsh afternoon sun.

Basically, legume plants are not fussy about soil type, just as long as it is fertile and have a good drainage to avoid water logging. But it is best if legume plants are provided with soil that is high in organic matter. According to Dunnet (2008), moisture and nutrients of the soil of organic matter will help climbers to vigorously produce shoot. The bacteria of nitrifying have specific moisture requirement (Keefer, 2000). When the moisture level in the soil is too low, the nitrification process will be retarded. However, too much water in soil as in case of root flooding will have more negative results as the nitrification could reduce rapidly. According to Keefer (2000), the best condition of soil to carry out nitrification is to allow the soil alternately dried and wetted, as this stimulates more rapid oxidation of organic matter.

When dealing with plants, an adequate planter box size may affect the plant growth. Rooms for healthy roots could bring a healthy shoots. Furthermore, as stated by Dunnet (2008), plant growth may lack in nutrients when the pot size is too small. It is therefore crucial to have adequate pot size to support the growth of biofacade on a long term basis. Regular irrigation and good drainage is other key aspects that help keep soil moisture on an optimum level. As such, the water source must be close to the plant. Systems like dripping or sprinkler might be an alternative for watering a large-scale building biofacade. Basically, the best time to water is in morning and early evening. Irrigation at noon hours should be avoided because the plant could have a shock or distress in terms of moisture level. There is some doubt when planting the climbers on exposed land. It may be after all, Gregory (1988) evidence on tendril climbing plants was adapted to grow in low light saturation point. Three of plants selected were as well known as tendril climbing mechanics. However this depends on performance or hardiness of the plant chosen. Otherwise, it can overcome with mulching stones on the soil to keep it shaded, i.e. as suggested by Dunnet (2008).

According to Hill (1975), methods of pest control may be divided into four different categories physical, cultural, chemical and biological. However, Singh (1990) states there should only be three categories stated that it is cultural, biological and chemical. In this research, physical and chemical methods for integrated pest management were used. Cultural method also was used to keep the area free of conducive conditions by eradicating or storing the waste properly, eradicating disease plants properly. Biological control method was not a viable alternative in pest management because it requires introducing new predator species which may be invasive to the environment. Proper investigation into the advantages and disadvantages of this method has to be explored further beforehand. The physical control in this research was in the form of handpicking of pests that appeared on plant leaves. This method was used when the pests were still under control (the amount of attacked are little).

5. Conclusion and Future Work

Insecticides or chemical control as pest management are easy to use, and has long been used as a pest management. However, it may bring the adverse effects to human and environment. From the viewpoint of sustainability, especially in terms of economics, chemical insecticides should be used sparingly, not as a priority. More and various choices of chemical control with natural extracts e.g. *Cymbopogonnandus* liquid should be used instead as the main alternative. As a conclusion, the species *P. tetrogonobulus* has been chosen for further studies in view of its positive photosynthetic assimilation performance and biomass productivity.

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Figure 1. Pods were put in dryer beaker (right) to absorb the moisture for 30 minutes, before measure the weight using analytical balance (left).

Figure 2. Four legume plants were planted on wall (bio-façade wall). Three pots on every species make 12 pots in total. From left: *P. sativum, V. unguiculata sesquipedalis, P. tetrogonobulus* and *P. vulgaris.* There were stem entanglement amongst the neighbouring pots. Tracking the stems was done in order to identify leaves during the measurement of the photosynthetic assimilation rate.

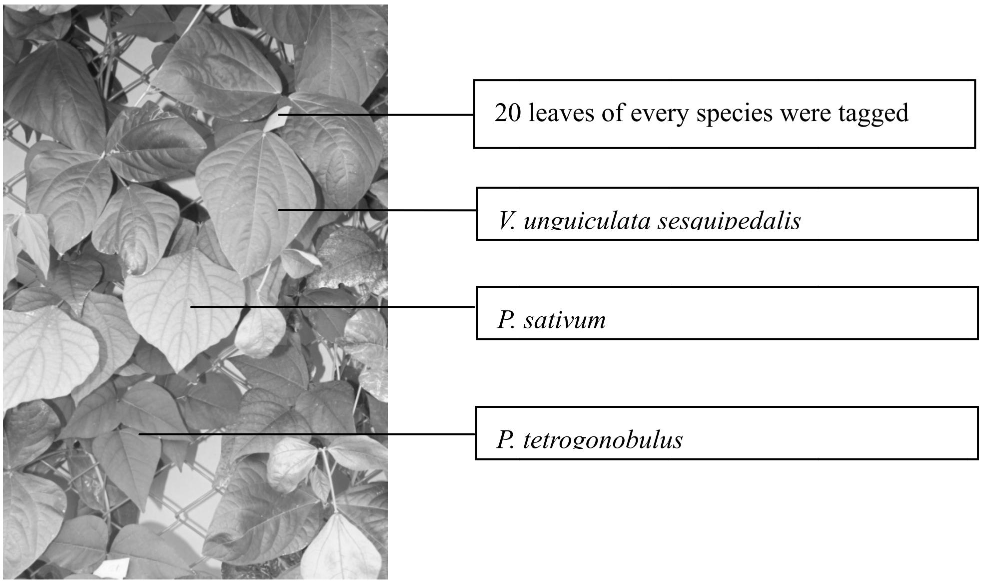
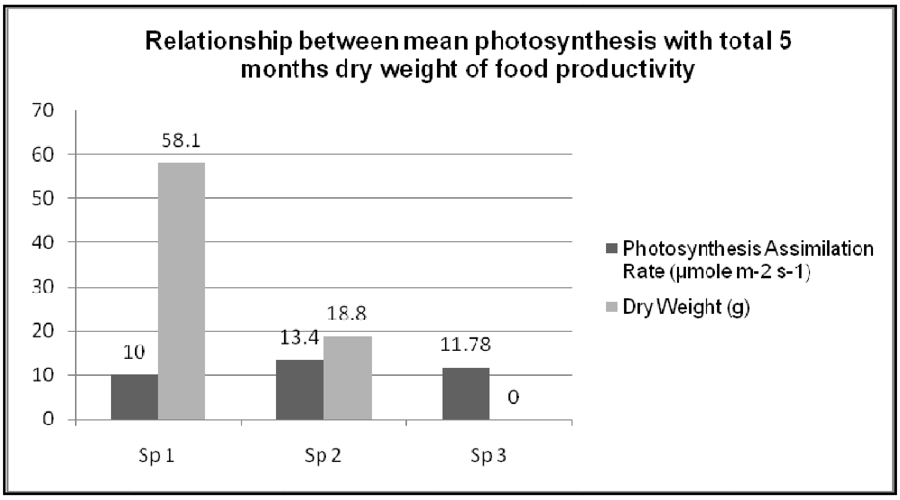


Figure 3. Comparison of the sizes of three different legume leaves



Graph 1: *Vigna unguiculatasesquipedalis* (long yard bean) has recorded the highest average photosynthetic assimilation rate of 13.275 µmole m^{-2} s^{-1}. Followed by *P. sativum* and *P. tetrogonobulus* of 10 µmole m^{-2} s^{-1} and 11.78 µmole m^{-2} s^{-1} respectively. However, according to pod dry weight measurement, *P. sativum* (sweet pea) has recorded the highest total dry weight which was 58.1 g. Followed by *V. unguiculatasesquipedalis* of 18.8 g and no bean pod produced by *P. tetrogonobulus.*

 **Name:** leaf miners (*Chromatomyia syngenesiae*) **Cause**: leaf miner larvae feed and bore their way between the outer and upper epidermis of the leaf. The lower leaves sustained more damages. **Effect:** slight damage. No detrimental effect on the growth. **Overcome:** Chemical control. (Biddle, 2007).	 **Cause**: large insect (grasshopper from Acrididae family) **Effect:** the leaves and soft shoots are eaten, leaving irregularly shaped leave marks. **Overcome:** handpicking of pests (Singh, 1990)	 **Name:** Yellowing of younger and middle leaves. **Cause:** Iron deficiency. The symptom is transitory and rarely results in yield reduction. **Effect:** Slight damage. No detrimental effect on the growth. (Biddle, 2007), (Greentrees hydroponics, 2009)
 **Name:** Bean golden yellow (Mosaic Virus) **Cause:** *Bemisia tabaci* as a vector **Effect:** fail to produce an adequate amount of nutrient to fruit (Bird, 1975) **Overcome:** Remove infected part quickly.	 **Name:** Bean rust (*Uromyces appendiculatus*) **Cause:** damage in warm seasons where night time temperatures drop and humidity high. **Effect:** Infected leaves desiccated and caused growth retardant (Biddle, 2007).	 **Name:** Pale green leaves colour **Cause:** Insufficient soil nutrient **Effect:** Growth retardant. (Greentrees hydroponics, 2009)

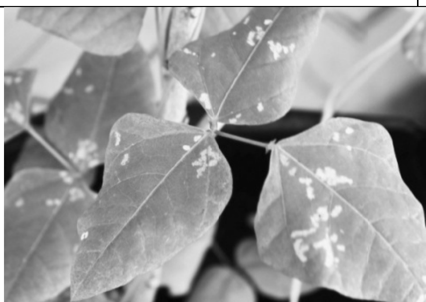
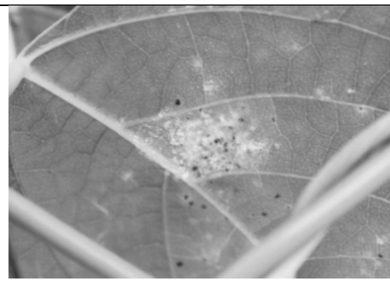
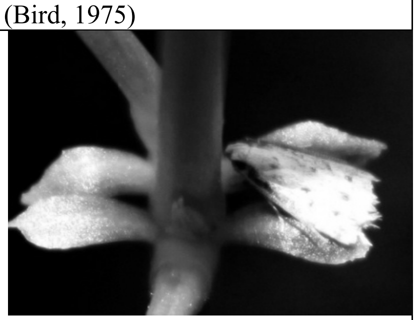
 **Cause:** Fungi disease (unidentified) **Effect:** Minimum as infected parts was quickly removed.	 **Name:** Leaf curl over/wiltered **Cause:** over-fertilized or lack of watering (Greentrees hydroponics, 2009)	 **Name:** Common blight **Cause:** long periods of warm and humid weather (Biddle, 2007).
 **Name:** Fungus infection (unidentify) **Overcome:** Remove infected part quickly	 **Name:** Insect consumption Effect: Lost in leaf size **Overcome:** Pesticide application if necessary	 **Name:** *Bemisia tabaci* (white flies) **Cause:** transmitted diseases attributed to viruses **Effect:** viruses slow the photosynthesis n fruit harvest. **Overcome:** Washing the plant, especially the underneath of leaves. (Bird, 1975)
 **Name:** Acrididae **Effect:** damage through leaves feeding **Overcome:** aerosol H_2O based-flying insect killer (Kranz, 1977)	 **Name:** Fungus infection (unidentify) **Effect:** Lost in leaf size **Overcome:** Pesticide application if necessary	 **Name:** Cutworms (larvae of the *Agrotis segetum*) **Effect:** the larvae feed on the soil surface attacking young plant stems. **Prevention:** irrigation reduced the larval activity (Biddle, 2007).

Figure 4. Example of diseases and pest attack problem occurred on site