

# Comparison of *Shibataea kumasasa* and *Equisetum hyemale* as vertical greenery system for thermal and light shade in student's architectural design studio in surabaya

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**Abstract.** Vertical greenery system (VGS) is commonly used for facade shading. It has many advantages in its natural aesthetic, air filter, carbon sequestration, and many more. This research is the continuation of the previous research in 2019, which used *Shibataea kumasasa* as VGS. It was found that using *Shibataea* as VGS has reduced the indoor air temperature by 0.5-2°C on average, with 5°C maximum temperature difference. On the other hand, it decreased more light (in range 26-95%), made the illuminance of the room lower than the standard requirement. A studio room should have minimum 5% daylight factor or 500 lux, while on the room measurement, the lowest was 20 lux in the morning hours, the highest was only 200 lux in the afternoon. As an attempt to look for vegetation with better performance, this research uses another bamboo species, *Equisetum hyemale* to be examined and then being compared to *Shibataea*. The result is that for the thermal shade, *Equisetum* performs less effectively than *Shibataea*. As for light shade, the *Shibataea* reduces more illuminance than *Equisetum*, thus makes it a less favorable alternative. The balance of thermal-light effective performance maintained by the leaf area index can be the focus of future research.

## 1. Introduction


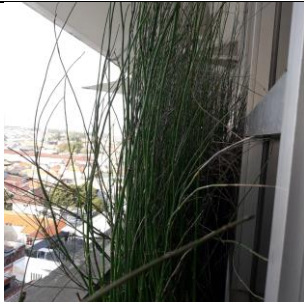
As a building is being built, there will be a decrease in soil area and vegetation, being replaced by the building material, such as concrete, steel, and glass. To replace the shading function of the missing land and vegetation, nowadays architects have developed the greeneries as the facade of the building, with their supporting structures. These greeneries are usually called vertical greenery system (VGS) [1] VGS has many advantages in its natural sun-tracker role [2], natural aesthetic [3], air filter and carbon sequestration [4],[5], bio-diversity [6], man-nature relation [7], as well as phytoremediation [5]. This research focuses on the potential of VGS to lower the air temperature and filter the high brightness from solar radiation in the tropic region.

Previous research has found that the VGS affects the indoor thermal and illuminance performance, as the greenery with dense and wider leaf will reduce the heat gain, and give significant shading to the indoor room [8]. This result matches another research that concludes that the height and the density of the vegetation will affect their shading performance [9], [10]. To have an optimal shading performance throughout the year, the ideal examined vegetation growth should not depend on the seasonal changes and does not need constant maintenance [11].

Bamboos belong to grass taxonomy (*Gramineae*), but unlike other grass, it has nodes and diaphragm that makes them able to resist more load than other common grass. This characteristic makes them ideal to resist bigger wind loads in building facades. Bamboo on pot performance as a VGS is also being examined in the previous research in China, which concluded that bamboo has a stable effect on shading and enhance building thermal performance [12]. As there are climate characteristics differences in the subtropic (China) and tropic area (Indonesia), it is essential to study whether the bamboo can be effectively applied too as VGS in the tropic area.

This research is a continuation of the previous research in 2019 [13], where one of the bamboo species with wide and dense leaf, *Shibataea kumasasa*, was examined. The bamboo species were chosen, as it can be easily obtained in Indonesia, as well they need low maintenance. We use one vegetation at a time of research, so that the result affected only by the vegetation observed. The result is that, compared to its advantages on thermal variables, it was found that *Shibataea* decreased too much light, below the standards required. As an aim to find vegetation with better shading performance on light and thermal variable, this research applies another bamboo species, which is *Equisetum hyemale*, that has the same bamboo genus but different kind of characteristics, as summarized in table 1.

**Table 1.** The compared vegetation characteristics

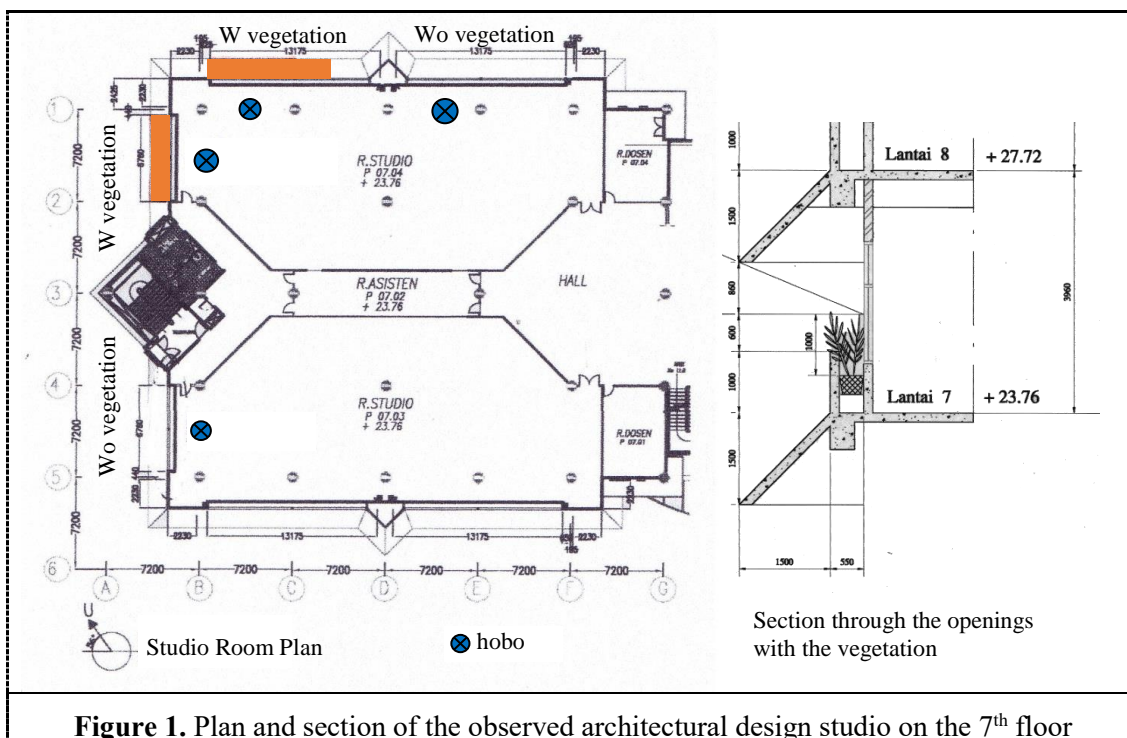
Species	Picture	Characteristics
<i>Shibataea kumasasa</i>		<ul style="list-style-type: none"> <li>• Origin: North Japan and Anhwei or Zhejiang – china</li> <li>• Other Name: Ruscusblatterbambus, Sasaruscifolia or Masedornblattbambus.</li> <li>• It is perennial vegetation with broad dark green leaves with leaf area index (LAI) &gt; 3 and grows in small clusters; usually very dense so the stems are completely hidden by its leaves.</li> </ul>
<i>Equisetum hyemale</i>		<ul style="list-style-type: none"> <li>• Origin: North America, Europe and Northern Asia</li> <li>• Other Name: Horsetail</li> <li>• This perennial vegetation is a spreading hollow, good vertical accent vegetation, with bamboo-like stems, but has no leaves (LAI &lt; 1).</li> </ul>

## 2. Research Methodology

This research has been done in two different period, in the same examined room, which is an Architecture design studio on the 7th floor P building Petra Christian University. The visual activities require illuminance with DF ranged from 5-8% [14] or equal to 500-800 lux for average outdoor illuminance of 10000 lux [15]. The Studio room was observed, due to its usage on ordinary studio days. The arrangement of the studio resembles the condition in an actual architectural office. Students use this studio all day, from 7.30 AM to 6 PM. Therefore, the optimum condition of the studio is essential, in thermal, and in lighting. This research could serve as feedback for the University, as an alternative to improve the building performance. The first research was on April-May 2019 with

*Shibataea kumasasa*, and the second measurement was on April-May 2021 with *Equisetum hyemale*. The goal of this research is to compare the effect of using each vegetation as VGS to indoor thermal and light conditions, therefore, the measurement dates of both research were quite similar, and facade orientation examined were the same, which are North and West. The West-oriented facade was chosen, as it was the orientation with the highest heat gain and sun penetration. As Surabaya is located in 7<sup>0</sup> Southern Hemisphere, the sun tends to be on the northern part of the sky throughout the year, making North the second orientation with the tense heat gain and sun penetration. If the VGS proved to be effectively applied to reduce heat gain in these two orientations of building, surely it can perform even better in the other orientation, East and South, that were cooler.

The measurement was taken by comparing the thermal variable (air temperature in °C and relative humidity in %) and light variable (illuminance in lux) of the facade with and without vegetation. The devices used were hobo pendant outdoor and hobo data logger U12-012 family. The hobo pendant has accuracy ±0.4 in temperature and 1-30000 lumen/ft2 in light (capable for outdoor light measurement). The U12-012 has accuracy ±0.35°C in temperature, ±2.5% in RH, and 1-3000 lumen/ft2 in light (capable for indoor light measurement). The point of measurements are indicated by the circular blue point in the room layout picture, place 1.5 m from the façade, and 0.75 m in height from the floor, as seen in figure 1. The condition of the room, before and after the application of each vegetation can be seen in table 2.



**Table 2.** The measurement condition

Species	Time of Measurement	Picture
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### 3. Result and Discussion

For the analysis, the first step is to compare the thermal and illuminance condition in the Studio room, with and without each vegetation. For ease of explanation, we will call the condition without the vegetation as the first condition, and the second condition where the vegetation is being applied. The next step is to compare the thermal and light shading performance of both vegetations. The result can be described below.

#### 3.1. *Shibataea kumasasa*

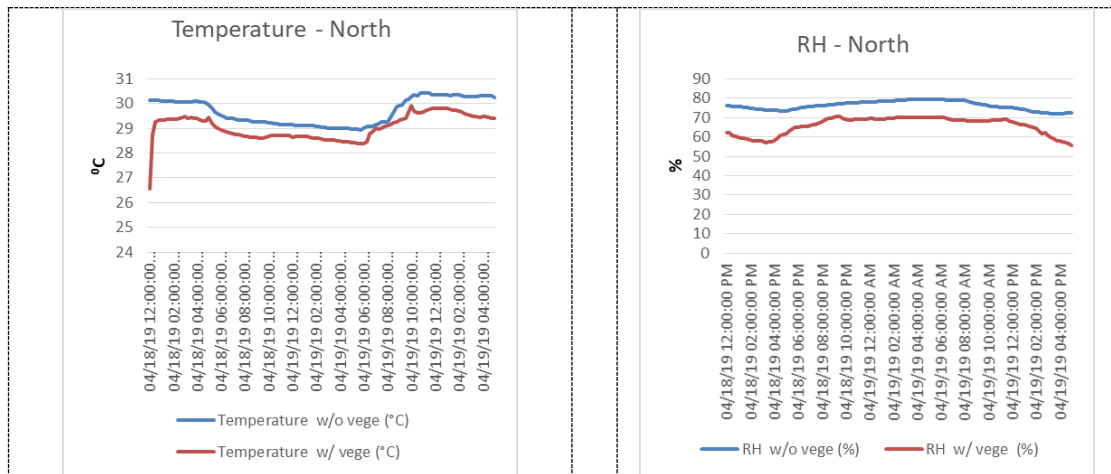
##### 3.1.1. Thermal

For North-facing windows in the first condition, the indoor temperature at 6 PM to 8 AM is around 29°C. The temperature is starting to rise at 9 AM, and 10.30 AM reaching 30.5°C. The temperature then is decreasing again at 4 PM. As seen in graphs, the second condition of North-facing windows behaves similarly to those without vegetation. The temperature at 6 PM to 8 AM is between 28.5 and 29°C and increasing from 9 AM. At 10.30 AM it reaches 30°C. So the difference between the two conditions is around 0.5°C.

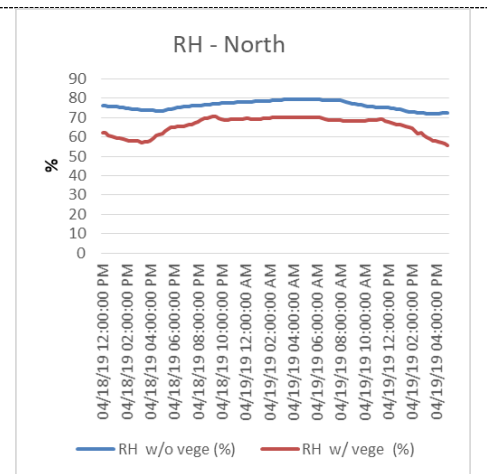
For the West oriented window, it can be found that the temperature of the second condition is lower, averagely about 1-2°C than the first condition. From the measurement on May 2019, the air temperature of the first condition was 30°C, whereas the second condition's temperature ranged from 28-29°C. The highest air temperature difference was 5°C at 3-4 PM (the first condition was 35°C and the second condition was 30°C).

The RH for North and West orientation has the same fluctuation; in the first condition was 80% on average; whereas in the second condition was drier, 70% of RH averagely. The result for the temperature and relative humidity in the West and North-facing windows can be seen in figure 2, 3, 4, and 5.

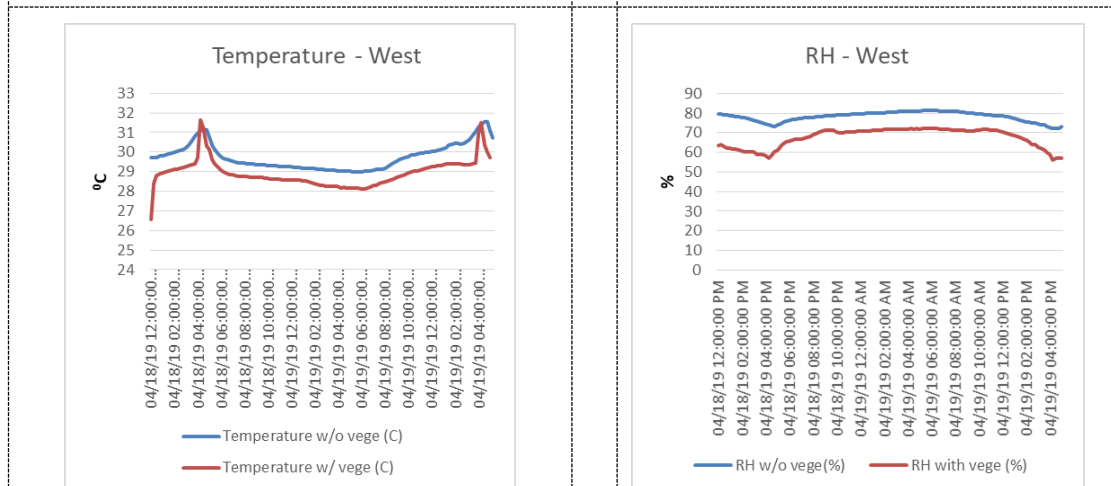
The comfort standard in Surabaya, according to the bioclimatic chart was 22-30°C with 18-78% RH, and 23-26°C with 50% according to Canada's National Occupational Health & Safety Resource (CCOHS). Comparing to the standards, we can see that the result's condition still needs more air circulation mechanism to reduce the RH to be in a comfortable state.



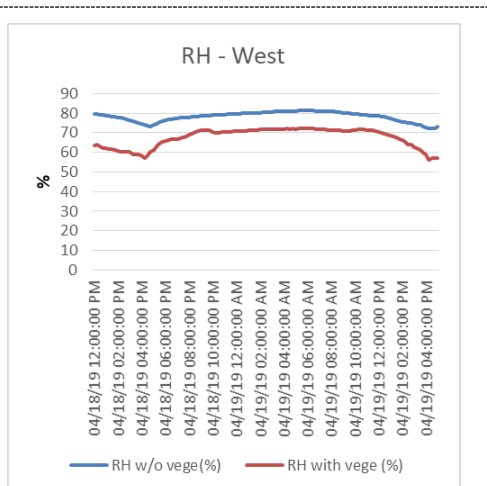
**Figure 2.** The temperature for the North-facing windows



**Figure 3.** The relative humidity for the North-facing windows



**Figure 4.** The temperature for the West-facing windows



**Figure 5.** The relative humidity for the West-facing windows

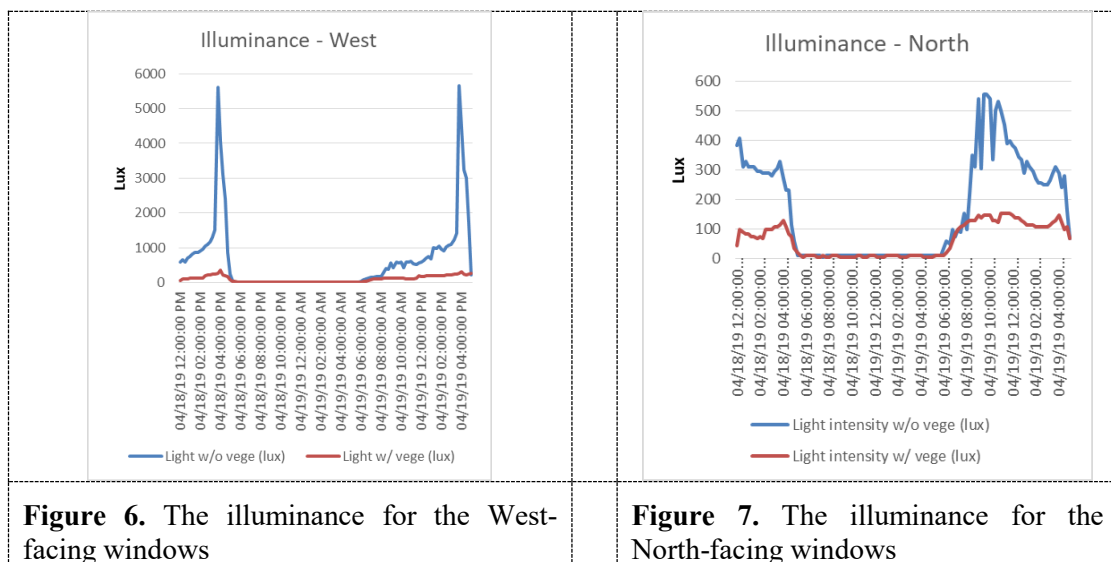
### 3.1.2. Light

For West orientation in the first condition, indoor illuminance at 6-8 AM is between 30-180 lux, 8.15 AM – 1 PM in the range 180-490 lux, 1.15-6 PM range between 800-5600 lux, and reach the highest point at 2.45 PM, then decreases to 0 lux at 6 PM. The average indoor illuminance was 858.34 lux. For the second condition at West oriented, indoor illuminance between 6–8 AM in the range of 20-110 lux, 8.15 AM–1 PM in the range 110-200 lux (highest), 1.15-6 PM in the range of 200-350 lux and reach the highest point at 2.45 PM, then decreases to 0 lux at 6 PM. The average indoor illuminance was 155.67 lux.

By this result, it was found that for the West window, the vegetation can reduce light by 37% (in the morning)- 95% (in the afternoon).

For North orientation in the first condition, indoor illuminance between 6-8 AM is in the range of 35-155 lux, 8.45-10.45 AM in the range 210 - 530 lux, at 11.15 AM-4.15 PM in the range 500 - 240 lux, then decreases to 0 lux at 6 PM. The average indoor illuminance was 291 lux.

For the second scenario facing North, indoor illuminance between 6-7.15 AM is in the range of 20-100 lux, 7.30 AM-4.45 PM in the range 105-155 lux (highest), then decreases to 0 lux at 6 PM. The average indoor illuminance was 118.24 lux. By this result, it was found that for the North window, the vegetation can reduce light 26-77% (the highest reduction happens at 10.45 AM). The result can be seen in figure 6 and 7.



**Figure 6.** The illuminance for the West-facing windows

**Figure 7.** The illuminance for the North-facing windows

### 3.2. *Equisetum hyemale*

#### 3.2.1. Thermal

The coolest indoor temperature for the first condition at West facing widows is around 29,84°C at 5.15-6 AM. After 6 AM, the indoor temperature increases and reaches the hottest temperature are at 4-4.30 PM in the range 34,05 until 35,29°C.

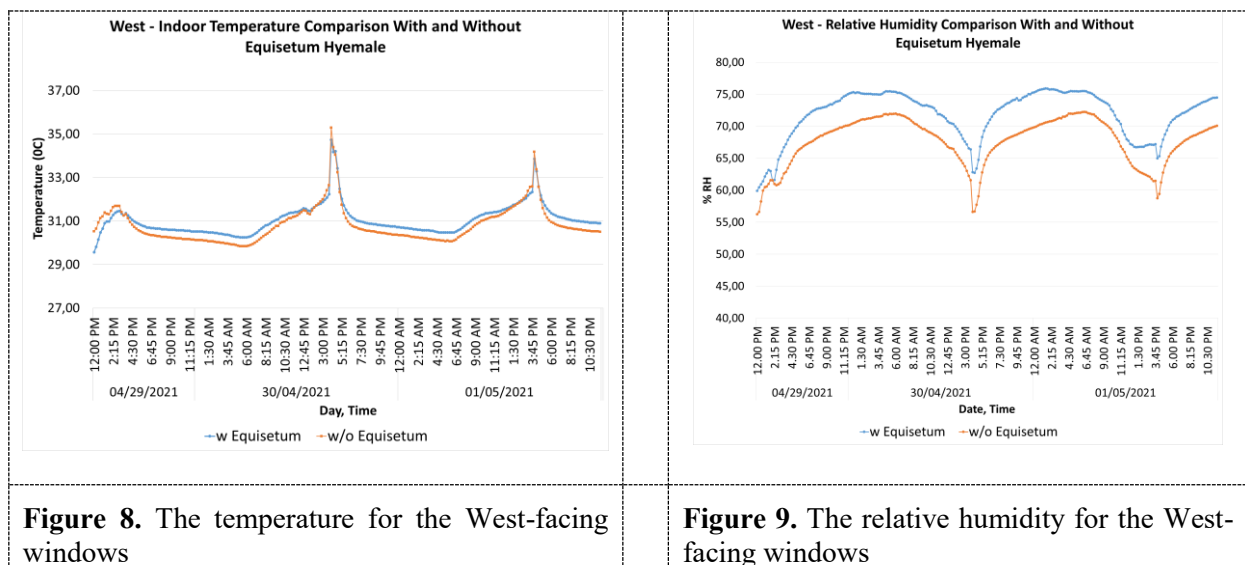
Comparing to the second condition with the same orientation, the room, in general, is slightly hotter than the first condition, at around 0.02-0.43 °C, during the afternoon, evening until the next morning. The coolest indoor temperature in the second condition is at 29,59°C and happens at 12 PM on the first day of measurement. This value is an anomaly due to a sudden cloudy sky (match with the illuminance graph in figure 12). The repeated lowest temperature is 30,84°C and happens at 5.15-6 AM during the days of measurement. After 6 AM, the indoor temperature grows hotter and the hottest 4-4.30 PM in the range 34,2 to 34,73°C.

The drier indoor Relative Humidity at West facing windows without *Equisetum hyemale* outside the windows, happens at 3 – 4 PM, on 57 – 59 %. The humid indoor Relative Humidity in 72% at 5 AM. The drier indoor Relative humidity with West facing windows with *Equisetum Hyemale* outside the windows, happens at 3 – 4 PM, on 62.5 – 65 %. The indoor Relative humidity is 75 % at 5 AM. The first and second condition has 0,02% to 6,25% relative humidity difference, and the second condition always has more humid indoor area than the first condition.

The condition of measurement shows no means of ventilation, as the windows are partly operable, but all closed. Therefore, it creates the air-trap condition. The humidity of the greenery is trapped too, therefore the indoor temperature is rising in the second condition during the afternoon, until the next morning. Given the chance of ventilation, the condition of measurement could be different, as the outdoor temperature may give a role too to the indoor temperature.

From the morning to noon, the outdoor temperature rises again. It also raises the indoor temperature, with or without *Equisetum*. In the condition where no *Equisetum* is installed, the sun penetrates the west side opening the most after 12 PM. Therefore, around 1.30 PM to 4.30 PM, the indoor temperature in the first condition is higher than in the second.

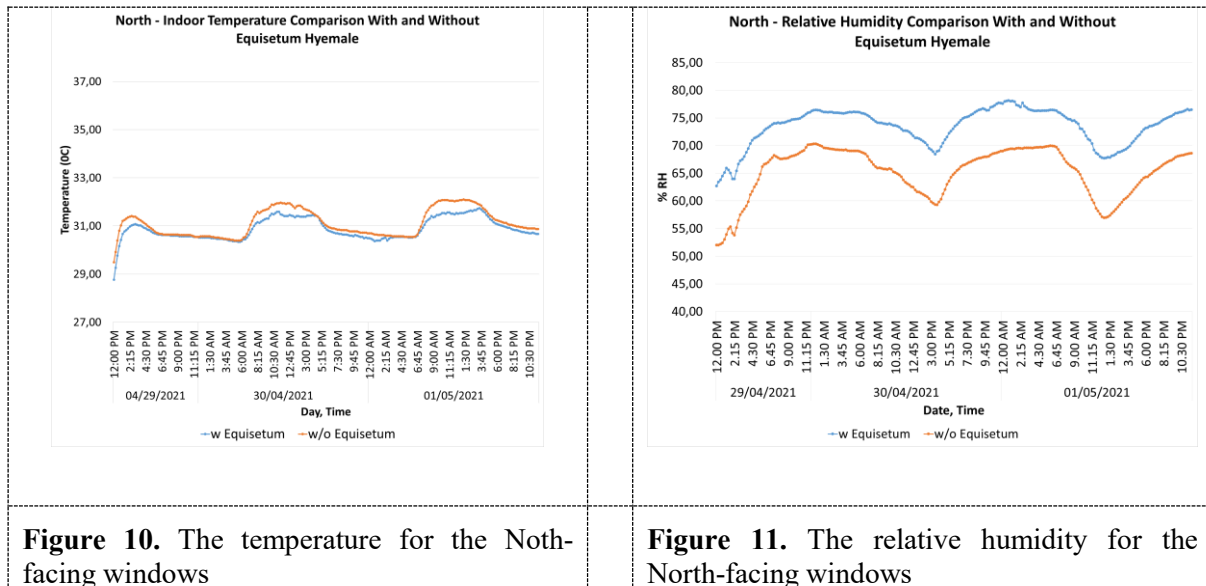
From the data, we can also calculate, that the application of *Equisetum* at times can reduce the indoor temperature by 0,95°C (3,13% than without it), but most of the time (4.30 PM to 1.30 PM on the next day), their presence makes the temperature slightly higher, ranged from 0,02 to 0,43°C. This data is reflected in the graphs in figure 8 and 9.



Slightly lower than the temperature on the West, the temperature on the Northside of the room is ranged from 29,49-32,10°C in the first condition, and 28,77-31,74°C in the second condition. Here we can find that the first and second conditions have only a maximum 0,72°C difference, as the openings are always closed. The first and second condition almost has the same temperature during 6 PM to 5.30 AM in the next day. We can also see from the graph in figure 10, that the temperature in the first condition (without *Equisetum*) is always higher than the second condition (with *Equisetum*).

The second condition also causes the relative humidity on the North section of the room more humid than the first condition throughout the measurement days, with the difference ranged from 5,77% to 12,09%. The lowest indoor humidity in the first condition happens in the afternoon, between 2 to 4 PM (minimum value of 59,29%), and the most humid happens at midnight to dawn, between 12 to 4 AM (maximum 70,32%). The lowest indoor humidity in the second condition happens in the afternoon, between 2 to 4 PM (67,27%) and the most humid happens at midnight to dawn, between 12 to 4 AM (maximum 78,16%). This condition is similar to the relative humidity in the West area.

The possible cause of this condition is that the application of *Equisetum hyemale* as greenery produces more water vapor that causes more humidity. The condition of the North faced area can be seen in figure 10 and 11.



**Figure 10.** The temperature for the North-facing windows

**Figure 11.** The relative humidity for the North-facing windows

### 3.2.2. Light

For the first condition facing West orientation, the indoor light illuminance started to increase at 6 AM from 19.7 lux, but at 6.30-7 AM, it reached hundreds lux until thousands lux at 3 PM, and the highest at 4 PM ranged from 1943-4986 lux. After that, it decreased to 0 lux at 5 PM until the next morning. The average indoor illuminance was 505.3 lux.

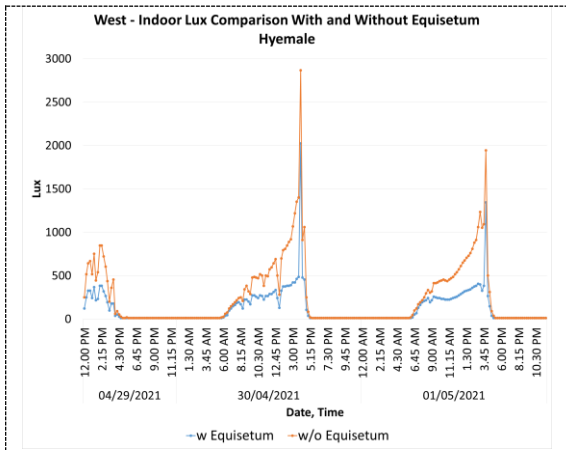
For the second condition facing West, the indoor light illuminance started to increase at 6.30 AM from 19.7 lux, reach hundreds lux at 7.30 AM, and the highest was 1048-3693 lux at 3.45-4 PM. And then, it decreases to 0 lux at 5 PM until the next morning. The average indoor illuminance was 262.1 lux.

From this result, the condition with vegetation reducing 46.97% of the room's illuminance on average. The highest percentage reduction was 72.88% at 3.30 PM.

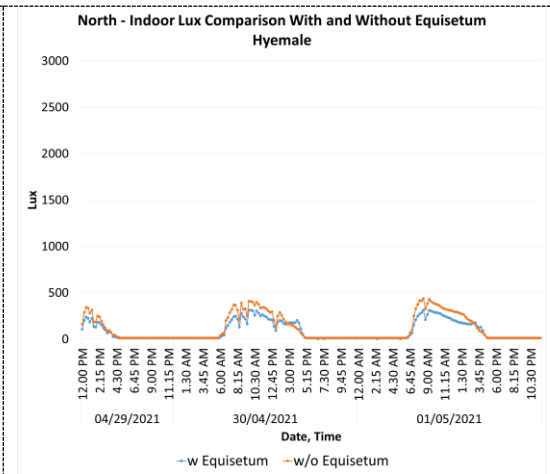
For North orientation without vegetation, indoor illuminance started to increase from 19.7-35.5 lux at 6 AM and become maximum at 406-492.7 lux at 8.15-10 AM, then decrease to 0 lux at 5 PM. The average indoor illuminance was 237.05 lux.

For North orientation with vegetation, indoor illuminance started to increase from 19.7 lux at 6 AM and reached the highest 311.4-382.4 lux at 8.15-10 AM, and then decreased to 0 lux at 04.15-05.00 pm. The average indoor illuminance was 181.08 lux.

From the morning to noon, the condition with vegetation can reduce light averagely by 30.92%. But at the afternoon until sunset, the indoor light with vegetation tend to higher 1-17% than light condition without vegetation. After monitoring this unusual phenomenon, it was found that there has been light penetration from the west window in the afternoon, taken by north lux meter of the second condition. The condition of the illuminance on the West and North faced opening can be seen in figure 12 and 13 below.



**Figure 12.** The illuminance for the West-facing windows



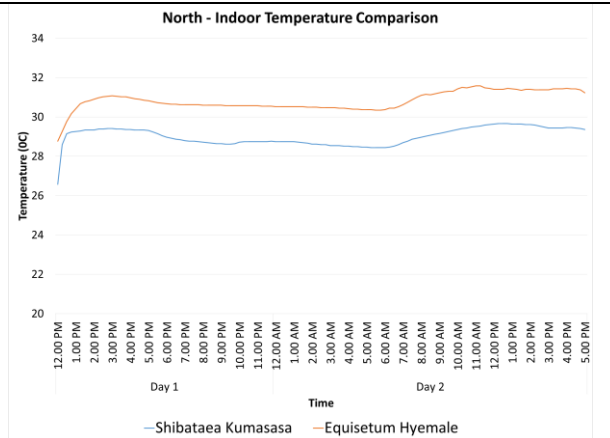
**Figure 13.** The illuminance for the North-facing windows

### 3.3. *Shibataea kumasasa* comparison to *Equisetum hyemale*

After examining the impact of *Shibataea kumasasa* and *Equisetum hyemale* application as VGS compare to the condition without the VGS, these two vegetation are then being compared one to another to find a better alternative. The thermal and light performance of *Shibataea kumasasa* and *Equisetum hyemale* is reflected in three variables, which are temperature, relative humidity, and illuminance. The information regarding these three variables can be found in table 3.

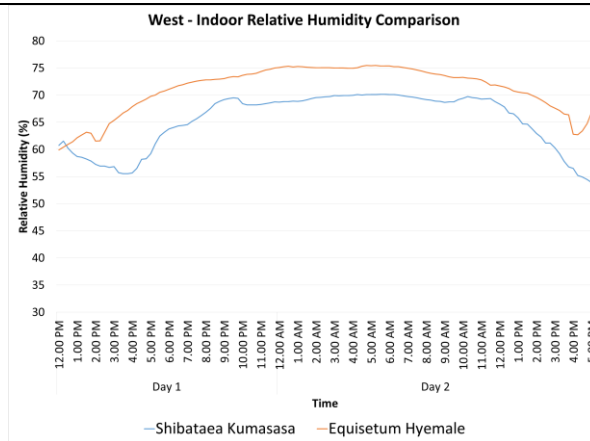
**Table 3.** The Comparison

Variable	Graph	Note
Temperature (°C)		<p>From the graph, we can see that the presence of <i>Shibataea kumasasa</i> can lower the indoor temperature better than <i>Equisetum hyemale</i> in both directions, West and North. The average temperature difference is 2,05°C on the West with the maximum 3,86°C difference, while on North 1,77°C with the maximum of 2,19°C.</p> <p>The average room</p>

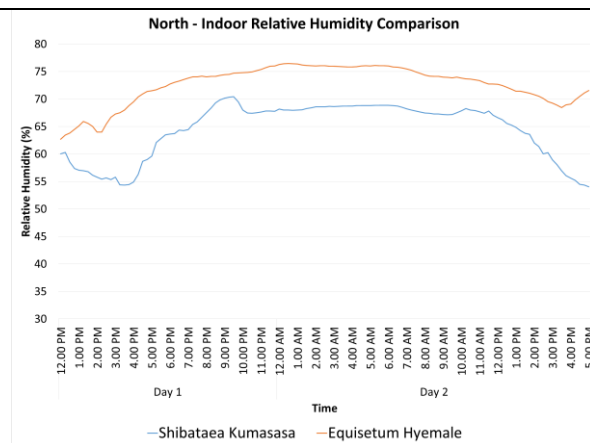


temperature with the application of *Equisetum hyemale* is 31,05°C in the West and 30,88°C in the North, while with the application of *Shibataea kumasasa*, the average temperature in both direction is lower, which are 28,91°C West, and 29,01°C North.

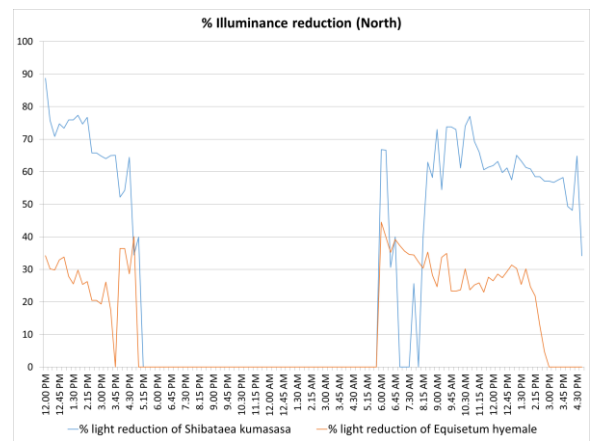
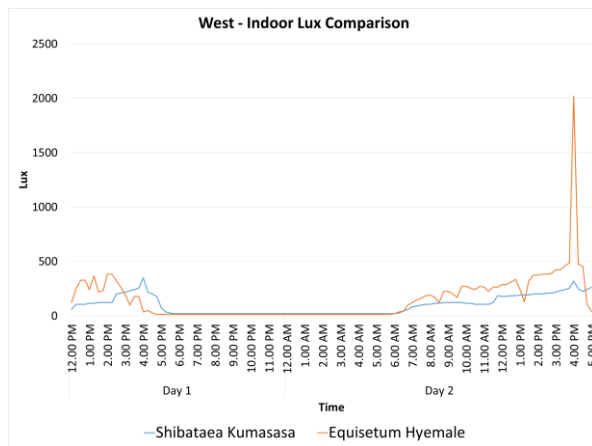
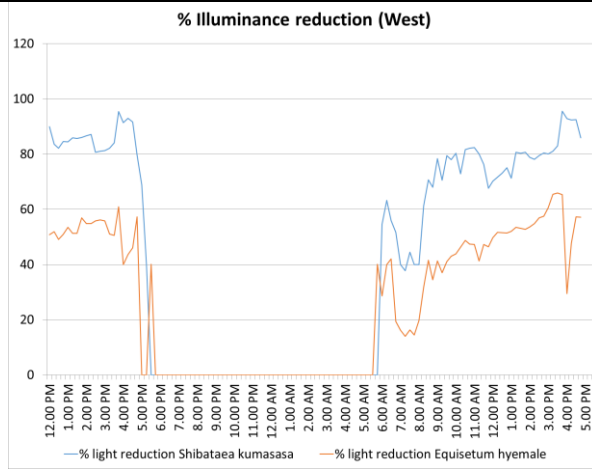
Relative Humidity (%)



As for the relative humidity, the *Equisetum hyemale* shows higher relative humidity than the application of *Shibataea kumasasa*. In the local Indonesian language, *Equisetum hyemale* is called ‘bambu air’, meaning water bamboo, as it grows best in the humid – watery soil. The average RH difference on the Westside is 3,79% with a maximum difference of 11,48% and in the Northside average 6,78% with the maximum difference of 15,09%. Yet, an anomaly is found due to the weather condition on the first day of measurement, between 12-1.30 PM where the RH in *Equisetum hyemale* drops, but still not as low as the RH in the application of *Shibataea kumasasa*.



Illuminance (lux)

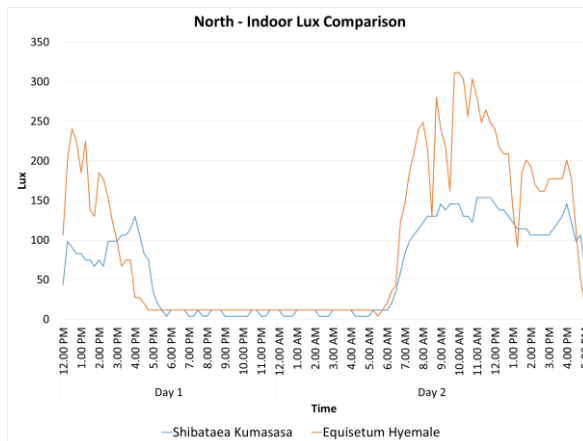


From the graph shown percentage of illuminance reduction of both conditions, found that *Shibataea* gives more light reduction than *Equisetum hyemale* all day long. For West orientation, the difference of light reduction ranged from 24-51% in the afternoon. In the morning until noon, the difference slightly lower ranged from 14-39%.

For North orientation, the % illuminance reduction results in almost the same as West orientation. Only sometime in the morning, the *Shibataea* drops in light reduction compared to *Equisetum*; it could be happened because of interruption from daily plant maintenance at that time. From the result, *Shibataea* gives more light reduction 36-55% in the afternoon; and 20-53% light reduction in the morning to noon compared to *Equisetum hyemale*.

For West orientation with high sun penetration, the *Shibataea* brings much shading to indoor illuminance compared to *Equisetum*. But with LAI >3, the light was too much decreased. So, the light condition with *Equisetum* which has DF ranged from 3-5%, was much better.

For North orientation, the *Equisetum* has indoor



illuminance higher than *Shibataea* averagely. But only fulfill DF 2% of the standard; so that the drafting activities will not perform adequately with this light condition.

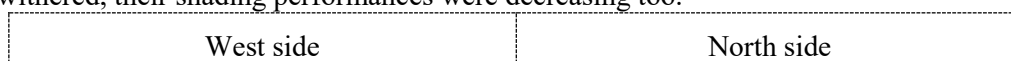
The recapitulation of the measurement can be seen in table 4.

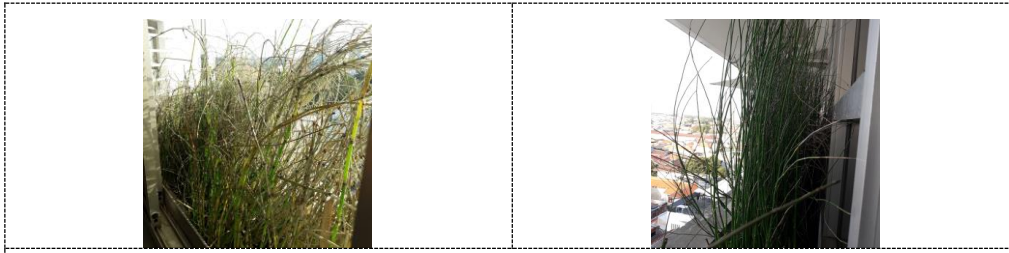
Table 4. The Summary of Measurement Result

Vegetation	Orientation	Average temp. reduction (°C)	Average RH addition (%)	Average light reduction (lux)	Average DF
<i>Shibataea Kumasasa</i>	North	0.5	10%	26-77%	2%
	West	1°-5°C	10%	37-95%	
<i>Equisetum Hyemale</i>	North	0.72	5.77%-12.09%	31%	3-5%
	West	0.95 to (+)0.43	0.02%-6.25%	47-73%	

### 3.4. Discussion

There are a few things that can be highlighted in this research. First is, how the presence of *Shibataea* related to cooler indoor temperature, whilst in the *Equisetum*, related to the higher indoor temperature at afternoon to nearly noon on the next day, all in the West oriented part of the room. In relation to the fact that West is the orientation with the highest heat gain, the vegetation characteristics also give effects on the shading performance. The *Shibataea* with bigger LAI can give the room better shading performance, therefore bring cooler indoor air temperature. On the other hand, the *Equisetum* that has no leaf (LAI<1) can not provide the shading as in *Shibataea*. The solar radiation can penetrate more through the *Equisetum*, creating hotter indoor air temperature, but still better than no *Equisetum* at times where the solar radiation directly hits the West opening (1.30 – 4 PM). The West side of the facade can not solely depend on the presence of VGS though, as the condition of both vegetations placed on the West was found slowly withered, and not so well flourished. As the vegetation was slowly withered, their shading performances were decreasing too.





**Figure 14.** *Equisetum* on the West vs North side, by the end of measurement days

The second is, how the presence of *Equisetum* brings more humidity to the indoor area, compared even to the use of *Shibataea*. Lower humidity allows the evaporation to happen, as in the human body, sweating. In higher relative humidity, as it is harder to sweat, the body will feel the heat more, because it can not be released to air, as the air already has water vapor in it. Therefore, the application of *Shibataea* will give a more positive impact on indoor humidity. Furthermore, though the application *Shibataea* causes lower relative humidity in the West and North area, the humidity has not met the standard for comfort, only makes the condition more comfortable than high humid condition.

#### 4. Conclusion

From this research, we can see that the presence of VGS brings different impacts on the indoor side of the openings. The characteristic of the vegetation applied especially foliage's thickness, brings certain consequences to indoor light and thermal condition. From the data examined, since the West orientation which has more intense sun radiation need shading than the North orientation, especially in the afternoon; the VGS will give benefit as shading for thermal and light. The leaf area index, which represents the foliage thickness plays the role in balancing its effectivity.

For West orientation, to fulfill the indoor illuminance requirement, the *Equisetum hyemale* with LAI < 1 was more effective than *Shibataea* that was too dense with LAI > 3. But for North orientation, both VGS made the indoor illuminance much lower than the standard required. In this case, no VGS applied will bring better light conditions.

As for thermal shading, the application of *Shibataea kumasasa* has better advantages as a thermal shade. It proved to reduce the indoor temperature more than *Equisetum*, and has lower relative humidity that allows evaporation more likely to happen. It is also found that the solar radiation in the Westside opening creates a greater impact on the indoor area. So, the application of VGS in the West part of the building can be integrated with architectural sun shading, which helps to first create shades and then lower the solar radiation.

Prior knowledge found that different VGS species can bring different impacts in thermal and light indoor, but from this research found that even for a specific species, can gives different effect on thermal and light performance at each orientation. In this case, the vegetation life cycle represents by its leaves condition determines its shading performance.

Further research should take more detail of leaf area density and leaf surface angle besides the leaf area index, to explain how this mechanism performs in filtering the light and radiation toward the sun path. Future research can also do the measurement at the same time for minimizing the solar radiation and sky condition difference, assuring a more valid variety comparison. This research focuses on the vegetation comparison; therefore, this research's base condition is the condition without the vegetation, and how the VGS can impact the indoor temperature, relative humidity, and illuminance. Considering outdoor temperature as one of the examined variables can enrich the research, as the outdoor temperature may impact the indoor temperature as well.

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