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ชื่อโครงการ **Transpiration of urban tree species in Chulalongkorn University Centenary park**

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ภาควิชา **Environmental Science**

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in Chulalongkorn University Centenary Park

Saowapa Namab

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บทคัดย่อ

ในสถานการณ์ปัจจุบันสังคมเมืองประสบกับปัญหาด้านสิ่งแวดล้อมเป็นอย่างมาก เช่น การเพิ่มขึ้นของมลพิษทางอากาศ และที่สำคัญคือ การเปลี่ยนแปลงสภาพภูมิอากาศ โดยปัญหาเหล่านี้สามารถแก้ไขได้โดยการสร้างพื้นที่สีเขียวเพิ่มมากขึ้นภายในพื้นที่เมืองและการส่งเสริมให้มีการจัดการพื้นที่นั้นอย่างมีประสิทธิภาพ เพื่อลดความร้อนที่เกิดขึ้นโดยการบริการเชิงระบบนิเวศของพันธุ์ไม้เมือง นั่นคือ การคายน้ำ และการตอบสนองต่อปัจจัยทางสิ่งแวดล้อมในด้านต่าง ๆในแต่ละฤดูกาล ในงานวิจัยนี้ได้ทำการศึกษาอัตราการคายน้ำของพันธุ์ไม้เมืองจำนวน 4 ชนิดบริเวณสวนอุทยาน 100 ปีจุฬาลงกรณ์มหาวิทยาลัย ได้แก่ ตะแบกนา (*Lagerstroemia floribunda*), มะค่าโมง *(Afzelia xylocarpa*), ขานาง (*Homalium tomentosum*) และชงโค (*Bauhinia purpurea*) ซึ่งมีลักษณะท่อลำเลียงน้ำแบบกระจายเหมือนกัน โดยผลการศึกษาพบว่าอัตราการคายน้ำในรอบวันในแต่ละชนิดพันธุ์ของทั้งฤดูร้อนและฤดูฝนมีรูปแบบที่คล้ายคลึงกัน โดยในฤดูร้อนจะพบอัตราการคายน้ำที่สูงกว่าในฤดูฝน นอกจากนี้ความสัมพันธ์ระหว่างอัตราการคายน้ำของแต่ละชนิดพันธุ์และค่าความแตกต่างของความดันไอ (VPD) แตกต่างกันในแต่ละชนิดพันธุ์ โดยส่วนใหญ่แล้วอัตราการคายน้ำสูงขึ้นเมื่อค่าความแตกต่างของความดันไอเพิ่มขึ้นในรูปแบบสมการเอกซ์โพเนนเชียล ยกเว้นมะค่าโมง *(Afzelia xylocarpa*) ที่มีอัตราการคายน้ำเพิ่มขึ้นแบบสมการ exponential และคงที่เมื่อ VPD สูงขึ้น ผลการศึกษานี้สามารถนำไปประยุกต์ในการจัดการการใช้น้ำในพื้นที่สีเขียวได้อย่างเหมาะสมและเป็นแนวทางในการจัดการพื้นที่สีเขียวอย่างยั่งยืน โดยการเลือกพันธุ์ไม้เมืองที่สนับสนุนต่อการคายน้ำในแต่ละฤดูกาลอย่างเหมาะสมและตอบสนองต่อการเปลี่ยนแปลงของปัจจัยทางสิ่งแวดล้อมต่าง ๆ น้อยที่สุด

คำสำคัญ: การคายน้ำ, พันธุ์ไม้เมือง, ค่าความแตกต่างของความดันไอน้ำ*, Lagerstroemia floribunda*, *Afzelia xylocarpa*, *Homalium tomentosum*, *Bauhinia purpurea*

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ABSTRACT

Urbanization has caused significant environmental problems such as atmospheric pollution and especially climate change. These problems can be solved by building urban greenery and promotes sustained management for mitigates excess urban heating by ecosystem service as transpiration of urban trees and its response to environmental factors in different seasons. We estimated the transpiration rate of four urban tree species in Chulalongkorn University Centenary Park and analyzed its seasonal difference. The studied species were *Lagerstroemia floribunda* (Crepe Myrtle), *Afzelia xylocarpa* (Black rosewood), *Homalium tomentosum* (Moulmein lancewood), and *Bauhinia purpurea* (Orchid Tree) that had diffuse-porous xylem. Our results found that daily transpiration individual species pattern of both wet and dry seasons had a similar pattern. In dry season had transpiration rate higher than wet season. Moreover, the relationships between daily transpiration rate (E) and vapor pressure deficit (VPD) differ among species. Transpiration increased with VPD when VPD increased in most species with an exponential pattern except *A. xylocarpa* where increased with an exponential saturating pattern. These results can be used to manage irrigation in urban greening effectively and apply in the management of urban greening to be sustainable by selecting suitable urban tree species that maintain transpiration in both seasons and be less affected by changing from the urban environment.

Keyword: transpiration, urban trees, vapor pressure deficit, *Lagerstroemia floribunda*, *Afzelia xylocarpa*, *Homalium tomentosum*, *Bauhinia purpurea*

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Saowapa Namab

CONTENTS

Page

CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Overviews

Urbanization influences higher temperature and pollution caused by the buildings that intercept solar radiation and the concrete surface that absorbs heat. As the result, temperature within the city becomes higher than rural area, the so-called Urban Heat Island, UHI (Youpei Hu et al., 2016) This problem can be solved using various methods including building urban green spaces like building roadside gardens, urban park and roof gardens. For all method should understand the diverse microclimate that urban areas are exposed, and urban tree's responding on environmental condition which promotes sustained urban greenery management and mitigates excess urban heating from ecosystem service that provides by urban trees (Jenny, Patrick and Jan, 2016). Urban trees have significant ecological services like cooling effect by providing shade and transpiration. Transpiration of urban trees show an ability to convert solar radiation to latent heat flux that is significant reduced temperature within the city (Mayer et al., 2019; Bowler et al., 2010; Hamada et al., 2010).

Therefore, this study estimated transpiration rate of urban tree in dry and wet season within Chulalongkorn University Centenary Park (CU 100 Park) and analyzed its seasonal difference. For this study, we measured stomatal conductance and use it to estimate transpiration of the urban tree species similar xylem anatomy in the park that were *Lagerstroemia floribunda* (Crepe Myrtle), *Afzelia xylocarpa* (Black rosewood), *Homalium tomentosum* (Moulmein lancewood), and *Bauhinia purpurea* (Orchid Tree), respectively. All of study trees are deciduous trees and have diffuse-porous xylem which can tolerate drought better than ring-porous xylem (Berdanier et al, 2016). The result from this study will use to manage water in urban greening effectively and apply in the management of urban greening to be sustainable by selecting urban trees that promote transpiration in both seasons as a result decreased the temperature within the city.

1.2 Objectives

1.2.1 To estimate transpiration rate by *Lagerstroemia floribunda* (Crepe Myrtle), *Afzelia xylocarpa* (Black rosewood), *Homalium tomentosum* (Moulmein lancewood), and *Bauhinia purpurea* (Orchid Tree) in CU Centenary Park.

1.2.2 To compare transpiration rate of studied urban trees species within the park in wet and dry season.

CHAPTER 2

LITERATURE REVIEWS

2.1 Steady state method for measuring stomatal conductance by using Leaf Porometer SC-1.

One component to measure transpiration rate are the leaf conductance (mostly determined by how open the stomata are, i.e., the stomatal conductance, g_s) which depends on the water content within plant. Therefore, g_s may be used to screen for water status in maize (Sanguineti et al., 1999), and the current generation of easy-to handle porometers as the Decagon Leaf Porometer SC-1 (Dacagon Devices, Inc., Pullman, USA). The leaf porometer measures the stomatal conductance of leaves by putting the conductance of the leaf in series with two known conductance elements by measuring the humidity difference across one of the known conductance elements, the water vapor flux is known. The conductance of the leaf can be calculated from these variables. The leaf porometer effectively calculates the resistance between the inside and outside of the leaf: the stomatal conductance. Resistance is measured between the leaf and the first humidity sensor, and the first and second sensors. The following diagram schematically illustrates this:

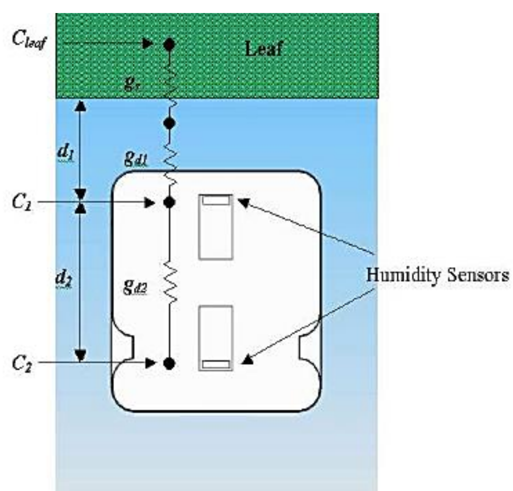


Figure 2.1 Leaf porometer probes set up for stomatal conductance measurement.

Where C_{leaf} is the mole fraction of vapor inside the leaf

C_1, C_2 are the mole fraction of vapor at node 1 and node 2

g_s is stomatal conductance of the leaf surface

g_{d1} is vapor conductance of the diffusion path between leaf and node 1

g_{d2} is vapor conductance of the diffusion path between node 1 and node 2

d_1 is distance between the leaf surface and the first humidity sensor

d_2 is distance between the two humidity sensors

The studied variable is stomatal conductance(g_s). First the vapor flux along the diffusion path will be determined using the relative humidity difference between nodes 1 and 2 as follows:

$$F_{vapor} = g_{d2} (C_1 - C_2) \quad \text{(Equation 1)}$$

And where C is related to relative humidity by

$$C_i = \frac{h_r e_s(T_a)}{\rho_{atm}} \quad \text{(Equation 2)}$$

Next, determining the value of g_{d2} by the equation:

$$g_{d2} = \rho D_{vapor} d_2 \quad \text{(Equation 3)}$$

Using these C_i and g_{d2} values we can now solve equation 1 for the flux:

$$F_{vapor} = \left[\frac{\rho D_{vapor}}{d_2}\right] \frac{1}{P_{atm}} \left[h_{r1} e_s(T_{a1}) - h_{r2} e_s(T_{a2})\right] \quad \text{(Equation 4)}$$

Next, we assume that all conductance values are in series so that the flux is constant between any two nodes and assume that the leaf's temperature is equal to the first humidity sensor's temperature. After that set it equal to equation:

$$g_{s+d_1} = \frac{\left(\frac{\rho D}{d_2}\right)\left[h_{r1} e_s(T_{a1}) - h_{r2} e_s(T_{a2})\right]}{e_s(T_{a1})(1-h_{r1})} \quad \text{(Equation 5)}$$

Using the rule for series combination of conductance, we can solve for g_s:

$$\frac{1}{g_s} = \frac{1}{g_{s+d_1}} - \frac{1}{g_{d_1}} \quad \text{(Equation 6)}$$

Finally, the measurement shows g_s value from:

$$g_s = \frac{\rho D_{vapor}}{\frac{|e_s(T_{a1})(1-h_{r1})|d_2}{h_{r1}e_s(T_{a1})-h_{r2}e_s(T_{a2})}-d_2} \qquad \text{(Equation 7)}$$

Therefore, g_s is a function of the distances between humidity sensors, temperature, and the two relative humidity readings. The resulting g_s is in units of mmol m^{-2} s^{-1}.

2.2 Stomatal conductance and transpiration.

In a general, transpiration depends on stomatal conductance space (g_s), net radiation received (R,), and upon air saturation deficit (D), temperature (T_A) and wind speed (u). And then, saturation deficit and wind speed change through leaf boundary layers, through canopies and the atmosphere above the canopies, so that it matters where they are measured (Jarvis and McNaughton, 1986) . Therefore, the value of stomatal conductance (g_s) can calculate to find the transpiration rate (E) according to the simplification equation suggested by Monteith and Unsworth (1990) by calculating transpiration rate from mean canopy stomatal conductance (m s^{-1}) and D:

$$E_T = \frac{g_s D}{K_G(T)} \qquad \text{(Equation 8)}$$

where K_G is the conductance coefficient (115.8 + 0.4236T; kPa m^3 kg^{-1}), which depend on temperature on the psychrometric constant, latent heat of vaporization, specific heat of air at constant pressure and the density of air (Phillips and Oren 1998). D is closed to the leaf-to-air vapor pressure deficit, i.e., boundary layer conductance and no vertical gradient in D through the canopy.

Both of stomatal conductance and transpiration are influenced by two variables including air temperature and vapor pressure deficit (VPD) (Schulze and Hall, 1981). In these studies, they studied response of transpiration rate and canopy conductance to changing in VPD in four trees species in Mexico City and measured over 2-week period. The result showed that transpiration was strongly dominated by VPD and stomatal conductance tended to decrease linearly as VPD increased (Monica and Victor, 2016) as a result of prevention the transpiration loss, over dehydration and cell damage.

2.3 Environmental factors affecting transpiration.

Transpiration in plant is a process that water is lost through evaporation from the surfaces of leaves called stomata for control the water within the plant by regulating stomatal movement and atmospheric demand. Tree transpiration responds to climatic changes such as light, vapor pressure deficit, soil moisture, relative humidity, and temperature (Granier et al., 1996; Mellander et al., 2004; Oguntunde, 2005; Burgess, 2006).

As transpiration involves diffusion of water vapor from part of high concentration in intercellular spaces of leaves to that of low concentration outside air, Relative humidity (RH) or amount of water vapor in the atmosphere affected stomata conductance when RH higher the stoma tends to close and thus limit the exit of water vapor from the plant that mean decreasing transpiration rate.

Air temperature is the one factor that can also affect transpiration rate. Evaporation and diffusion are faster at higher temperatures causing transpiration rate increased also related to water potential and relative humidity. Hopkins (1995) suggest that the relationship of temperature (T, in °K), relative humidity (RH, in %) and water potential (Ψ_w, in pascal) is shown in the following equation:

$$\Psi_w = 1.06\ T \log (RH/100) \qquad \text{(Equation 9)}$$

Applying the equation, an increase in temperature will decrease water potential or transpiration rate.

Soil moisture influence the transpiration rate where the supply of water from the soil is limiting, transpiration tends to decrease as a result of stomatal closure and reduce the rate of transpiration that is a result of this research used soil moisture content compare with 70% field capacity (amount of soil water content after drainage of the water contained in the macropores by gravity force) for assessing whether the amount of water in the soil is sufficient for the growth of studied trees throughout the measurement periods .

Wind speed affects transpiration by removing that boundary layer, which lies next to the surface of a leaf. The moist air in boundary layer causes a slight water potential gradient from the leaf resulting to reduced rate of transpiration. This layer also reduces light penetration into the leaf however wind operate this boundary layer is replaced with drier air thus increasing water potential gradient and enhancing transpiration (Moore et al., 2003).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study area

The study area is Chulalongkorn University Centenary Park in Bangkok, the capital city of Thailand (13.739274°N 100.524914°E). The elevation is 0.5-1 meters above sea level (Royal Thai Survey Department, 2018). Bangkok has a tropical climate with the annual maximum temperature of 32-34 ºC and minimum temperature of 24-26 ºC based on collected data in 1981 -2010. The annual mean rainfall of 1,275 mm $year^{-1}$ (Meteorological Department of Thailand, 2018) and there are 706 trees consist of 48 species in this park based on a survey in February 2017.

3.2 Sampling design

For this study, we selected 4 tree species that were *Lagerstroemia floribunda* (Crepe Myrtle), *Afzelia xylocarpa* (Black rosewood), *Homalium tomentosum* (Moulmein lancewood), and *Bauhinia purpurea* (Orchid Tree), which were similar diffuse-porous xylem and selected 5 trees for each species by stratified random sampling from trees that had similar height and diameter at breast (DBH). After that selected position of trees in CU Centenary park randomly (from Figure 3.1).

Figure 3.1 Satellite image of position of all studied trees in the Chulalongkorn University Centenary Park, Bangkok.

(*Source*: “CU Centenary Park.” 13.739274°N and 100.524914°E.**Google Earth**. December 21, 2018.)

3.3 Experimental method

3.3.1 Environmental measurement

The environmental factors that influenced transpiration rate of studied trees were light, wind speed,air temperature, relative humidity and soil moisture. The hourly air temperature and relative humidity collected from Environment Bureau Bangkok database, Pollution Control Department that away from studied site 800 m. And collected atmospheric data from August 19, 2018 to January 16, 2019 and was calculated vapor pressure deficit (VPD, kPa) which was the difference between the actual amount of moisture in the air and how much moisture the air can hold when it is saturated. The VPD will calculate using the following equation:

$$VPD = \left(1 - \frac{RH}{100}\right) \times SVP \quad (1)$$

where RH was relative humidity (%); SVP was Saturation vapor pressure in kPa that calculated using the following equation:

$$SVP = 610.7 \times 10^{\frac{7.5T}{237.5+T}} \quad (2)$$

where the temperature was T in degrees Celsius (°C).To determine whether an enough water in the soil throughout the studied period by analysis from soil moisture due to frequent irrigation and compare against 70% field capacity was 70% of the amount of water in the soil held in the soil after excess water has been drained. This study collected 5 soil samples about 5 cm depth once a week randomly distributed within the park to measured soil moisture and bulk density. Soil moisture calculated using the following equation:

$$\theta_m = \left(\frac{m_{soil,wet} - m_{soil,dry}}{m_{soil,dry}}\right) \quad (3)$$

where θ_m was soil moisture is in kg kg^{-1}. $m_{soil,wet}$ was wet mass of soil in kilogram (kg) and $m_{soil,dry}$ was dry mass of soil in kilogram (kg). To assure that there was enough water in the soil for growth, would be compared against 70% field capacity. The field capacity of soil can be determined based on laboratory measurement of water content by collected soil samples by using core soil at 5-15 cm depth. Therefore, put soil samples in straining cloth and soak them for 24 hours. Drained water out from soil by gravitation method and weighed soil sample before and after drying in oven approximately 24 hours at 105 ºC (Robock et al., 2000).

3.2.2 Studied variable

This study calculated the transpiration rate of studied trees in wet and dry seasons by using stomatal conductance (g_s, mm s^{-1}) and leaf area Index (LAI).

Stomatal conductance (g_s, mm s^{-1}) means value that explain stomatal regulation when plants transpire through stomata. Stomatal conductance was measured 4 tree species by Leaf Porometer (SC-1, Meter services). Each tree species should 3 fully sunlit leaves and collected from 7.00 am. to 5.00 pm. The measurement was divided into two seasons are wet and dry season with three replicates in each season. Wet season collected in July to September and dry season in November to January.

Leaf area Index (LAI) means leaf area index per unit area and measured by using LAI-2200C Plant Canopy Analyzer. LAI measured the canopy structure at the low sunlight and calculated by the canopy model. The studied trees measured in form Isolated trees and placed monitor at the bottom of the canopy.

3.4 Transpiration Calculation

Transpiration rate (E, mmol m^{-2} s^{-1}) means rate of water movement through a plant and its evaporation from stomata calculating from Stomatal conductance (g_s, mm s^{-1}) in all studied trees using the following equation:

$$E = \frac{g_s \times VPD \times LAI}{K_G} \qquad (6)$$

When VPD was vapor pressure deficit is in kPa. LAI is leaf area index and K_G was the coefficient (115.8 + 0.4236T ; kPa m^{-3} kg^{-1}), depended on temperature (T, °C) which accounts for temperature effects on the psychrometric constant, latent heat of vaporization, specific heat of air at constant pressure and the density of air (Phillips and Oren, 1998).

3.5 Data analyses

The comparison of urban tree stomatal conductance (g_s) and transpiration rate (E) in dry and wet season analyzed using t-test statistics analysis with SPSS program and testing of difference diurnal patterns of daily g_s and E in wet and dry season of individual tree species by using two-way ANOVA.

Regression analysis was done to find out the relationship between individual E and VPD in wet and dry season by fitting curve that were performed with Sigma pot software (version 4.5) with the following two functions: (1) $y = a + bx$ and (2) $y = a(1-e^{-bx})$ where x is vapor pressure deficit (VPD) and y is transpiration rate (E).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Characteristics of urban trees species and environmental conditions

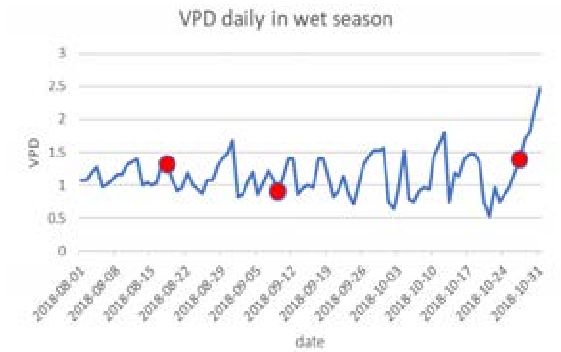
Table 4.1 showed the characteristics of four selected urban trees species within CU centenary park that had mean and standard deviation of height and diameter at breast (DBH) in meter.

Table 4.1 Characteristics of urban trees species selected for estimate stomatal conductance and transpiration rate.

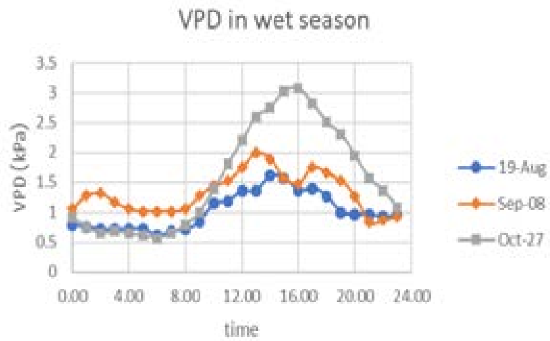
Species	**DBH (cm)**	**Height (m)**	**n**	**LAI**	
				Wet season	Dry season
Lagerstroemia floribunda	11.71 ± 1.11	5.99 ± 0.37	5	0.75	0.61
Afzelia xylocarpa	14.16 ± 2.75	6.20 ± 0.45	5	0.65	0.81
Homalium tomentosum	10.58 ± 2.29	7.66 ± 0.42	5	0.43	0.55
Bauhinia purpurea	9.65 ± 2.83	6.82 ± 3.08	5	1.15	0.93

DBH= diameter at breast in meter at 1.3 m from ground. n= number of individuals used in stomatal conductance data collection, the mean±1standard definition (1SD) of 5 individuals of each species. LAI = leaf area index showed in wet and dry season.

Figure 4.1 and 4.2 showed environmental condition that involved VPD, as calculated from air temperature and relative humility, and soil moisture at the study area. For vapor pressure deficit (VPD) that divided into two season which were wet season (August 19^{th}, September 8^{th} and October 27^{th}, 2018) and dry season (November 12^{th}, 2018 and 13^{th}, 16^{th} January 2019)

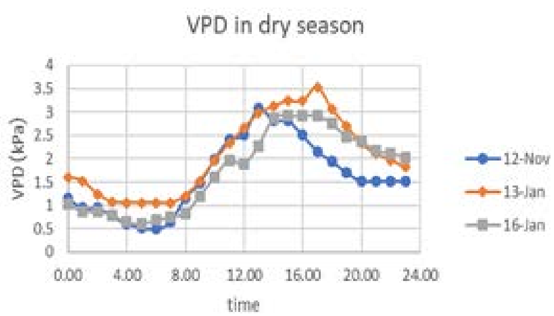


a)



b)

c)



d)

Figure 4.1 Environmental condition are air temperature and relative humidity at study site during stomatal conductance measurement were presented in vapor pressure deficit. (a) daily vapor pressure deficit (VPD) in wet season and date of measurement showed in red points. (b) variation of diurnal vapor pressure deficit (VPD) in wet season. (c) daily vapor pressure deficit (VPD) in dry season date of measurement showed in red points. (d) variation of diurnal vapor pressure deficit (VPD) in dry season.

Stomatal conductance and transpiration rate depended on vapor pressure deficit (Prior et al. 1997) that was calculated from air temperature and relative humidity in measurement period. For all three days that measured in dry season showed generally similar pattern with some slight changes, increasing with time to reach its maximum value around midday until the evening and after that slight decreasing.

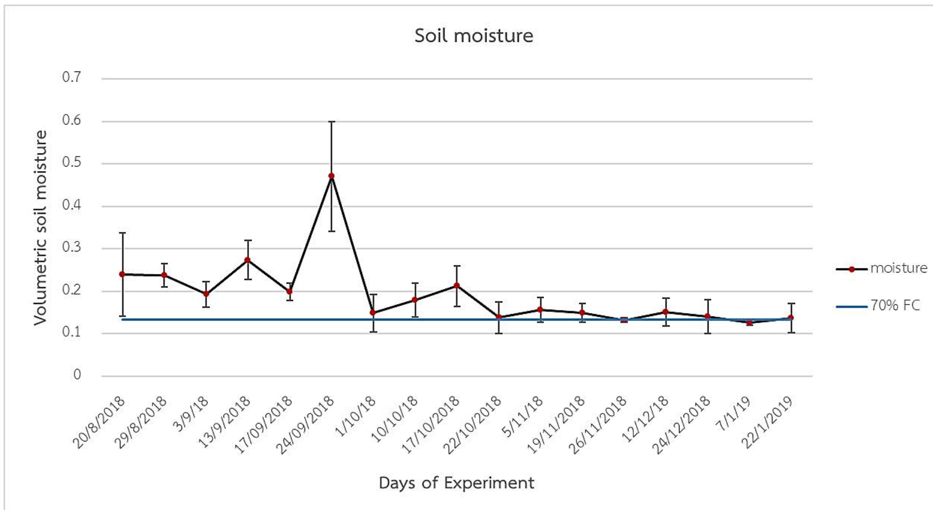


Figure 4.2 Variation of soil moisture during studied period in two seasons and 70% field capacity.

Soil moisture contents were generally greater than 70% field capacity (70% of the water quantity in the soil can be stored), however in 24 September,2018 had the highest soil moisture content due to we collected soil sample after rainy that affect soil moisture content higher other days and in 7 January,2018 had the highest soil moisture content because around this period time is long weekend as a result of lacking of irrigation. This result could be concluded that soil moisture or soil water content is enough for growth of plants throughout the studied period. Therefore, we removed soil moisture factors and studied only the weather factors.

4.2 Stomatal conductance of selected urban tree species in wet and dry season.

Figure 4.3 represented daily stomatal conductance (g_s, mmol m^{-2} s^{-1}) of urban tree species were *L. floribunda*, *A. xylocarpa*, *H. tomentosum* and *B. purpurea* in wet and dry season.

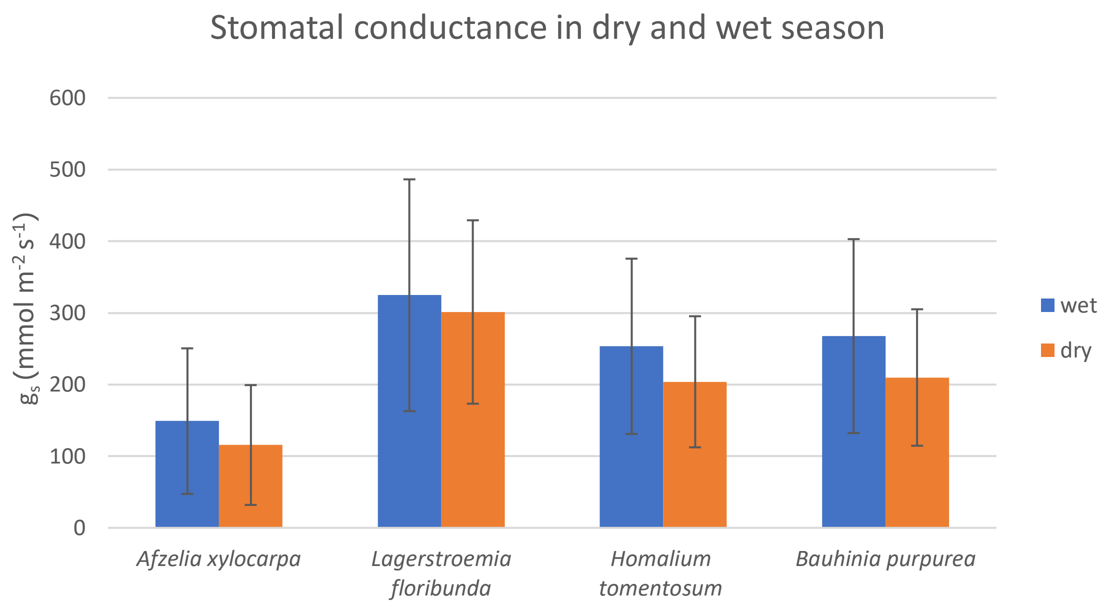


Figure 4.3 showed comparison daily stomatal conductance (g_s) between wet season and dry season values of studied tree species.

Comparison daily stomatal conductance (g_s) between wet and dry season values of studied tree species. Eamus and Cole (1997) found, leaf stomatal conductance and assimilation rates higher in the wet season than in the dry season and showed higher in the morning than in the afternoon. Our study similarly concluded that studied species had g_s in wet season higher than dry season values. *L. floribunda* presented maximum g_s values in wet and dry season, however *A. xylocarpa* showed minimum g_s values. We analyzed the difference between g_s in wet and dry season by using independent-samples t-test statistical methods was presented in p-values (Table 4.2) and p-value of all studied species showed higher than 0.05 which can be concluded that g_s values in wet and dry season was non-significant difference in all species.

Table 4.2 Daily stomatal conductance (g_s) in wet and dry season of studied tree species showed in mean ± 1 standard deviation (1SD).

Species	wet	dry	n	p-value
Lagerstroemia floribunda	348.8 ± 161.74	301.2 ± 128	15	0.129
Afzelia xylocarpa	155.1 ± 101.57	115.6 ± 86.61	15	0.440
Homalium tomentosum	281.2 ± 122.32	203.8 ± 01.45	15	0.625
Bauhinia purpurea	290.6 ± 135.33	209.8 ± 95.23	15	0.854

Stomatal conductance (g_s) in two seasons showed in Figure 4.4 and 4.5 In general, *L. floribunda* had the highest g_s values among all species while *A. xylocarpa* show the lowest g_s values. *A. xylocarpa, H. tomentosum* and *B. purpurea* has a similar variation pattern of g_{sdry}, g_{sdry} tended slightly increase during morning and reached a peak around 11.00 am to 2 pm. However, g_{sdry} of *L. floribunda* tended steady increase and reach a peak during midday and then decreased in the evening. In wet season had a similar g_s value. *A. xylocarpa*, *L. floribunda* and *B. purpurea* had similar variation pattern of g_{swet} that increased in the morning until midday and then decreased whereas *H. tomentosum* tended increased in the morning after that decreasing around 11.00 am to 1.00 pm and steady increased. For this study, the difference between g_{sdry} and g_{swet} in four species was with p-value by using two-way ANOVA method. From table 4.3 showed that p-value > 0.05 that concluded g_{sdry} and g_{swet} was non-significant difference.

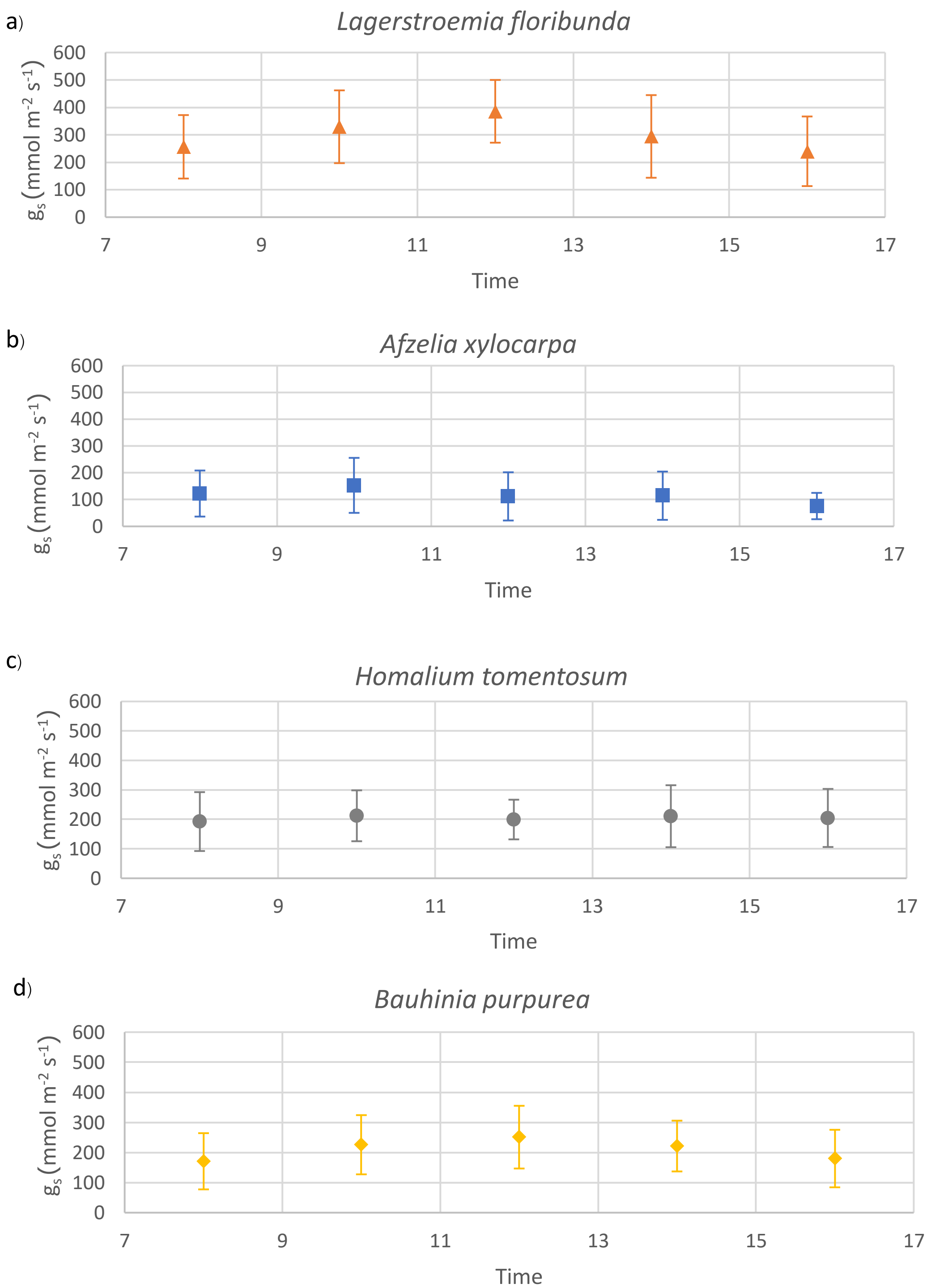


Figure 4.4 Pattern of diurnal stomatal conductance for four tree species in dry season that measured every 2 hours 5 periods throughout day until 7.00 am to 5.00 pm. Each data point showed average from 45 stomatal conductance values in 2 hours period.

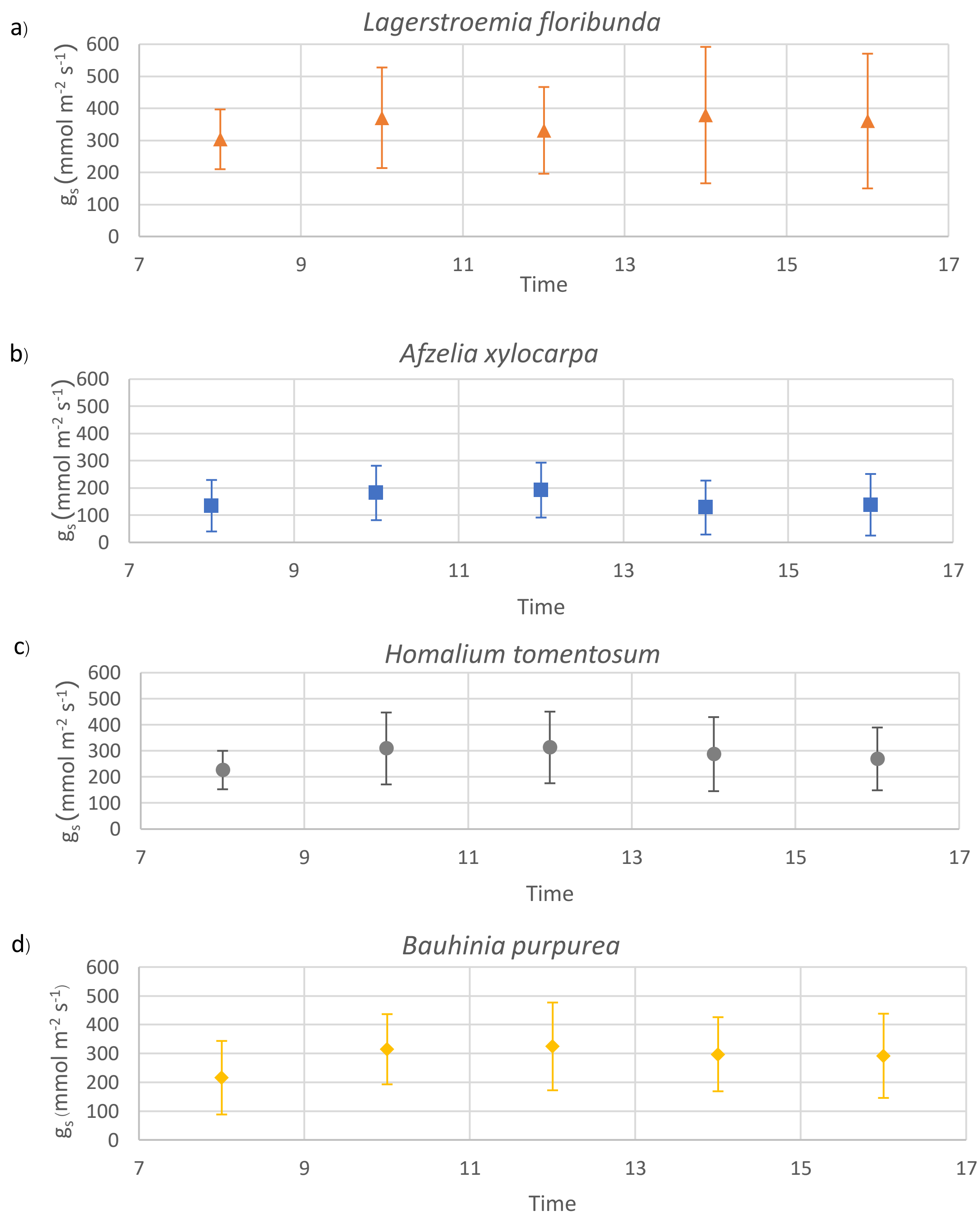


Figure 4.5 Pattern of diurnal stomatal conductance for four tree species in wet season that measured every 2 hours 5 periods throughout day until 7.00 am to 5.00 pm. Each data point showed average from 45 stomatal conductance values in 2 hours period.

Table 4.3 Test of difference diurnal patterns of daily stomatal conductance (g_s) in wet and dry season of individual tree species by using two-way ANOVA statistical method.

Species	p-value
Lagerstroemia floribunda	0.530
Afzelia xylocarpa	0.937
Homalium tomentosum	0.957
Bauhinia purpurea	0.878

4.3 Transpiration rate of selected urban tree species in wet and dry season.

Figure 4.6 presented daily transpiration rate (E, mmol m^{-2} s^{-1}) of urban tree species were *L. floribunda*, *A. xylocarpa*, *H. tomentosum* and *B. purpurea* in wet and dry season.

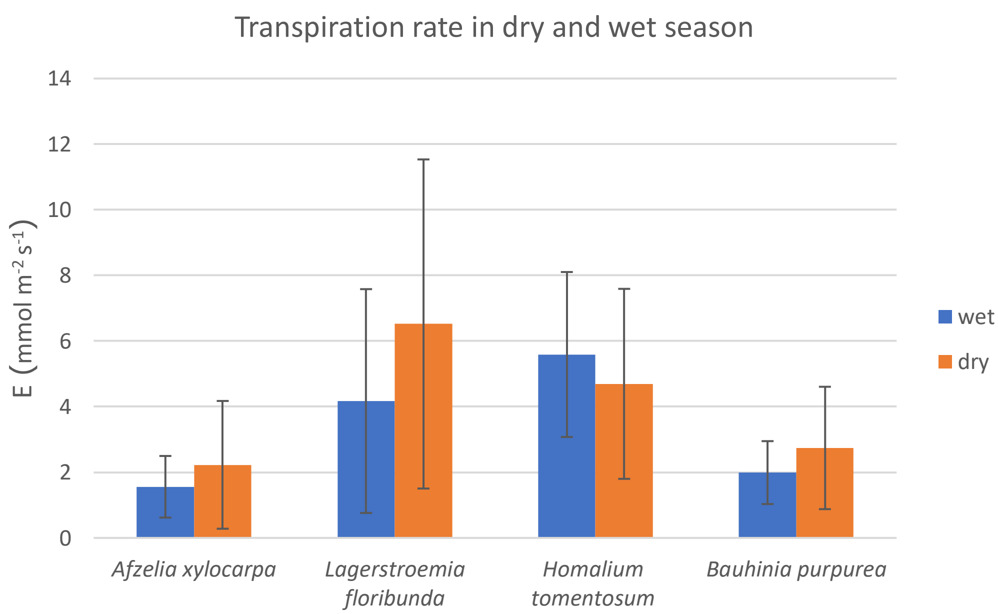


Figure 4.6 Comparison between daily transpiration rate (E) wet and dry season values of studied tree species.

To compare daily transpiration rate (E) between wet and dry season values of studied tree species, *L. floribunda, A. xylocarpa* and *B. purpurea* had E in wet season higher than dry season values but only *H. tomentosum* showed difference. *H. tomentosum* presented maximum E values in wet and dry season, however *A. xylocarpa* showed minimum E values. To test the difference between E in wet and dry season by using independent-samples t-test statistical methods that present in p-values (Table 4.4). and p-value of all studied species showed higher than 0.05 which can be concluded that E values in wet and dry season non-significant different in all species.

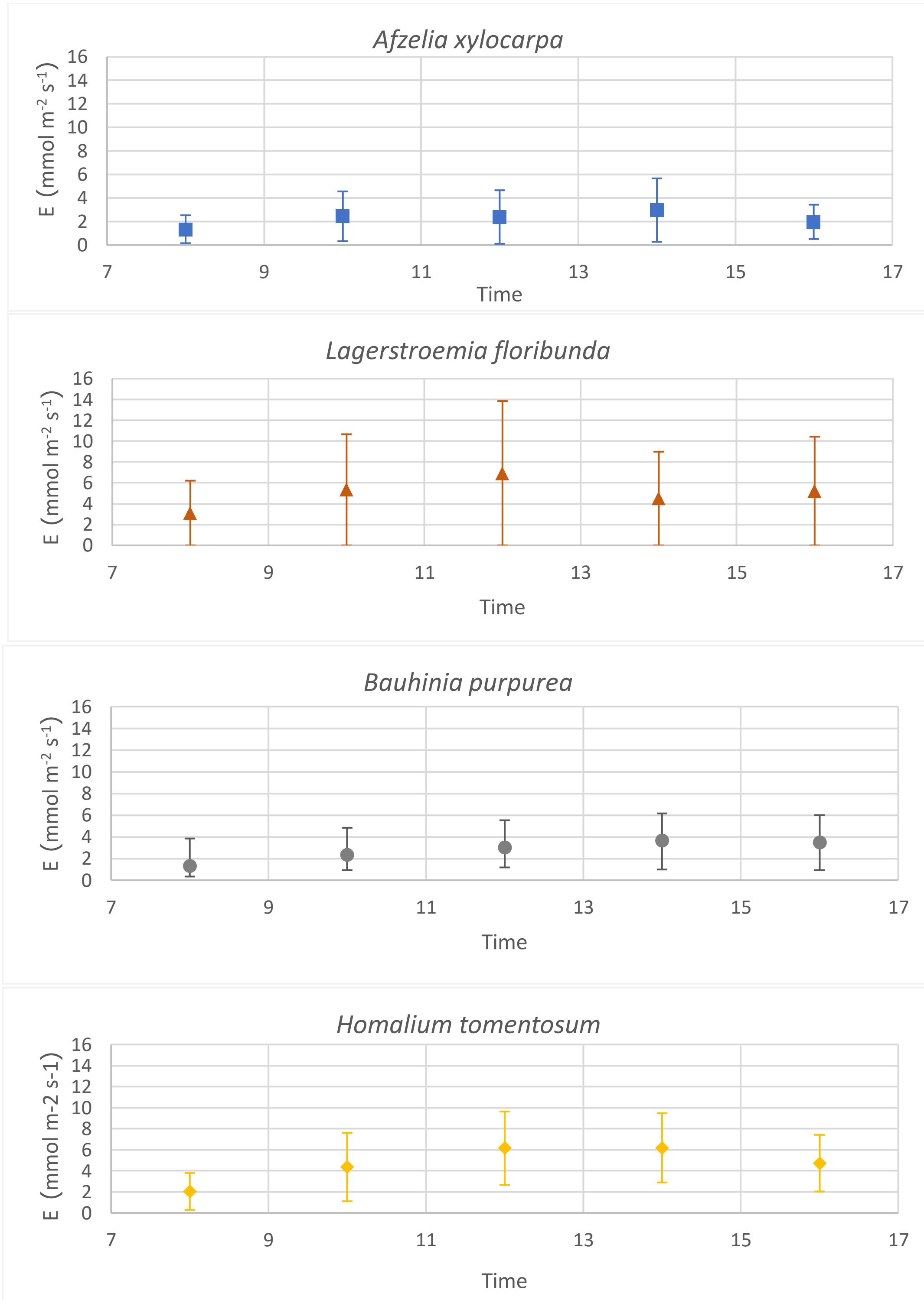
There are many researches to support that daily transpiration rate (E) in dry season were higher in wet season. Transpiration rates were higher during the dry season than during the wet season since seasonal drought causing the decline in leaf stomatal conductance and predawn leaf water potential observed in many species (Fordyce et al. 1997, Myers et al. 1997, Prior et al. 1997). However, only *H. tomentosum* showed difference due to this studied species This species responds to other environmental factors that were not studied such as wind speed and sunlight.

Table 4.4 Variation of daily transpiration rate (E) in wet and dry season of studied tree species showed in mean ± 1 standard deviation (1SD).

Species	**Wet**	**dry**	**p-value**
Lagerstroemia floribunda	4.17 ± 3.41	6.52 ± 5.02	0.124
Afzelia xylocarpa	1.56 ± 0.94	2.23 ± 1.95	0.664
Homalium tomentosum	1.99 ± 0.96	2.74 ± 1.86	0.242
Bauhinia purpurea	5.59 ± 2.51	4.69 ± 2.89	0.244

In dry season, diurnal transpiration rate in four studied species tended slightly increasing during the morning and reach a peak around 11.00 am to 3.00 pm and then decreased or stable in the evening. *H. tomentosum* showed E_{dry} maximum as 9.60 mmol m^{-2} s^{-1}whereas E_{dry} for *L. floribunda* and *B. purpurea* was intermediate and *A. xylocarpa* showed the minimum values as 1.35 mmol m^{-2} s^{-1}. E_{dry} of all studied species was stable or invariable during daytime.

In wet season showed a similar pattern of transpiration rate in four studied species however E_{wet} had higher than E_{dry}. *L. floribunda* represented E_{wet} maximum as 3.96 mmol m^{-2} s^{-1} between 11.00 am to 1.00 pm. The value of E_{wet} for *B. purpurea* and *H. tomentosum* were intermediate and *A. xylocarpa* showed the E_{wet} minimum as 0.66 mmol m^{-2} s^{-1}. E_{wet} for *A. xylocarpa, B. purpurea* and *H. tomentosum* was stable or invariable during daytime but *L. floribunda* had E_{wet} that was sensitive with time. For this study, the difference between E_{dry} and E_{wet} in four species was described with p-value by using two-way ANOVA method. From table 4.5 showed that p-value > 0.05 that concluded E_{dry} and E_{wet} was non-significant difference.


Afzelia xylocarpa
E (mmol m-2 s-1)
16
14
12
10
8
6
4
2
0
7
9
11
13
15
17
Time
Lagerstroemia floribunda
E (mmol m-2 s-1)
16
14
12
10
8
6
4
2
0
7
9
11
13
15
17
Time
Bauhinia purpurea
E (mmol m-2 s-1)
16
14
12
10
8
6
4
2
0
7
9
11
13
15
17
Time
Homalium tomentosum
E (mmol m-2 s-1)
16
14
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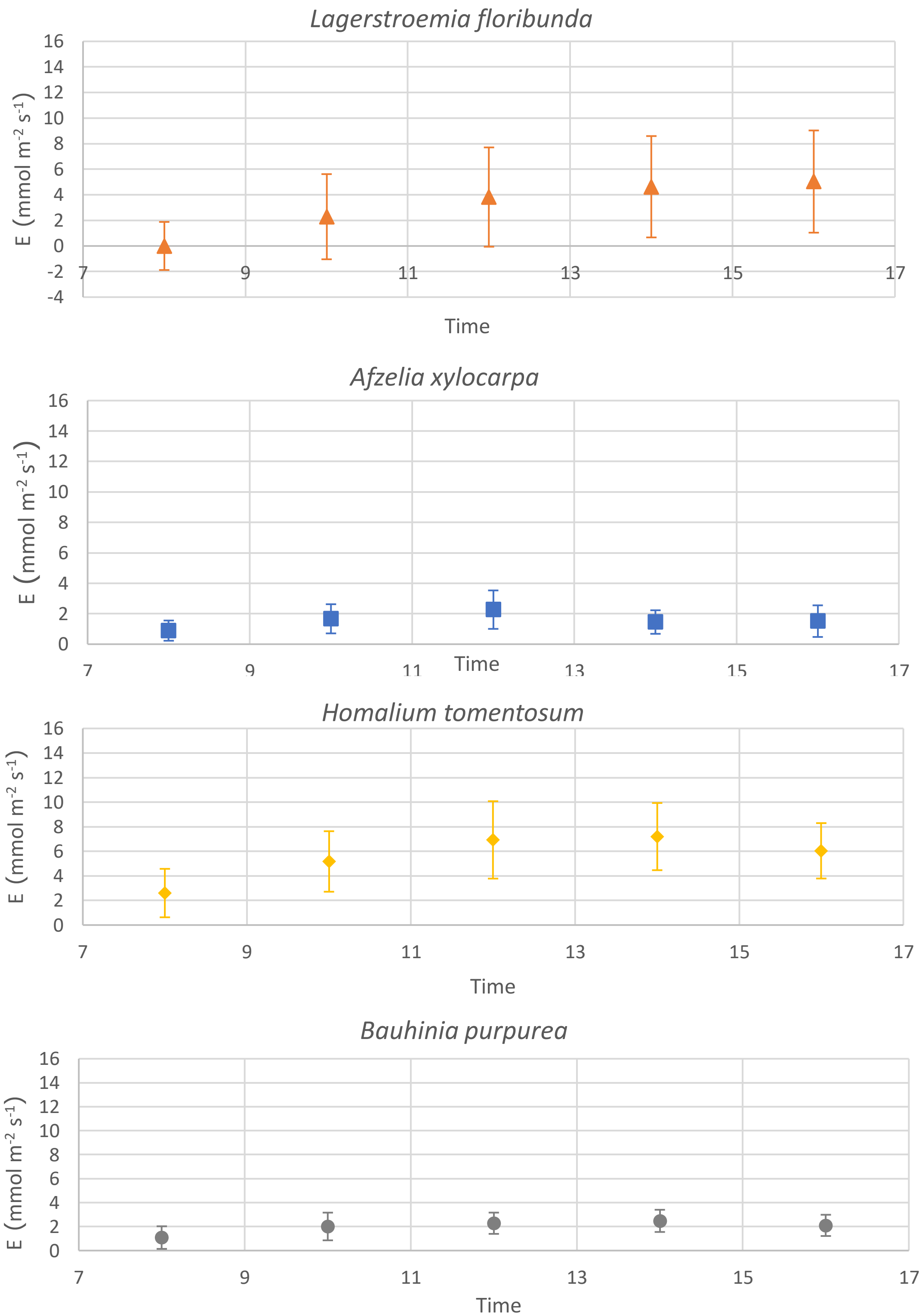
17
Time

a)


Lagerstroemia floribunda
E (mmol m-2 s-1)
Time
Afzelia xylocarpa
E (mmol m-2 s-1)
Time
Homalium tomentosum
E (mmol m-2 s-1)
Time
Bauhinia purpurea
E (mmol m-2 s-1)
Time

b)

Figure 4.7 Pattern of diurnal stomatal conductance of four tree species in (a) dry season and (b)wet season that measured every 2 hours 5 periods throughout day until 7.00 am to 5.00 pm. Data points represent the mean of 45 times measurments on different trees. Bar represent the standard deviation.

Table 4.5 Relationship between daily transpiration rate (E) in wet and dry season of individual tree species by using two-way ANOVA statistical method.

Species	p-value
Lagerstroemia floribunda	0.739
Afzelia xylocarpa	0.702
Homalium tomentosum	0.539
Bauhinia purpurea	0.989

4.4 Responses of transpiration rate of each studied tree species in wet and dry season to vapor pressure deficit.

Relationship between transpiration rate (E) and VPD in wet and dry season of each studied tree species was described by exponential saturating equation of the form: $E= a\ (1- e^{-b\,(VPD)})$ where a and b are fitting parameters. The pattern and equation of individual studied species in are shown in Fig 4.8 and Table 4.6.

Transpiration rate in four species tended to increase as VPD increased for two seasons. In general, dry season values tended higher than wet season values. O'grady, Eamus and Hutrey (1998) observed the relationship between transpiration rate to VPD in an E. miniata-E. tetrodonta open forest Australia and concluded that transpiration rates response to VPD and this was larger during the dry season than during the wet season. Whereas *H. tomentosum* showed had tended of wet season higher as a result of this species responds to other environmental factors that were not studied such as wind speed and sunlight that difference from other studied species. Moreover, *B. purpurea* had non-pattern of the wet season tend due to having a linear regression pattern that showed *B. purpurea* no respond or slightly to changing weather conditions in each season.

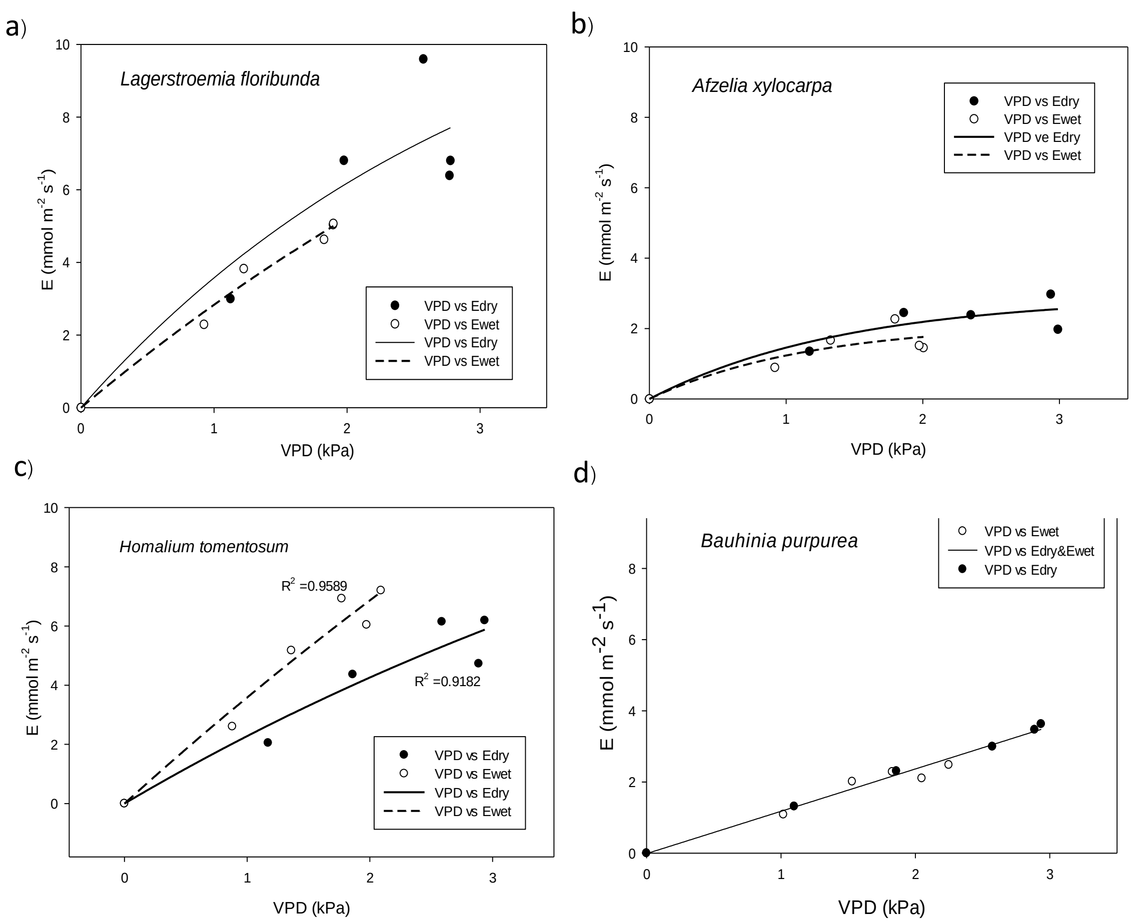


Figure 4.8 Relationship between seasonal transpiration rate (E) and VPD in wet and dry season for (a) *L. floribunda,* (b) *A. xylocarpa.,* (c) *H. tomentosum* and (d) *B. purpurea.*

From Figure 4.8, increasing the transpiration rate with VPD without saturation, except for *A. xylocarpa*. The rate in dry season was higher than in wet season showed in *L. floribunda* and *A. xylocarpa* however *H. tomentosum* showed in contrast and presented higher transpiration rate. Moreover, *B. purpurea* showed transpiration rate increased with VPD and no seasonal difference in tree response. For all species, transpiration rate in dry season tends to decrease when VPD increased before decreasing transpiration rate in wet season as the result of tree showed saturation for leaf stoma closure when higher VPD to prevent water loss from the trees. Regression statistics are shown in Table 4.6.

Table 4.6 Exponential saturating equation and R^2 individual studied tree species in two seasons.

Species	**Saturating equation**	R^2	**p-value**
Lagerstroemia floribunda	E_{wet} = 18.55(1-exp$^{-0.1657VPD}$)	0.9360	0.0096
	E_{dry} = 13.20(1-exp$^{-0.3157VPD}$)	0.5941	0.0001
Afzelia xylocarpa	E_{wet} = 2.153 (1-exp$^{-0.08508VPD}$)	0.3721	0.0168
	E_{dry} = 2.921(1exp$^{-0.6908VPD}$)	0.8727	0.0064
Homalium tomentosum	E_{wet} = 41.17(1-exp$^{-0.0913VPD}$)	0.9589	0.0026
	E_{dry} = 17.36(1-exp$^{-0.1407VPD}$)	0.9182	0.0006
Bauhinia purpurea	E_{wet}/ E_{dry}= 0.0131+1.1892 VPD	0.9842	<0.0001

CHAPTER 5

RESEARCH CONCLUSION

5.1 Conclusion

Our results revealed that, daily transpiration individual species pattern of both wet and dry seasons had the similar pattern but there was no significant difference. In both seasons, *L. floribunda* showed the highest transpiration rate value and *A. xylocarpa* showed the lowest values. In dry season had transpiration rate higher than wet season and tended decreasing the transpiration rate before wet season due to the prevention of excessive water loss by closing leaf stoma when higher VPD to save the balance of water within the tree. In addition, the relationship between daily transpiration rate (E) and VPD showed that when the VPD value increased, the transpiration rate also increased and at one point it would be stable in both seasons with an exponential saturating patterns, however *B. purpurea* showed the relationship a linear regression pattern and there was no significant difference between E and VPD values in both seasons ($p > 0.005$).

5.2 Research recommendations

5.2.1 Other environmental parameters that can affect to stomata conductance and transpiration rate, i.e. sunlight, rainfall, carbon dioxide and wind speed should also be considered to analyze the transpiration response to the environmental factors both two seasons.

5.2.2 The study of transpiration in Thailand hadn't a clearly indication periods of the season and the variable weather that may be a reason to make inaccurate results.

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