

Comparative assessment of carbon dioxide (CO₂) absorption capacities in *Koompassia malaccensis* and *Hopea nervosa* in Tekam Forest Reserve, Pahang, Malaysia

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Manuscript received: 29 February 2024. Revision accepted: 2 June 2024.

Abstract. Ruziman HH, Mohti A, Yo NES, Pardi F. 2024. Comparative assessment of carbon dioxide (CO₂) absorption capacities in *Koompassia malaccensis* and *Hopea nervosa* in Tekam Forest Reserve, Pahang, Malaysia. *Nusantara Bioscience* 16: 185-191. Trees, the dominant life form in forests, are essential in the functioning of the terrestrial biosphere, especially for the carbon cycle of the ecosystem. This study aims to assess CO₂ absorption by two forest production species: *Koompassia malaccensis* Maingay and *Hopea nervosa* King. The experiment was carried out in an acrylic box, and the variation of carbon dioxide concentration, humidity, light, and temperature was measured using a Carbon Dioxide, Light, Temperature, and Humidity (CLTM) sensor. The experiment was conducted in an open area from 7:30 am to 6:30 am the next day (23 hours). The results showed that *H. nervosa* absorbed more CO₂ (71.13 ppm/hour) than *K. malaccensis* (51.54 ppm/hour), thus promoting its ability to address climate change in the microenvironment. As for the relationship between carbon dioxide absorption and photosynthesis variables, both species show a positive correlation between CO₂ absorption and humidity. In contrast, light and temperature were very weakly correlated to CO₂. Therefore, it was identified that *H. nervosa* (Dipterocarpaceae) and *K. malaccensis* (Fabaceae) are tree species with high CO₂ absorption capacity and thus can be considered suitable trees for replanting, especially in light of carbon mitigation initiatives.

Keywords: Carbon dioxide absorption, climate change, forest, trees

INTRODUCTION

Carbon dioxide is necessary for the biochemical process of photosynthesis, such that all plants require CO₂ to thrive. However, excessive CO₂ emissions harm the environment because they are mostly greenhouse gases released at the highest rate. This has led to an environment where greenhouse gases, mainly carbon dioxide, have increased significantly, and the Earth's climate is changing due to rising temperatures. According to the Malaysian Meteorological Department Scientific Report 2018, higher temperatures have been recorded in Peninsular Malaysia due to global climate change, with the western Peninsular Malaysia region having seen the highest increase in temperature (Rahman 2018). Because these emissions increase the greenhouse effect and contribute to global climate change, they affect the health of people, crops, forest species, numerous ecosystems, and the environment. Based on recent reports from the International Panel on Climate Change (IPCC), the global mean concentration of carbon dioxide is almost 400 parts per million (ppm). However, the most thorough studies indicate that the safe level of carbon dioxide concentration is below 350 ppm.

Malaysia is also not exceptional in being affected by climate change. This country is recorded as the fourth largest emitter of greenhouse gases in ASEAN, contributing to 0.52% of the total carbon emissions in the world (Rahman 2018). The importance of forest resources in providing valuable natural resources and ecological services contributed to the development of socioeconomic, forest biodiversity, conservation of land and water resources, and ecosystem stability (Ministry of Energy and Natural Resources 2022). However, the industrial revolution in the agricultural sector has become a contributing factor to the changing climate in addition to CO₂ emissions from deforestation and forest degradation (Pearson et al. 2017; Wadanambi et al. 2020).

The inevitable consequences may include temperature increase and other devastating impacts such as increasing frequency and intensity of heat waves, coastal adaptation, and extremity of flood events. The role of forests in mitigating and adapting to climate change is essential. Forests are capable of effectively sequestering and storing of atmospheric carbon in above-ground and below-ground biomass through photosynthesis and tree growth. According to Kanniah et al. (2014), trees from family of Dipterocarpaceae have high potential to absorb a

significant amount of CO₂ from the atmosphere thereby contributing to mitigating the localized effects of global warming. Fabaceae family is found to be the most popularly grown plants in the urban forest due to their rapid growth and good absorber of air pollution. According to Daud et al. (2019), *Pterocarpus indicus* from family of Fabaceae absorbed the most carbon dioxide per tree per year with 16,608,610.88 kg/tree/year compared to other families. In comparison of carbon dioxide absorption among several tree species, a study in Indonesia's tropical lowland forests found that CO₂ absorption rate ranged from 3.42 to 20 $\mu\text{mol m}^{-2} \text{s}^{-1}$. *Dadap merah* (*Erythrina cristagalli*) from Fabaceae's family was the third highest absorption of CO₂ (15.49 $\mu\text{mol m}^{-2} \text{s}^{-1}$) after *entabuloh* tree (*Teijsmanniodendron bogoriense*) and *jati* (*Tectona grandis*) (Davis and Hidayati 2020). Based on a study by Suwanmontr et al. (2013), *Peltophorum pterocarpus* and *Samanea saman* from Fabaceae's family reach their maximum CO₂ uptake rates of 24.5 and 20.9 CO₂ $\mu\text{mol m}^{-2} \text{s}^{-1}$ and are good carbon sink and they should be planted in the city for optimal CO₂ absorption. Dipterocarpaceae are known as economical timber trees and ecologically important because of their abundance can contribute to the total biodiversity of forests and function in absorbing CO₂ to the forest ecosystems (Zafriakma et al. 2020). Based on a study conducted by Trisurat et al. (2011) in Peninsular Thailand showed that *Dipterocarpus* species are more vulnerable to future climate change than species in other families such as *Parkia timorina* from Fabaceae family and *Callophylum calaba* from Guttiferae family. Dipterocarps, including *Hopea* sp. are dominant in Southeast Asian tropical rainforests. Meanwhile, *Koompassia malaccensis* is a leguminous tree, which forms a symbiotic relationship with nitrogen-fixing bacteria, enhancing the microbial diversity within tropical peat swamp forests (Too et al. 2018). Both species are highly valued for timber wood's quality and durability. Thus, they are equally crucial to Malaysia's ecology and economy (Asanok et al. 2020). However, due to the increasing demand for timber and greenhouse gas emissions leading to global climate change, these species are expected to be at risk of endangerment if adequate protective measures are not implemented. Much

research on CO₂ absorption rate was conducted mainly on the wayside trees in urban areas (Misni et al. 2015; Daud et al. 2019, 2021), but fewer studies focus on timber trees in tropical forests.

Thus, the study aims to assess CO₂ absorption by forest tree species namely *K. malaccensis* (Fabaceae) and *H. nervosa* (Dipterocarpaceae) and to determine the relationship between CO₂ absorption of tree species and environmental variables. This study may be beneficial in providing information on the carbon sequestration capacity of these timber trees, and those with higher CO₂ uptake will be advantageous as the trees can reduce environmental pollution and CO₂ emission in the environment. The importance of fully understanding the rate of CO₂ absorption and their possible responses is needed so that a comprehensive management and conservation action plan can be carried out to maintain the sustainability of the forest under changing climate in the future.

MATERIALS AND METHODS

Materials

The materials used in this study were *K. malaccensis* and *Hopea nervosa* that categorized as production forest species. They are sampled from Tekam Forest Reserve, Pahang. The average age of the saplings used in this study is between 3 to 4 months.

Apparatus

Four units of acrylic transparent box shape as a medium for sampling with size of 40 cm width x 60 cm height x 40 cm length were used as a medium for sampling. Acrylic box was used to place the seedlings and the Carbon Dioxide, Light, Temperature and Moisture (CLTM) sensor to undergo photosynthesis. The acrylic box is shown in Figure 1. CLTM sensor was used as a source of electrical. The sensor was used to measure and store the amount of carbon dioxide that will capture the saplings, the temperature and light intensity. The CLTM sensor is shown in Figure 2.

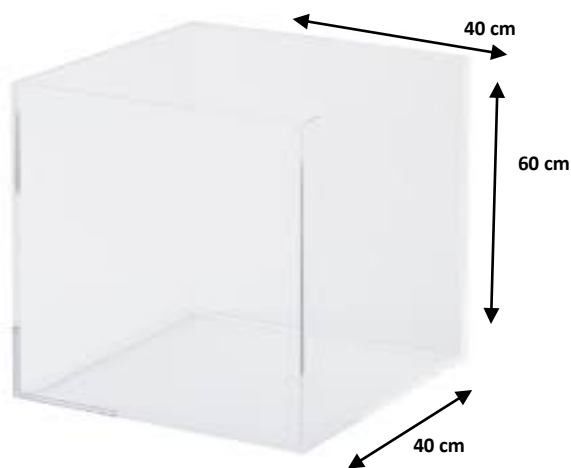


Figure 1. Two dimensional geometric model of the acrylic box



Figure 2. CLTM sensor used in the experiment

Procedures

Each sapling was located in an acrylic box, then stand under a completely clear sky for 23 hours to undergo the photosynthesis and respiration process. One acrylic box was used as a control by recording the carbon dioxide levels with no plant inside. The measurement of environmental variables including daily CO₂ concentration, temperature, light and humidity was conducted from May 8th to 9th starting from 7:30 am to 6:30 am on the next day. Carbon dioxide, Light, Temperature and Moisture (CLTM) sensor was inserted into each acrylic box to measure each environmental variable. The door of the acrylic box was closed to prevent the carbon dioxide (CO₂) from going in and out during the experiment. Any cracks in the plastic door were insulated so that the CO₂ inside the box did not escape. After the experiment was completed, all the saplings and the sensors were removed from the acrylic box to transfer the data of the environmental variables to computer. The data collected throughout the experiment was used to calculate the average of carbon dioxide concentration, humidity, light and temperature. The level of absorption of CO₂ by the saplings under different initial concentrations was calculated by using the following formula (Fathurrahman 2023):

$$\text{Total absorption of CO}_2 = \text{CO}_2 \text{ first reading} - \text{CO}_2 \text{ next reading}$$

Data analysis

Statistical analysis was performed using PAST Statistical Software to perform T-test (Hammer 2001). It is used to compare the means between the production forest species and determine whether any of those means are statistically significantly different from each other. Relationship between environmental variables of light, temperature, humidity and their influence on carbon dioxide absorption was determined using linear regression analysis.

RESULTS AND DISCUSSION

Carbon dioxide concentration and absorption level of *Hopea nervosa* and *Koompassia malaccensis*

Quantification of carbon dioxide concentration and absorption level by both species of *H. nervosa* and *K. malaccensis* are presented in Table 1. The study of variation of CO₂ concentration is separated into daytime period (08:30 am to 18:30 pm) and night-time period (19:30 pm to 05.30 am). For daytime, the concentration of carbon dioxide for *H. nervosa* decreases from 626.61 ppm to 446.54 ppm and for *K. malaccensis* decreases from 637.50 ppm to 475.58 ppm. Average values at night for *K. malaccensis* rises from 486.80 ppm to 548.09 ppm and for *H. nervosa* rises from 454.02 ppm to 601.48 ppm. The CO₂ concentration inside the box at night-time gradually increases because of the atmosphere is relatively calm when the sun is no longer heating the surface, the ground losses heat and cools down and photosynthesis do not occur at night. In contrast, the concentration gradually

decreases during the day due to the plants' involvement in photosynthesis (Yarn et al. 2013).

Carbon dioxide absorption rate

Figure 3 shows the carbon dioxide absorption rate monitored between May 8th and 9th 2023, from 7:30 am until 12:30 pm for *H. nervosa* and *K. malaccensis*. For *H. nervosa*, the carbon dioxide absorption rate ranges from 3.04 ppm to 71.13 ppm, while for *K. malaccensis*, ranges from 10.85 ppm to 51.54 ppm. This study found that the highest carbon dioxide absorption was found in *H. nervosa* from family of Dipterocarpaceae compared to *K. malaccensis*. At 7:30 am, *H. nervosa* absorbs carbon dioxide at a value of -10.54 ppm and *K. malaccensis* at a value of -10. -10.63 ppm. This negative value of carbon dioxide absorption during this time due to the saplings consuming and breaking down carbohydrates and using them in other metabolic processes (Daud et al. 2021). Thus, there is a temporary negative carbon dioxide absorption during this time because plants typically release more carbon dioxide. In addition, at 7:30 am, there is no photosynthesis because plants have not received sufficient light intensity of sunlight. At this time, the light intensity for *K. malaccensis* is 251.31 lux and *H. nervosa* only absorbs 207.51 of light. Photosynthesis cannot occur if one of the required factors (sunlight) does not exist (Daud et al. 2019).

The rate of carbon dioxide absorption value for *H. nervosa* in the afternoon from 13:30 pm until 18:30 pm ranges from 7.95 ppm to 27.30 ppm and the value of carbon dioxide absorption rate for *K. malaccensis* ranges from 6.28 ppm to 13.78 ppm. This study found that carbon dioxide absorption by *H. nervosa* was higher compared to *K. malaccensis*. According to the result, from 8:30 am until 14:30 pm, the carbon absorption by *K. malaccensis* decreased. Throughout the day, the temperature may rise and possibly go above the range that is optimal for photosynthesis. High temperatures can cause photosynthesis to be less effective, which in turn causes less CO₂ to be absorbed. One of the other potential causes of the decreased carbon dioxide absorption value in this study is that the stomata, or tiny pores on plant leaves that regulate gas exchange, may partially close in order to reduce water loss through transpiration, which would then reduce the amount of CO₂ that plants can absorb (Wahidah et al. 2017).

At night or in the absence of light, photosynthesis stops and respiration is the dominant process. The dark respiration rate, which is the rate at which leaves take in oxygen and give out carbon dioxide is represented by the negative (-ve) value in the graph. The amount of CO₂ released through respiration is typically less than the amount of CO₂ absorbed throughout the day during photosynthesis (Yacob 2021). On 8th May 2023, the rate of carbon dioxide absorption for both species was observed between 21:30 pm and 00:30 am. For *H. nervosa*, the carbon dioxide ranges from -2.53 ppm to -131.93 ppm while for *K. malaccensis* ranges from -3.15 ppm to -32.67 ppm. On 9th May 2023, the rate of carbon dioxide absorption was observed from 01:30 am until 06:30 am at a

value of -3.67 ppm to -4.00 ppm for *H. nervosa* and *K. malaccensis* at a value of - 3.70 ppm to -75.11 ppm. Therefore, the carbon dioxide absorption during the night is a result of respiration and is generally negative, indicating a release of carbon dioxide rather than absorption.

The finding shows that both species undergo carbon dioxide absorption in the morning and evening. However, it can be seen that there is also active carbon dioxide absorption in both species at night, which is around at

22:30 pm until 23:30 pm. It also demonstrates that photosynthesis works best between at 8:30 am (for *H. nervosa*), at 09:30 (for *K. malaccensis*) and at 15:30 pm. for both species during the day. Then, as the light faded, it started to gradually decrease (Yacob 2021). Photosynthesis stops or slows down in the absence of light, lowering plants ability to absorb carbon dioxide. In the absence of light, photosynthesis ceases or slows down, reducing the carbon dioxide absorption capacity of plants.

Table 1. Variation of carbon dioxide concentration and carbon dioxide absorption level of *Hopea nervosa* and *Koompassia malaccensis*

Time (h)	<i>Hopea nervosa</i>		<i>Koompassia malaccensis</i>	
	Mean of Carbon Dioxide Level in Acrylic Box	Carbon Dioxide Absorption (ppm/hour)	Mean of Carbon Dioxide Level in Acrylic Box	Carbon Dioxide Absorption (ppm/hour)
07:30 am	616.07	-10.54	626.87	-10.63
08:30 am	626.61	48.62	637.50	51.54
09:30 am	577.99	71.13	585.96	39.03
10:30 am	506.86	7.33	546.93	15.39
11:30 am	499.53	19.48	531.54	14.03
12:30 pm	480.05	3.04	517.51	10.85
13:30 pm	477.01	7.95	506.66	9.45
14:30 pm	469.06	8.17	497.21	9.13
15:30 pm	460.89	27.3	488.08	13.78
16:30 pm	433.59	-7.94	474.30	6.28
17:30 pm	441.53	-5.01	468.02	-7.56
18:30 pm	446.54	-7.48	475.58	-11.22
19:30 pm	454.02	-3.79	486.80	-12.92
20:30 pm	457.81	-4.29	499.72	-9.57
21:30 pm	462.10	-131.93	509.29	-32.67
22:30 pm	594.03	15.38	541.96	5.77
23:30 pm	578.65	3.87	536.19	1.42
00:30 am	574.78	-2.53	534.77	-3.15
01:30 am	577.31	-3.67	537.92	-3.70
02:30 am	580.98	-6.41	541.62	-3.09
03:30 am	587.39	-6.72	544.71	-1.41
04:30 am	594.11	-7.37	546.12	-1.97
05:30 am	601.48	-10.59	548.09	-3.67
06:30 am	612.07	-4.00	551.76	-75.11

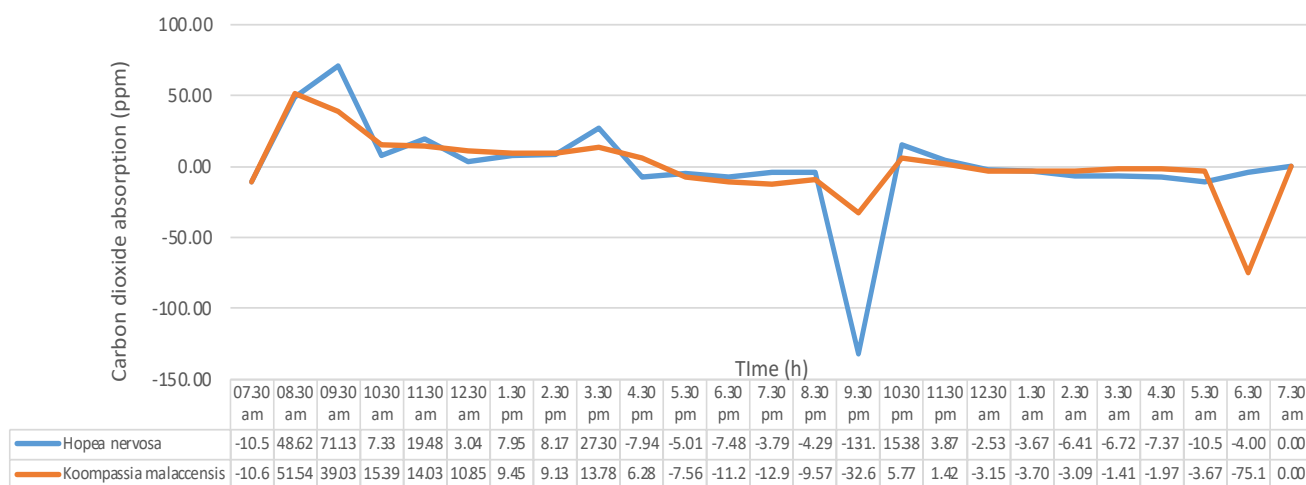


Figure 3. Carbon dioxide absorption level of *Hopea nervosa* and *Koompassia malaccensis*

Different rate of CO₂ absorption by tree species

This result demonstrates that the two types of forest tree species can absorb different amounts of carbon dioxide through photosynthesis. The data collected show that *H. nervosa* was the higher CO₂ absorber plant at 71.13 ppm/hour compared to *K. malaccensis*. At a value of 51.54 ppm/hour (Table 2). Kanniah et al. (2014) stated that the dipterocarp forest typically has a wide variety of valuable tree species, with the majority belonging to the genera *Hopea*, *Dryobalanops*, *Dipterocarpus*, *Shorea*, and *Parashorea*. The *H. odorata*, a member of the same family as *H. nervosa*, can absorb and store the most carbon dioxide among the other tree species studied at Linear Park, with a value of 274.06 kgCO₂ e. In comparison, *Evatamia divaricata* had the lowest carbon dioxide absorption (35.59 kg CO₂ e) (Othman et al. 2019). Thus, this indicated that *Hopea* trees have a high rate of carbon absorption, which is mainly related to their rapid growth. In tropical climate zones, fast-growing trees frequently exhibit comparatively more excellent rates of CO₂ absorption, indicating that CO₂ assimilation rates may serve as indicators for assessing fast-growing characteristics.

Meanwhile, *K. malaccensis* from Fabaceae family recorded slightly lower carbon dioxide absorption at 51.54 ppm/hour, similarly in another study conducted by Yunusa and Linatoc (2018) which reported that *K. malaccensis* absorbs the second highest carbon dioxide at a value of 14.03 μmol m⁻² s⁻¹. Among Fabaceae family, *P. indicus* Willd is commonly reported to have the highest capacity to absorb CO₂ per tree per hour with a capacity of up to 4624.29 grams (Daud et al. 2019). Similarly, *P. indicus* was identified with higher capacity to absorb carbon dioxide according to the findings of studies by Misni et al. (2015) and Pane et al. (2016).

Environmental variables and carbon dioxide absorption

Environmental variables are categorized as external factors that might influence absorption capacity such as light, humidity and temperature. In assessing the influence of these factors towards carbon dioxide absorption, linear correlation analysis was conducted among the environmental variables of light, temperature and humidity with the carbon dioxide absorption capacity. The analysis showed that only humidity factor was positively correlated with the carbon dioxide absorption, while other factors of light and temperature had negative correlation. According to Rawson et al. (2004), humidity affects photosynthesis, transpiration and water use efficiency in leaves of various plant species. Figure 4 shows positive correlation between humidity and carbon dioxide absorption for both species. From the allometric equation, the R² value for *H. nervosa* was 0.30 or in percentage, in other words, 30% of the differences in humidity were explained by carbon dioxide absorption of plants, while the R² value for *K. malaccensis* was 0.78 or 78%. The R² value of this sapling was higher than the R² value for *H. nervosa*. This implied that the decreased humidity would have less carbon dioxide absorption by plants. Based on the collected data, *K. malaccensis*'s humidity decreased from 91.56% to 83.98% and at the same time, carbon dioxide absorption also

decreased from 51.54 ppm to 6.28 ppm. Besides, *H. nervosa*'s humidity also decreased from 59.38 % to 62.03 % and CO₂ absorption decreased from 71.13 ppm to 27.30 ppm.

Meanwhile, other factors, such as temperature and light, negatively correlated with the carbon dioxide absorption for both species. A negative correlation describes a situation where one of the variables sees an increase in value while the other one experiences a decrease. For *H. nervosa*, a simple linear regression that predicts temperature from carbon dioxide absorption has an R² value of 0.70. From this R² value, 70% of the changes in carbon dioxide absorption are attributed to changes in temperature, and 30% are unexplained by the model. The R² value for *K. malaccensis* was 0.90 or, in percentage, 90%. Both R² values indicated that they have a strong negative correlation with carbon dioxide absorption. This means that carbon dioxide absorption appears to decrease when temperature increases. According to some research by Suwanmontr et al. (2013), air temperature has no direct impact on the activities of the photosynthetic enzymes.

Table 2. Carbon dioxide absorption level by two different saplings

Type of saplings	CO ₂ absorption level (ppm/hour)
<i>Hopea nervosa</i> (Dipterocarpaceae)	71.13
<i>Koompassia malaccensis</i> (Fabaceae)	51.54

Table 3. Carbon dioxide absorption rate for *Hopea nervosa* and *Koompassia malaccensis* and the record of environmental variables of temperature, light and humidity

CO ₂ absorption (ppm)	Environmental variables		
	Temp. (°C)	Light (lux)	Humidity (%RH)
<i>Hopea nervosa</i>			
48.62	28.00	1061.94	88.92
71.13	40.93	2185.45	59.38
7.33	64.41	2509.65	52.52
19.48	65.07	2256.76	52.49
3.04	62.82	2143.17	57.92
7.95	64.94	2412.21	52.66
8.17	64.53	2397.34	52.00
27.30	61.37	1337.51	62.03
48.62	28.00	1061.94	88.92
<i>Koompassia malaccensis</i>			
51.54	52.51	566.43	91.56
39.03	54.00	1076.96	86.82
15.39	55.95	1397.75	83.55
14.03	56.98	1229.26	82.06
10.85	56.57	888.82	84.39
9.45	56.88	917.29	83.85
9.13	57.26	1214.68	84.37
13.78	58.39	1032.57	82.15
6.28	57.87	764.82	83.98

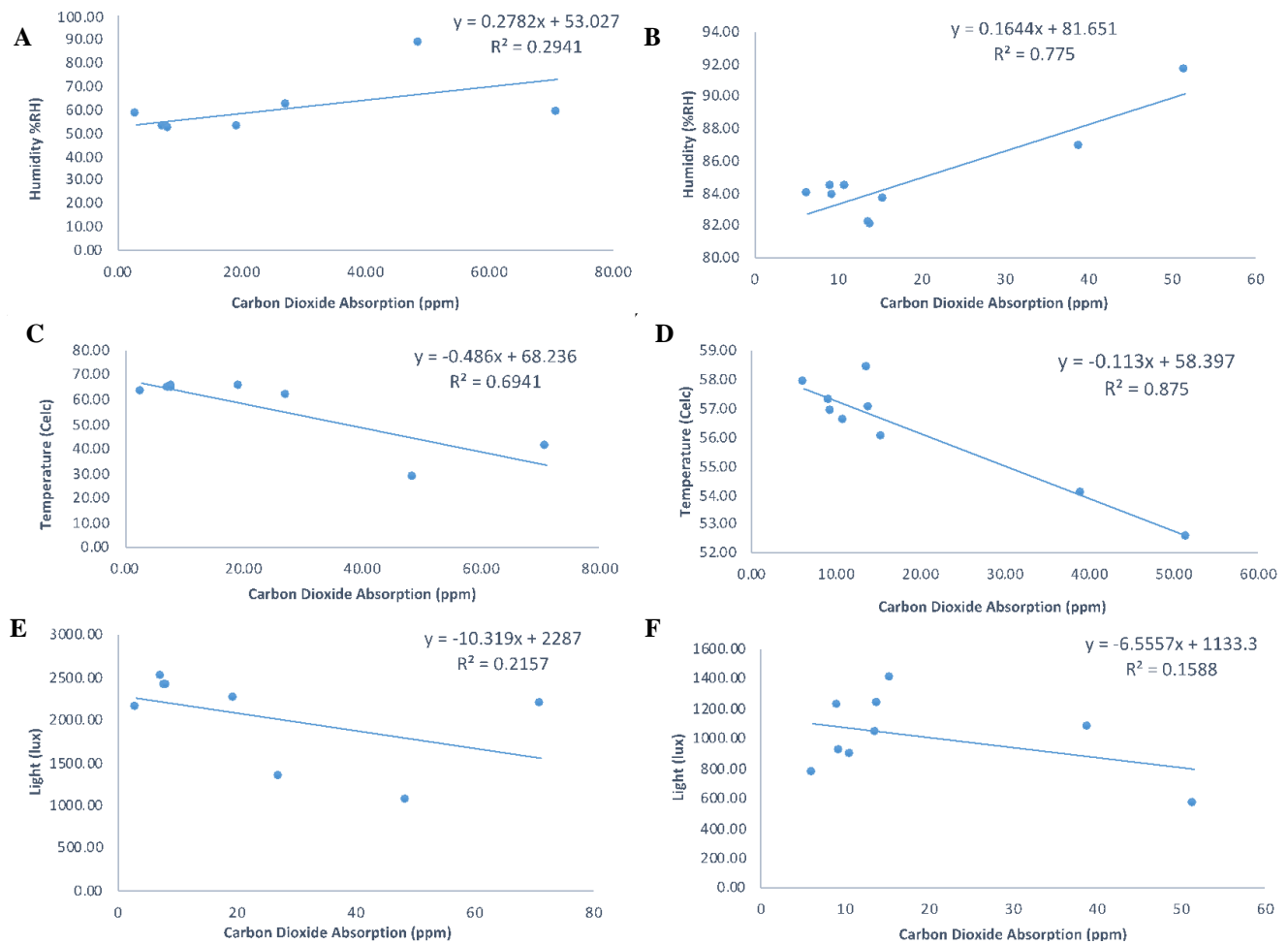


Figure 4. Relationship between carbon dioxide absorption and other environmental variables (humidity, temperature, light) for both species. Note: A, C, E, for *H. nervosa*, B, D, F, for *Koompassia malaccensis*

Light factor is also reported to have less influence on the carbon dioxide absorption capacity, as indicated by the downward slope of the graph in Figure 4. The equations show that R² value for *H. nervosa* was 0.22 and *K. malaccensis* with lower R² value of 0.16 or 16%. A lower R² value did not necessarily imply that plants would absorb more carbon dioxide at higher light intensities. When light intensity was 2185.45 lux, *H. nervosa* absorbed 71.33 ppm. When the light intensity was 2509.65 lux, the carbon dioxide absorption was only 7.33 ppm. For *K. malaccensis*, when light intensity was 1079.96 lux, the carbon dioxide absorption was 39.03 ppm, and at 1397.75 lux, it only absorbed 15.39 ppm of carbon dioxide (Table 3). According to Sari et al. (2005), the light intensity rises and falls based on cloud conditions in the atmosphere, affecting the carbon dioxide absorption rate (Daud et al. 2019). During the day, plants experience many changes in the type and amount of radiation they receive. Light is necessary for photosynthesis in plants, but too much light can cause harm. When there are frequent changes in light or plants cannot adapt to the prevailing light conditions, there may be a surplus of stimulation in the photosynthetic apparatus. This can lead to photoinhibition, where the excess energy from light damages the plant's photosynthetic pigments and

proteins (Alves et al. 2002). As a result, this may hinder the plant's capacity to perform photosynthesis and absorb carbon dioxide. A 2000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ (full sunlight) exposure to algal cells in an experiment revealed that photosynthesis was quickly inhibited (Powles 1984).

In conclusion, trees in forests may give advantages in mitigating greenhouse gas emissions, mainly CO₂, and reducing the impact of global warming. In this study, a semi-closed technique to measure the concentration of CO₂ was used to determine the type of saplings with a high potential of absorbing CO₂. The study results concluded that the variation in CO₂ absorption ranged from 1.42 ppm to 71.13 ppm for both species. The highest rate was observed in *H. nervosa*, followed by *K. malaccensis*. Therefore, both *H. nervosa* and *K. malaccensis* could be suggested to stakeholders in planning or developing urban forests to reduce air pollution and, consequently, reduce the carbon emissions from various urban sources like power plants, discharge of industrial gases, and from passing vehicles on the roadsides. Other than that, both environmental variables, namely light and temperature, negatively correlate with carbon dioxide absorption, while humidity positively correlates with carbon dioxide absorption by plants.

ACKNOWLEDGEMENTS

This research was funded by the Ministry of Higher Education, Malaysia, under the Fundamental Research Grant Scheme (FRGS)-FRGS/1/2021/WAB03/ UTM/02/1.

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