# THE EFFECTS OF WATER STRESS ON LEAF WATER RELATIONS, TRANSPIRATION AND PHOTOSYNTHESIS OF KAPUR PAJI (*DRYOBALANOPS LANCEOLATA* BURCK) WILDINGS IN KAWANG FOREST RESERVE, SABAH.

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**ABSTRACT**

*The occurrence of drought due to the changing global environment has led to water stress in tropical forest. The effects of water stress on Kapur Paji (Dryobalanos lanceolata Burck) species has been carried out to study the changes in its water relation, the rate of transpiration and photosynthesis. Two blocks of study areas, each with 2 subplots of 5 m X 10 m were established in Kawang Forest Reserve, Papar, Sabah. Each block had 1 subplot acting as a treatment plot and the other as a control plot. A total of 240 wildings of Dryobalanops lanceolata with a mean height of 64.5 cm height and 5.6 cm diameter were sampled throughout 3 months of the study period. The water stress was induced by a ground covering method using a high quality transparent plastic sheet adapted from the rainfall reduction technique. The results showed that the water potentials become more negative over time, with some fluctuation during the second week after experiment begun. The water potentials ranged between -0.28 ± 0.08 MPa to -0.64 ± 0.20 MPa. The relative water content showed a fluctuating trend throughout the data collection period with mean ranged between 94.3 ± 4.00% to 97.8 ± 1.31%. The mean transpiration and photosynthesis were ranged between 1.20 ± 0.20 to 1.83 ± 0.70 mol $m^{-2}$ $s^{-1}$ and 3.30 ± 1.90 to 17.31 ± 6.77 µ mol $m^{-2}$ $s^{-1}$ respectively. The ANOVA revealed that there was a significant difference in the interaction of time and treatment in producing water stress effect for water potentials, relative water content and on the rate of photosynthesis of Dryobalanops lanceolata. The predawn water potential was significant with $p < 0.001$, while the midday water potential had the reading of $p = 0.0005$. Relative water content also produced a significant interaction where $p = 0.0005$. The rate of photosynthesis also proved to have a significant interaction of time and treatment in producing water stress with the value of $p < 0.001$.*

Key words: Water stress, Leaf water potential, Relative water content, Transpiration, Photosynthesis, Kapur Paji, *Dryobalanops lanceolate,* Kawang Forest Reserve.

## Introduction

One of the major concerns that are being widely spoken by all layers of community is the phenomena of global warming and its impact on the environment. The air temperature of earth's environment is getting warmer significantly compared to many years ago (Adam, 2010). According to Adam (2010), the warming of the global environment has come to an intensified level, as many greenhouse gases such as carbon dioxide, methane and chlorofluorocarbon are released into the atmosphere. Adam (2010) has also mentioned that air temperature plays an important role in determining vegetation growth and distribution. Due to the changing environmental condition, there is a high concern towards the yielding and the growth of vegetations and this depends much on the plants adaptation towards the changing environment. The change that takes place in these plants is needed to be identified, so that the adaptation and its survivality can also be determined to prevent any species extinction.

Drought events in Borneo are usually connected with the occurrence of the El Niño-Southern Oscillation (ENSO) phenomenon which happens around the month of March to May (Walsh, 1996). ENSO is the term used for the climatic change that take place in the ocean's atmosphere system occurring at certain interval of years, for instance varying from 2-7 year interval (Corlett, 2011). A research by Nakagawa (2000) proved that the occurrence of El-Niño in the 1997-1998 had caused a drought in Sarawak area. Walsh (1996) stated that if the drought that takes place in the Northern Borneo and Sabah is very severe, it may produce damaging impact to the trees which include crown dieback and tree death. It has also been reported that the tropical regions are also subjected to the phenomena of drought occasionally which could affect tree growth and may lead to tree mortality (Medina, 2006). In the nutshell, tropical forests which is dominated by dipterocarps (Eschenbach, Glauner, Kleine and Kappen, 1998) are also vulnerable to the occurrence of drought.

According to McGinley (2011), Malaysia is known to have a very uniform high temperature, together with high humidity and rainfall throughout the year. Areas of Sabah and Sarawak, are usually known to experience heavy rainfall during the northwest monsoon. Earlier study by Maripa, Arndt, Tay and Gunsalam (2015) in the Crocker Range of Sabah revealed that the water relations of dipterocarps during dry season were significantly lower compared to wet season. This showed that trees may experience drought stress if the dry season continue. The objectives of this study were to identify the impacts of water stress on the water relations, photosynthesis, and transpiration of Kapur Paji or *Dryobalanops lanceolata* Burck. wildings. This research was aimed to investigate whether or not the impact of simulated drought that lead to water stress is large enough to bring changes in the transpiration and photosynthetic rate of the plant as it is still growing in its natural habitat. Thus, this study was needed as it will be able to provide information on the changes that occurs on the plant in terms of the water relation and the basic plant physiological process.

**Methodology**

The study had been conducted at Kawang Forest Reserve (KFR) which is located at Papar, Sabah as shown in Figure 1. It is located about 30 km away from the south of Kota Kinabalu City, Sabah. The coordinates of the KFR which is also known as Pusat Sejadi Kawang is N 05° 46' and E 116° 04'. The slope of the forest area tends to be more than 25 degrees. KFR is now reserved as a class 1 forest reserve. Sabah normally undergoes dry spell seasons during the month of January, February and March. Where else the wet spell seasons are known to be in the month of September, October and November. According to the Meteorological Department of Sabah, Papar was recorded to have an average annual rainfall of 3294 mm from the year 1990-2000 (Juis, 2002). Figure 1 shows the location of KFR which is marked in red in the map. *Dryobalanops lanceolata* species were chosen because they are one of the dominant species found in KFR (Maripa, Arndt, Tay, 2016) and endemic to Sabah.

Randomized complete block design (RCBD) was used in this experiment. The total number of sample size, *n* that has been used for this study was 60 which were divided into two groups, in which 30 samples were under control and another 30 samples were under the treatment of drought. The samples collected at each plot were 15 samples for each study objective. The size of the subplots within the 2 different blocks that was established was 5 m X 10 m, with 1 m buffer zones surrounding each plot. The treatment and control of each block are located beside each other so that similar environmental condition can be provided for both the plot apart from the drought simulation. An important environmental condition that has been taken into account while carrying out this study was also the direction of sunlight and the terrain of the situated plot to prevent any natural manipulation to occur and to provide similar treatment to all samples. The treated and control plots are shown in figure 2.

Drought to the wildings was simulated by inducing water stress to the plant. The technique of water stress was adapted from the rainfall reduction technique where roofs were constructed to reduce the precipitation (Gimbel *et al*., 2015; Maripa *et al*., 2016). In this experiment, a layer of plastic sheet was laid on the ground surrounding the wildings to prevent water penetration through the soil.

Water potential of the wildings was measured by using the Model 600 Pressure Chamber Instrument (PMS). The measurements of leaf water potential were taken during predawn and midday. Predawn measurement was carried out on site between 4.30 to 6.30 am, while the midday measurements were performed around 11.30 am to 1.30 pm (Arndt, Wanek, Clifford and Popp, 2000). Relative water content (RWC) in percentage was measured by using the formula; RWC = [(FW-DW)/(TW-DW)] X 100, where FW is the fresh weight, DW is the dry weight and TW was turgor weight of the leaf sample (Bars and Weatherley, 1962; Krouma, 2010). The photosynthesis and transpiration rate was measured by using TPS-2 instrument during midday as well. The wilding height and base diameter were measured pre and post experiment. The experiment was begun on 12 June 2016 with site survey and plot establishment. Data collection was carried out between 13 July to 11 October 2015. Plot maintenance was done once in every two weeks.

Figure 1: Map of Sabah Forest Reserve with location of Kawang Forest Reserve (inset). Source: Sabah Forestry Department (2016).

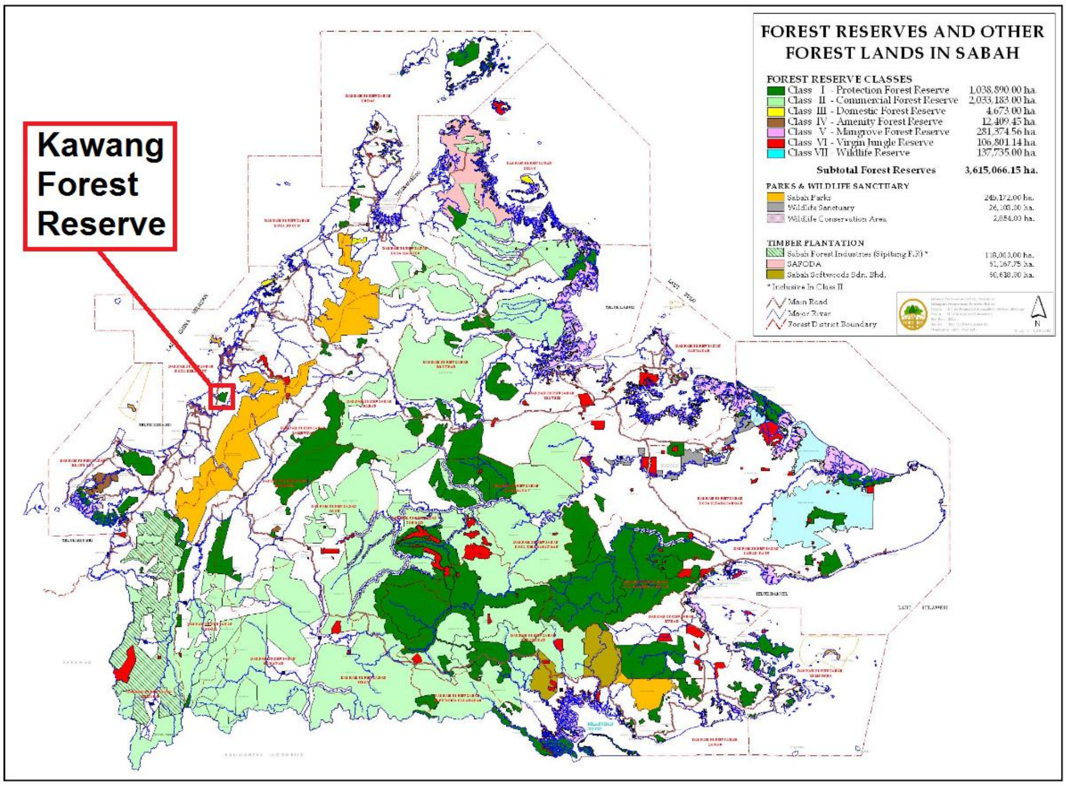



Figure 2: The condition of treatment plots a) treated and b) control plots


In the research analysis of the research findings, both descriptive analysis and inferential analysis were carried out. The steps in inferential analysis that was carried out was running Univariate ANOVA under the General Linear Model, run for the residual analysis, the outliers were then assessed, and tested on normality. The obtained results are then checked on its significance and the interaction of the time and treatment is tested again under main effects and simple main effects. Significant interaction is tested in simple main effect where one way ANOVA is carried out for each treatment. The non significant interactions were further tested under main effects and post hoc was further carried out. The software system that has been used to analyze the all the data obtained is the SPSS 20.0.

**Results**

The value of predawn water potential for the covered plots ranged from -0.05 MPa to -0.60 MPa in the thirteen weeks of data collection. Meanwhile, the predawn water potential for the exposed plots was recorded to be in the range of -0.05 MPa to -0.50 MPa. In overall the total mean of predawn water potential for the covered plot is -0.18 MPa. Where else the overall mean in the predawn water potential for the exposed plots is -0.15 MPa. The maximum and minimum mean values of both treatment and exposed plots are as tabulated below as shown in table 1. The graph of predawn water potential is as shown in figure 3.

Table 1: Descriptive analysis of all parameters. Values are in mean ± standard deviation.

| Parameters | Unit | Covered | | Exposed | |
|---|---|---|---|---|---|
| | | Min | Max | Min | Max |
| Predawn water potential | MPa | -0.14 ± 0.05 | -0.28 ± 0.08 | -0.13 ± 0.10 | -0.21 ± 0.10 |
| Midday water potential | MPa | -0.22 ± 0.15 | -0.64 ± 0.23 | -0.26 ± 0.18 | -0.54 ± 0.24 |
| Relative water content | % | 94.31 ± 4.00 | 97.13 1.65 | 93.17 ± 3.77 | 97.81 ± 1.31 |
| Transpiration | mol $m^{-2}$ $s^{-1}$ | 1.20 ± 0.20 | 1.70 ± 0.59 | 1.24 ± 0.22 | 1.83 ± 0.69 |
| Photosynthesis | µ mol $m^{-2}$ $s^{-1}$ | 3.30 ± 1.90 | 17.31 ± 6.78 | 5.37 ± 2.55 | 11.14 ± 7.40 |

The result of the Univariate ANOVA analysis showed a very positive result in its significance for the treatment, time as well as to the interaction between time and treatment. The interaction has a significant difference $F(6,406) = 4.917$, $p = 0.0005$, and $\eta^2 = 0.068$ stating that both the time and treatment have functioned in producing a significant difference in the predawn water potential of *Dryobalanops lanceolata* wildings. The effect of treatment alone also proved to be significant on its effect on the predawn water potential of *Dryobalanops lanceolata*. The significance of time was $F(6,406) = 15.385$, $p = 0.0005$, and $\eta^2 = 0.185$ on the predawn water potential.

As the interaction of the time and treatment for the predawn water potential was significant, simple main effects (SME) study was carried out to identify the presence of significance between each time period and also each treatment imposed. The simple main effect reveals that both the covered as well as the exposed are independently significant. SME was run for each week beginning from week 0 to week 12 to identify whether the covered and exposed have significance within each week. From the *F*-test of SME, the weeks that had significance between covered and exposed wildings is week 2 and week 4. Week 2 is significant with $F(1,406) = 36.180$ and $p < 0.001$. Where else the significance of week 4 is $F(1,406) = 4.784$, with the $p$ value of 0.029. A further analysis of SME is carried out within the treatments which is covered and exposed. Both treatments were shown to be significant as the overall significance of covered is higher than the significance of exposed in which for covered $F(6,406) = 15.666$ with $p < 0.01$, where else for exposed is $F(6,406) = 4.635$ with $p < 0.01$.

The value of midday water potential for the covered plots ranged from -0.05 MPa to -1.30 MPa in the thirteen weeks of data collection. On the other hand, the midday water potential for the exposed plots was recorded to be in the range of -0.05 MPa to -1.20 MPa. In overall the total mean of midday water potential for the covered plot is -0.41 MPa. Where else the overall mean in the midday water potential for the exposed plots is -0.34 MPa. The value of both minimum and maximum mean for covered and exposed plots are as tabulated in table 1. The graph of midday water potential is as shown in figure 3.

According to two way analysis that has been done, statistically there was significant interaction between treatment and time on the midday water potential, $F (6, 0.145) = 3.440$, $p = 0.003$, $\eta^2 = 0.048$. Apart from that, time also shows significant interaction $F (6, 0.714) = 16.984$, $p = 0.0005$, $\eta^2 = 0.201$ and treatments also significant on its effect on the midday water potential of *Dryobalanops lanceolata* with $F (1, 0.539) = 12.828$, $p = 0.0005$, $\eta^2 = 0.031$.

Simple main effect analysis also had been run on treatment and time. All the pairwise comparisons have been analyzed for all the simple main effect with 95% confidence level and Bonferroni correction p-value for all the simple main effect. From the result, the simple main main effect treatment on time was significant in week 4 with $F (1, 0.353) = 8.389$, $p=0.004$, partial $\eta^2 = 0.020$, week 6 with $F (1, 0.176) = 4.187$, $p = 0.041$, partial $\eta^2 = 0.010$, week 10 with $F (1, 0.459) = 10.927$, $p = 0.001$, partial $\eta^2 = 0.026$ and week 12 with $F (1, 0.165) = 3.934$, $p = 0.048$, partial $\eta^2 = 0.010$ showing that there was significant difference on water pressure in week two and week four for both covered and exposed wildings. In simple main effect of time on both treatment for covered and exposed wildings were significant where for covered, $F (6, 0.581) = 13.830$, $p = 0.0005$, partial $\eta^2 = 0.188$ and exposed is $F (6, 0.277) = 6.594$, $p = 0.0005$, partial $\eta^2 = 0.089$.

The relative water content for the covered plots ranged from 84.08 % to 99.93 % during the thirteen weeks of data collection. Meanwhile, the ranges of relative water content value for the exposed plots were from 72.06 % to 99.96 %. The total mean of relative water content recorded for the covered plot is 95.71 %. Where else the overall mean in the relative water content for the exposed plots is 95.44 %. The maximum mean and minimum mean value was tabulated in table 1. The graph of relative water content is as shown in figure 4.

Figure 3: Graph of a) predawn water potential against time b) midday water potential against time c) rate of transpiration against time d) rate of photosynthesis against time.

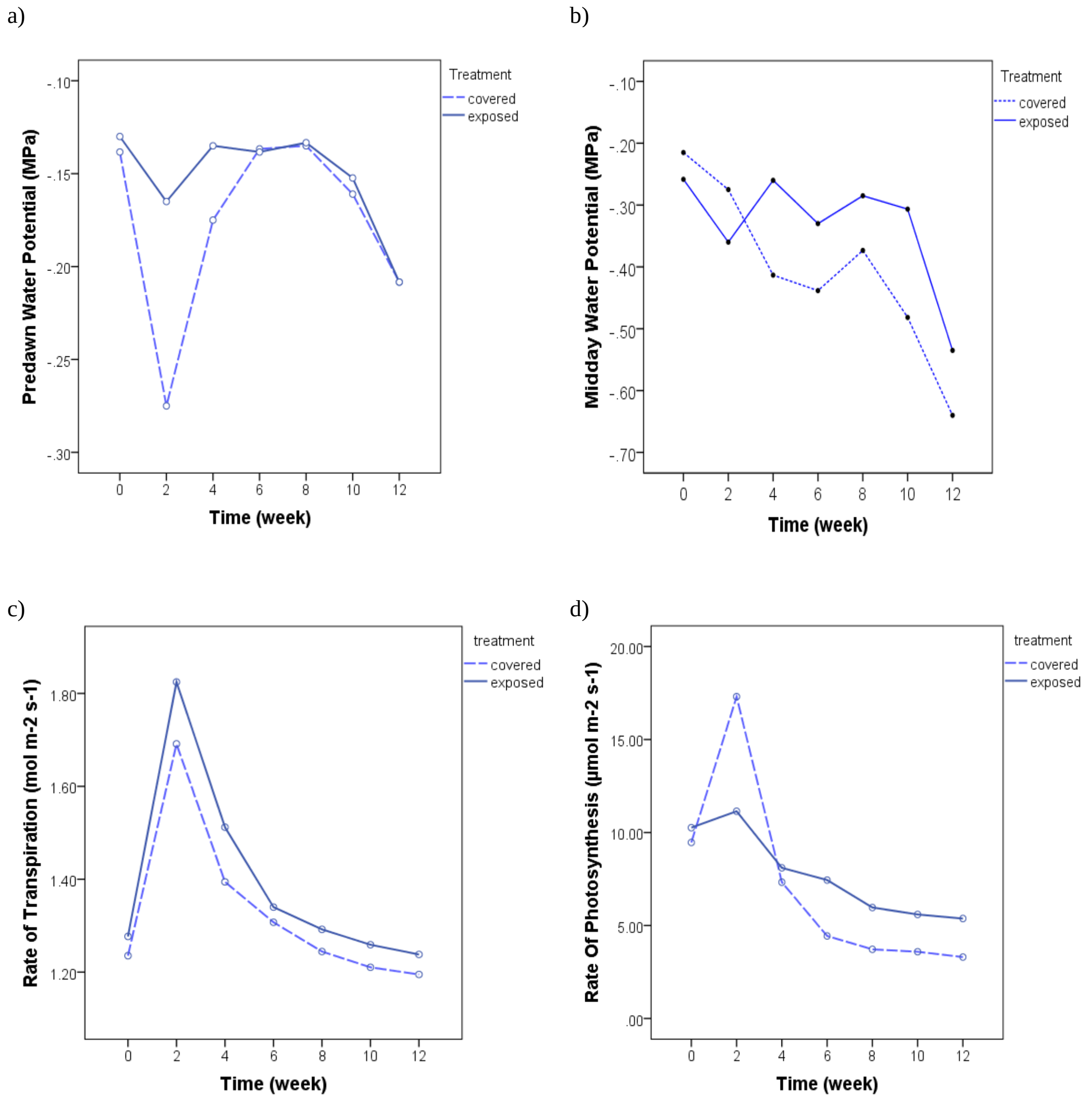
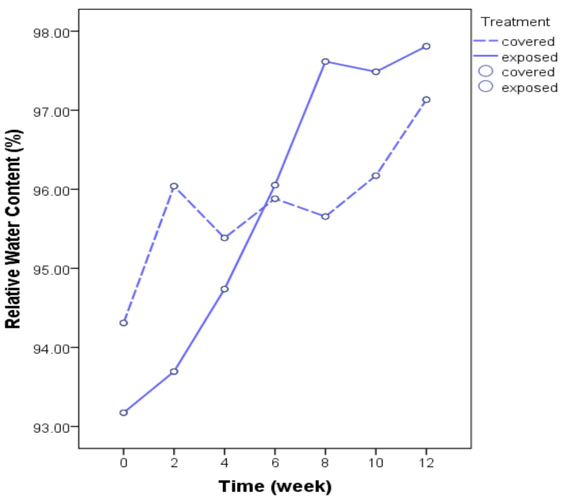



Figure 4: Graph of relative water content against time



The Univariate ANOVA analysis was also carried out for the RWC data. From the analysis, the RWC showed a significant interaction between time and treatment. The significance level of the interaction between time and treatment for the relative water content on the *Dryobalanops lanceolata* wildings was significant with $F(6,406) = 4.816$, $p = 0.0005$ , and $\eta^2 = 0.066$. The time in the test of between subjects was also significant with value $F(6,406) = 14.858$, $p = 0.0005$ , and $\eta^2 = 0.180$. Meanwhile, the treatment imposed did not have a significant level, $F(1,406) = 0.0005$, $p = 0.997$ , and $\eta^2 = 0.000$ for the relative water content of the *Dryobalanops lanceolata*. This show that the relative water content was not affected much by the treatment imposed. The graph plot of RWC is as shown in figure 4.

The simple main effect analysis that was run for the time, for each week to identify the week that has the significant different revealed that the treatment that has functioned to produce the significant difference in RWC of *Dryobalanops lanceolata* between covered and exposed was during week 2 and week 8. The significance of week 2 was $F(1, 406) = 11.985$ with $p = 0.001$. Where else, the significance obtained at week 8 is $F$ (1, 406) = 8.373 with $p = 0.004$. SME within the treatment reveals both the covered and exposed to be significant. But differing from the SME significance of predawn water potential, in RWC the exposed plot seems to be having higher significant difference in producing the water stress effect as its significance was $F(6,406) =16.481$ with $p =0.0005$. The covered plot had a significance of $F(6,406) = 3.193$ and $p= 0.004$.

The value in the rate of transpiration of *Dryobalanops lanceolata* for the covered plots ranged from 1 to 2.5 in the thirteen weeks of data collection. Meanwhile, the rate of transpiration recorded for the exposed plots was recorded to be in the range of 1 to 2.6. The total mean of rate of transpiration recorded for the covered plot is 1.33.Where else the overall mean in the rate of transpiration for the exposed plots is 1.39.The obtained maximum and minimum mean values were tabulated in table 1. The graph of transpiration rate is as shown in figure 3.

The test of between subjects effect test the significance of time, treatment imposed on the wildings of *Dryobalanops lanceolata* and the interaction of time and treatment on the transpiration was not significant, $F(6,406) = 0.211$, $p = 0.973$, and $\eta^2 = 0.003$. The time was significant in producing an effect on transpiration when $F$ (6,406) = 18.784, $p = 0.0005$, and $\eta^2 = 0.217$. Figure 6 shows the graphical representation of the rate of transpiration. This indicates that the time which was the weeks of data collection had significant differences between each week. The treatment showed a significance of 0.05 when $F$ (1,406) = 3.878, $p = 0.05$, and $\Pi^2 = 0.009$ which also means that it was significant and the treatment imposed on the plants did bring a significance difference to the transpiration readings. The interaction seems to show no significance yet the condition was further explained through main effects analysis.

The main effects of transpiration revealed that the effect of time in producing water stress was not prominent enough to cause a significant difference between the covered and exposed of each week. Yet, both the treatments covered and exposed independently prove to be significant in overall analysis for covered plot, it was significant with the value of $F(6,406) = 7. 714$ with p value of 0.000. In the meantime time for the exposed plot, the significance was $F(6,406) = 11.281$ and p = 0.0005.

The rate of photosynthesis recorded on the wildings for the covered plots ranged from 0.7 to 27.8 during the period of data collection. Meanwhile, the photosynthetic rate of *Dryobalanops lanceolata* wildings in the exposed plots was recorded to be in the range of 1 to 20.3. In overall the total mean of rate of photosynthesis for the covered plot is 7.02. Where else the overall mean in the rate of photosynthesis for the exposed plots is 7.70. The value of both minimum and maximum mean for covered and exposed plots are as tabulated in table 1 .The values are given in the form of mean ± standard deviation, unless stated. The graph of rate of photosynthesis is as shown in figure 3.

Following the same steps of analysis as for the other parameters, the test of between subjects effect is again obtained for photosynthesis by carrying out univariate ANOVA. From the results obtained it is known that the interaction of time and treatment showed a significant difference in the rate of photosynthesis of *Dryobalanops lanceolata* wildings, $F(6,406) = 5.828$, $p = 0.0005$, and $\eta^2 = 0.079$. This shows that the interaction that has taken place is significant in affecting the photosynthesis of the *Dryobalanops lanceolata*. The result also shows that the time alone is significant as well. Time had the significance of $F(6,406) = 31.393$, $p = 0.0005$, and $\eta^2 = 0.317$. Where else for the treatment it did not show a significant difference in the rate of photosynthesis of *Dryobalanops lanceolata* as $F(1,406) = 1.916$, $p = 0.167$, and $\eta^2 = 0.005$. This shows that the treatment has failed to function in producing the significant difference in the photosynthesis of the two different treatments imposed on the wildings of *Dryobalanops lanceolata* for the total of 14 weeks which includes the 7 weeks of data collection.

The plotting of photosynthetic rate against the time which is from week 0 to week 12 is represented in figure 3d. The plot generally shows a decreasing trend except for the hike in week 2. The hike is higher in covered wilding compared to the exposed wildings. The drop in photosynthetic rate is more prominent in from week 2 to week 8, as the difference was higher. Where else, in week 10 and week 12 the photosynthesis of *Dryobalanops lanceolata* was reduced only slightly.

Similarly with the other parameters, SME was also tested between treatments, and it revealed that both the covered and exposed to be significant. The significance of the covered is higher in producing water stress as the significance value obtained was $F$ (6, 406) = 30.937. Where else for the exposed plot, the test shows that $F$ (6, 406) = 6.283 with $p = 0.0005$.

The growth of the wildings to be sampled was taken at the beginning of the research as a pre-measurement detail in week 0 and at the end of the research in week 12. The growth measurement included the height of the wildings, the diameter of the stem of the wildings, and the number of leaves present on the wildings. For the growth data, frequency analysis was made and the difference of the growth measured in week 0 and week 12 is tabulated to show the overall pattern and changes that the wildings go through. Data was stated as mean ± standard deviation unless stated otherwise.

The height measured was run under the frequency analysis to identify the mean and standard deviation of the height of the wildings, to determine the minimum and maximum values as wells as to test the normality of the samples. The data are tabulated as shown below in table 2. From the difference of mean of the height, it is evident, that the overall growth of the *Dryobalanops lanceolata* wildings in terms of height has decreased in the final week of data collection. This is an indication that the growth rate of the plant might have been slow down due the water stress induced. Similar to the height of the wildings, the diameter was also measured and run for analysis. The obtained data were as tabulated in table 2.

Table 2: Summary of *Dryobalanops lanceolata* wildings growth throughout the experiment. Values are in mean ± standard deviation.

| Parameters | Unit | Week 0 | Week 12 |
|---|---|---|---|
| Height | cm | 64.47 ± 24.39 | 64.27 ± 25.18 |
| Diameter | mm | 5.62 ± 1.70 | 6.04 ± 1.94 |

The diameter of stems of *Dryobalanops lanceolata* wildings proves to be not very influenced by the water stress imposed. This was because the difference shows that there was a positive growth in the mean of diameter of week 0 and week 12. Although it's a positive growth in terms of diameter, the growth was still not very large as the average growth was only 0.4197 mm for a period of 12 weeks. The number of leaves were also taken and analysed as a part of growth performance checking. Statistically, there was a decrease in the number of leaves of the wildings although not very large difference. The obtained data was as tabulated in table 2.

While the research was being carried out, the observed weather was recorded for the reference purposes. The important weather information taken includes the observed weather condition which varies from being sunny, cloudy, stormy and rainy. Apart from that, the temperature of the area as well as the relative humidity of the surrounding area was taken using the dry and wet hygrometer. The average of the obtained data was tabulated as shown in table 3.

Table 3: Observed weather data prior to sampling in Kawang Forest Reserve

| Week | Dates | Weather | Temperature (°C) | Relative Humidity (%) |
|---|---|---|---|---|
| 0 | 2-5 July 2015 | Sunny | 29 | 93 |
| 2 | 30 July to 2 August 2015 | Stormy | 30 | 93 |
| 4 | 13-16 Agusut 2015 | Rainy | 30 | 65 |
| 6 | 26-28 August 2015 | Rainy | 30 | 65 |
| 8 | 11-13 September 2015 | Cloudy | 30 | 65 |
| 10 | 23-25 September 2015 | Sunny | 31 | 57 |
| 12 | 9-11 October 2015 | Sunny | 30 | 65 |

**Discussions**

The results of the data analysis revealed that the research carried out did have significance according to the expectation. Transpiration and photosynthesis decreased gradually after the week 2 as a result of increasing water stress. This indicates that the treatment imposed had function of producing the water stress effect. Apart from that, it should also be noted that the result did not only solely depend on controlled water irrigation, but it was left to be determined by the natural environmental condition. Thus, the identified deviations in certain parts of the parameters such as the predawn water potential and relative water contents is closely related to other influencing factors as well. Even the transpiration and photosynthesis is somehow affected by weather conditions and other possible factors such as light intensity, plant adaptance towards water stressed condition and more as the decreasing trend is not only present in the covered plot but also in the exposed plots of wildings. The parameters do indicate the stress levels, but for better analysis on its water status, all the other parameters that is to be stated should be correlated to produce the synergistic effect on the dependent variables.

The research has given a better perspective on the water stress tolerance level of the wildings. The management and maintenance of leaf turgidity is essential for not affecting the metabolic activities in the mesophyll during drought season (Hanson & Hitz, 1982). One of the early precaution to prevent the loss of turgidity in the tree is by closing the stomata in response to the dry air, reducing the soil water potential or both (Tenhunen et al., 1987) especially for plants in tropical forest that closes the stomata either every day or in season (Robichaux *et al*., 1984) in response to the water deficit in the atmosphere and soil. Every plant needs to control the water status to continue grow well (Kirkham, 2014). The lower the humidity in the air, the more negative the water potential in the leaf. During midday, the stoma closes more significantly than at predawn. The leaf turgidity is maintained through any mechanisms that help in increasing the flow of water to the leaf. This can be done by reaching the more negative water potential level than the water inside the solute xylem that has an active concentration in the mesophyll cell during drought season (Tyree & Jarvis, 1982). Plants that have a good water system have a high osmotic potential (González, L. & González-Vilar, 2001).

Furthermore, although the treatment imposed has successfully functioned to reduce the water availability for the wilding, there are a number of important things to look upon. For example, the availability for the wildings cannot be controlled to maximum has the seasons and natural condition changes. Secondly, there is still a high possibility of water to reach the plants through interceptions. Moreover, the soil water content also plays and important role in producing the drought effect. The plot location, slope, and soil type can also contribute to the water availability to the plants. Even if the plot is secured with plastic covering and buffer layers, but if the plot is located in a very sloppy area, the plants or wildings may still receive water through the underground water. Canopy criteria are equally important with the leaf criteria in determining the drought tolerance. Collectively, a leaf can reduce the water loss during the gas exchange by less sensitive to the evaporation during dry season (Mulkey & Wright, 1996). Besides that, the *Dryobalanops lanceolata* species are known to have a good tolerance level towards water stressful conditions. This can surely be supported because there was no recorded plant death due to water stress that has inhibited transpiration and photosynthesis. The plant deaths that have occurred in the research is only due to mechanical damage on the wildings. These mechanical damages occurred during the fixing of plastic cover on the plots. So, it can be inferred that, although water stressful conditions have been created the plants did not face mortality due to its drought tolerance mechanism and also other influencing environmental factors.

**Conclusions**

By the end of this research, all objectives were certainly achieved. From this research, the changes in leaf water relations in terms of water potential and relative water content were able to be identified when the plants undergo the drought effects. Furthermore, the rate of transpirations of the wildings was studied, enabling us to identify on how and what rate the water loss of the plant via transpiration was reduced. The objective on photosynthesis, which were to calculate the rate of transpiration has also been achieved and the effect of water stress level on the wildings were identified providing us the information on the changes in its yielding and plant growth. As expected. Although there were recorded changes, it has been identified that the changes were still minimal to produce damaging effects to the wildings.

Generally, the expected and the obtained results were indeed positive. The statistical analysis of predawn water potential, relative water content, transpiration and photosynthesis showed that the treatment imposed had a significant difference as the water stress increases along with the increase in time. According to the hypothesis, the water relations of *Dryobalanops lanceolata* wildings were affected by water stress. The photosynthesis rate of *Dryobalanops lanceolata* was also affected by water stress. For transpiration, all the interactions were not significant, yet the transpiration rate decreased proving that it was affected by the water stress. Although, water stress was introduced to wildings, *Dryobalanops lanceolata* were still able to survive as it is tolerant towards drought effects. The water relations, transpiration and photosynthesis rate *of Dryobalanops lanceolata* wildings was indeed affected by the water stress.

There a number of limitations were identified while this project was carried out. Firstly, after the second week, a very strong storm had hit the area of study causing some damages to the plots and wildings. This was indeed a limitation as the weather conditions were unexpected and may bring a huge damage as well as it can alter the assumed results. Secondly, the time was also a limitation for this research. This is because to study and understand the effect of water stress on the wildings, a longer time is needed to get the trend in various environmental conditions. A longer research period would have given a better significant difference on the wildings.

**Acknowledgements**

We would like to express our gratitude to staff of the Sabah Forestry Department, especially those in Pusat Sejadi Hutan Lipur Kawang and Kota Kinabalu Sabah Forestry Department for granting access and providing facilities to conduct our research in their area. Appreciation also goes to the management of the Universiti Malaysia Sabah for allowing us to utilize laboratory facility and resources throughout the experiment.

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