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Original Research

Determination of Diurnal Leaf Gas Exchange for Drip-Irrigated Kenaf Plant in Sub-Humid Climatic Conditions

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Abstract

Kenaf stands out as an important fiber source in the industry with its 4000-year history. Physiological properties have a great effect on the development process of kenaf. Physiological properties are significantly affected by seasonal air temperature changes and precipitation, as well as fluctuations during the day. The main reason for these fluctuations is seen as instant changes in environmental factors. In this study, it was aimed to determine the hourly changes of leaf gas exchange parameters of drip-irrigated kenaf plant and to examine the relationships between these parameters. Field experiment was conducted in Bursa, Turkey, which has sub-humid climatic conditions. For this purpose, net photosynthesis rate (A), stomatal conductivity (gs), intercellular CO_2 concentration (Ci) and transpiration rate (E) measurements were carried out on 18th September 2019 and 26th September 2020, between 08:00 h and 18:00 h. As a result of the study, while it was determined that A, gs, Ci and E parameters varied between 14.75-23.67 µmol CO_2 m^{-2} s^{-1}, 0.23-0.74 mol H_2O m^{-2} s^{-1}, 243-331 µmol CO_2 mol air^{-1} and 2.67-7.37 mmol H_2O m^{-2} s^{-1}, respectively in 2019, they varied between 13.97-22.30 µmol CO_2 m^{-2} s^{-1}, 0.29-0.58 mol H_2O m^{-2} s^{-1}, 217-278 µmol CO_2 mol air^{-1} and 6.3-14.7 mmol H_2O m^{-2} s^{-1}, respectively in 2020. Different measurement times had significant effects on all parameters at the $p<0.01$ level for both years. As a result of the evaluation of the relationships between gas exchange parameters, it was determined that the gs-A and E-A relationships were statistically significant at the $p<0.01$ level for both years. On the other hand, in 2019 and 2020, Ci-A relationships were significant at $p<0.05$ and $p<0.01$ probability levels, respectively. Information on the responses of leaf gas exchange parameters to weather changes occurring during the day in kenaf plant in sub-humid climate conditions

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is extremely limited. In this study, relationships that make it possible to predict hourly variation of A using gs and E parameters in sub-humid climate conditions were revealed.

Keywords: Kenaf, net photosynthesis rate, stomatal conductivity, transpiration rate, diurnal changes

Introduction

Kenaf (*Hibiscus cannabinus* L.) is an annual plant with high fiber potential. Today, the use of fibers obtained as a result of agricultural activities for the production of polymer composite materials is quite common. Extensive application of kenaf fibers has been reported in a variety of applications, including the building materials, furniture, consumer goods, and automotive industry [1]. Therefore, kenaf fiber is one of the most widely used natural fibers today. Kenaf fibers have become very popular for scientific research due to their unique properties and accessibility [2]. The main reasons for this situation are shown as the fact that the cultivation can be done in different climatic conditions and the high yield per unit cost can be obtained due to the rapid growth of the plant [3]. The yield and quality of the fiber can be affected by many external factors such as the changes in physiological parameters.

Environmental factors such as air temperature (T_{air}), vapor pressure deficit (VPD) and evaporation, which change during the day, causes instant changes in physiological characteristics. The direct environmental effects of photosynthetically active radiation (PAR), T_{air} and VPD on physiological mechanisms are primarily responsible for the diurnal variation in plant canopy and ecosystem flows [4]. Many studies declare that decline of the VPD arranges water balance by affecting the stoma of the plant, affect plant photosynthesis and growth [5, 6]. The difficulty of distinguishing VPD effects from temperature, radiation, and other climatic variables of plant function contributes to the ambiguity around VPD effects on plants [7, 8]. Accordingly, it is expected that the hourly changes of the physiological parameters of crop will show significant differences.

Stomatal regulation of transpiration is essential to maintain important processes such as allowing adequate CO_2 uptake into the leaf to maintain photosynthetic rates, leaf temperature and plant water status. Stomatal conductivity is hypothesized to regulate the balance between carbon uptake and water loss by being strongly related to photosynthetic rates [9]. Leaf gas exchange is one of the main factors that determine the yield of the plant and give information about its development [10]. Several studies were carried out to determine the seasonal changes in the net photosynthesis rate (A), stomatal conductivity (gs), intercellular CO_2 concentration (Ci) and transpiration (E) values of the kenaf [11, 12]. The determination of the changes in these parameters during the day is limited to the study conducted in central Greece by [13]. It has been reported that kenaf, which has a wide adaptation ability between 45° North and 30° South latitudes [14], can be successfully cultivated in Mediterranean climate conditions [15]. In addition, [16] and [17] reported that kenaf can be successfully grown in Bursa, Turkey, which has sub-humid climatic conditions. However, no study has been found on how the leaf gas exchange, which is effective on the development of the plant, is during the day or in the middle of the day for the kenaf plant in sub-humid climatic conditions. In addition, one way to evaluate the adaptability of plants to the weather conditions in the environment in which they will be grown is to determine the changes in gas exchange during the day [18]. Improvement of the process-based modeling of ecosystem gas exchange requires a better understanding of midday depression at the leaf size [19]. Some crop models have recently employed leaf gas exchange to simulate crop development and yield creation, as well as to assess the impact of environmental conditions on these processes, taking into consideration the impact of global changes on crops [20-22]. The aim of this study was to determine the responses of leaf gas exchange parameters to hourly measurements and the relationships between gs, Ci and E with A by measurements from pre-dawn to post-dusk for kenaf plant in Bursa, Turkey.

Material and Methods

Study Area and Experimental Design

The experiment was carried out at the Agricultural Application and Research Center (40º13'33" north (N) latitude and 28º51'34" east (E) longitude) of Bursa Uludağ University Faculty of Agriculture, Bursa, Turkey in 2019 and 2020. The soils of experimental area have clayey texture (average 22.8% sand, 28.7% loam and 48.5% clay) and for 0-120 cm soil depth considering 30 cm soil layers; the bulk density ranged between 1.35-1.38 g cm^{-3}. Total available water (TAW) in the effective rooting depth (0.90 m) is determined as 151.3 mm. The 2019 and 2020 growing seasons climate data of the experimental area, which has sub-humid climatic conditions, are given in Table 1 [23].

Kenaf (*Hibiscus cannabinus* L.) variety named "Tainung-2" was used as plant material in the study. The kenaf seeds were planted in 11^{th} June of 2019 and 23^{th} June in 2020 and row spacing was 70 cm for both years. Leaf gas exchange measurements were made in full irrigation plots (three plots) of a deficit irrigation experiment. Each plot constituted by 6 rows with 6 m length. In order to achieve the irrigation applications after the scheduled irrigations have started, the full irrigation plots were covered with a greenhouse nylon

Table 1. 2019 and 2020 monthly average climate data for growing period.

	Parameter	Months			
		June	July	August	September
2019	Average temperature (ºC)	23.1	23.2	23.9	20.5
	Avg. wind speed (m s^{-1})	2.2	2.1	2.4	2.1
	Relative humidity (%)	68.6	64.6	64.3	63.5
	Solar radiation (MJ m^{-2} day^{-1})	20.8	23.4	21.9	17.5
	Precipitation (mm)	47.4	27.2	39.1	11.3
2020	Average temperature (ºC)	21.7	24.8	24.7	23.0
	Avg. wind speed (m s^{-1})	1.7	2.6	2.3	2.1
	Relative humidity (%)	67.9	64.1	62.0	67.3
	Solar radiation (MJ m^{-2} day^{-1})	24.3	26.6	23.8	16.7
	Precipitation (mm)	40.5	1.3	1.5	5.9

that could prevent the incoming rain. For this purpose, constructions made of iron profiles were installed (like a greenhouse). The plots were covered before a possible precipitation event and opened after the precipitation [24]. The process of covering the plots started on 23rd July for the first year and 3rd August for the second year, when sufficient root development of kenaf plants was achieved. In the first year, the experimental plots were covered for a total of 2 times, 2 days each, from 23rd September to the measurement day (18th September). In the second year, experimental plots were covered for just 1 day until the measurement date (26th September). 60 kg ha^{-1} of NPK (15+15+15) compound fertilizer was applied at sowing, and 100 kg N ha^{-1} was added as 46% urea fertilizer when the plants reached a height of 40-50 cm. In the full irrigation application, 100% of soil water depletion (SWD) replenished when 30% of total available water (TAW) is depleted in 90 cm depth [25-27]. Soil water content was measured with a neutron meter (503 DR Hydroprobe, CPN International, Inc., Martinez, CA, USA) at 0.16 m, 0.45 m, 0.75 m and 1.05 m soil depths, using aluminum tubes placed in the plots for a soil profile of 0-120 cm. The calibration work of the neutron meter was carried out in the year of 2018. Wet and dry calibration plots were created in order to obtain calibration equations for 0-30, 30-60, 60-90 and 90-120 cm soil layers. Wet plot was brought to field capacity level and gravimetric measurements were made against neutron meter count ratio readings for each soil layer from wet and dry plots. In addition, volumetric water content for 0.30 m soil depth was controlled during the growing periods on the basis of soil sampling. According to the results of the water analysis, the quality of the irrigation water used in the research was determined as C_2S_1. At the beginning of field trial, sprinkler irrigation method used for the germination and emergence of seeds. Afterward, irrigation applications to trial plots were done by drip irrigation method. The lateral pipes with a diameter of 16 mm were installed in each plant row. Pressure-compensating emitters were used in the drip irrigation systems. The flow rate of the in-line drippers and the dripper spacing were 2.0 L h^{-1} and 0.33 m, respectively.

Measurements of Leaf Gas Exchange Parameters

Net photosynthesis rate (A), stomatal conductance (gs), intercellular CO_2 concentration (Ci) and transpiration rate (E) measurements were made in 18th September of 2019 (DAP 100) and 26th September in 2020 (DAP 96) from pre-dawn (08:00 h) to post-dusk (18:00 h) at 1 h intervals using a portable photosynthesis system (Li-6400, LI-COR Inc., Lincoln, NE, USA). The measurements were made from full irrigation plot and youngest fully expanded leaves were used [28, 29]. Portable photosynthesis system utilizes the equations derived by [30] for the A, gs, Ci and E.

Transpiration

The transpiration rate of any leaf with leaf area s (m^2) is measured as the difference between the rate of water vapor at the moment of entering to the chamber of the system and the water vapor rate at the leaving moment.

$$sE = u_o w_o - u_i w_i \quad (1)$$

In Equation (1); E transpiration rate (mol m^{-2} s^{-1}), s leaf area (m^2), u_i and u_o input and output flow rates (mol s^{-1}), w_i and w_o mole fractions of incoming and outgoing water (mol H_2O mol air^{-1}) shows the values and expression $u_o = u_i + sE$, can be written as $sE = (u_i + sE)$ wo – $u_i w_i$.

Portable photosynthesis system (Li-6400) performs measurements using the following relations.

$$u_i = F/10^6 \tag{2}$$

$$w_i = W_r/10^3 \tag{3}$$

$$w_o = W_s/10^3 \tag{4}$$

$$s = S/10^4 \tag{5}$$

The final form of the equation used by Li-6400 for transpiration is given in Equation (6).

$$E = \frac{F(W_s - W_r)}{100S(1000 - W_s)} \tag{6}$$

Stomatal Conductance

Li-6400 initially calculates the total conductance to against water vapor with Equation (7) to determination of stomatal conductivity.

$$g_{tw} = \frac{E\left(1000 - \frac{W_l + W_s}{2}\right)}{W_l - W_s} \tag{7}$$

W_l is the molar concentration of water vapor in the leaf (mmol H_2O (mol air)$^{-1}$) is given by Equation (8).

$$W_l = \frac{e(T_l)}{P} \times 1000 \tag{8}$$

T_l is the leaf temperature (ºC) and P the total atmospheric pressure (kPa) in Equation (8). Additionally, the $e(T_l)$ is calculated by Equation (9).

$$e(T) = 0.61365e^{\frac{17.502T}{240.97+T}} \tag{9}$$

Stomatal conductivity (g_{sw}) (mol H_2O m^{-2} s^{-1}), is computed with the determined total conductivity (g_{tw}) above.

$$g_{sw} = \frac{1}{\frac{1}{g_{tw}} - \frac{k_f}{g_{bw}}} \tag{10}$$

g_{bw} is boundary layer conductivity to water vapor (mol H_2O m^{-2} s^{-1}) and depends on whether there are stomata on one or both sides of the leaf. The k_f value is a factor based on the estimated K fraction of stomatal conductivity and calculated as,

$$k_f = \frac{K^2 + 1}{(K + 1)^2} \tag{11}$$

Net Photosynthesis Rate

$$sa = u_i c_i - u_o c_o \tag{12}$$

Equation (12) is the mass balance approximation of CO_2 existing in an open system. Assimilation rate (mol CO_2 m^{-2} s^{-1}) shows by a, input and output mol fractions (mol CO_2 mol air^{-1}) of CO_2 show by c_i and c_o. Besides, since $u_o = u_i + sE$, it can be written as $s_a = u_i c_i - (u_i + sE)c_o$.

$$a = \frac{u_i(c_i - c_o)}{s} - Ec_o \tag{13}$$

Li-6400 uses the following relations throughout measurements,

$$a = A/10^6 \tag{14}$$

$$c_i = C_r/10^6 \tag{15}$$

$$c_o = C_s/10^6 \tag{16}$$

A is net assimilation rate by leaf (μmol CO_2 m^{-2} s^{-1}), C_r is sample CO_2 concentration and C_s reference CO_2 concentration (μmol CO_2 (mol air)$^{-1}$). The above equations are evaluated together and Li-6400 uses Equation (17) to calculate net photosynthesis rate.

$$A = \frac{F(C_r - C_s)}{100S} - C_s E \tag{17}$$

Intercellular CO_2 Concentration

The formulation of the intercellular CO_2 concentration C_i (μmol CO_2 mol air^{-1}) is given in Equation (18).

$$C_i = \frac{\left(g_{tc} - \frac{E}{2}\right)C_s - A}{g_{tc} + \frac{E}{2}} \tag{18}$$

In equation g_{tc} used for the total conductance to CO_2 and it is calculated as,

$$g_{tc} = \frac{1}{\frac{1.6}{g_{sw}} + \frac{1.37k_f}{g_{bw}}} \tag{19}$$

The values 1.6 and 1.37 in the equation are the ratio of the diffusivities water and CO_2 for air and boundary layer, respectively.

Statistical Analysis

Data for A, gs, Ci and E were subjected to one-way analysis of variance (one-way ANOVA). The F-test was used to determine the effect of measurement time at the 0.05 and 0.01 probability levels, with F-protected least significant difference (LSD) calculated at 0.05. Regression analyzes were performed to determine the relationships between gs, Ci and E with A.

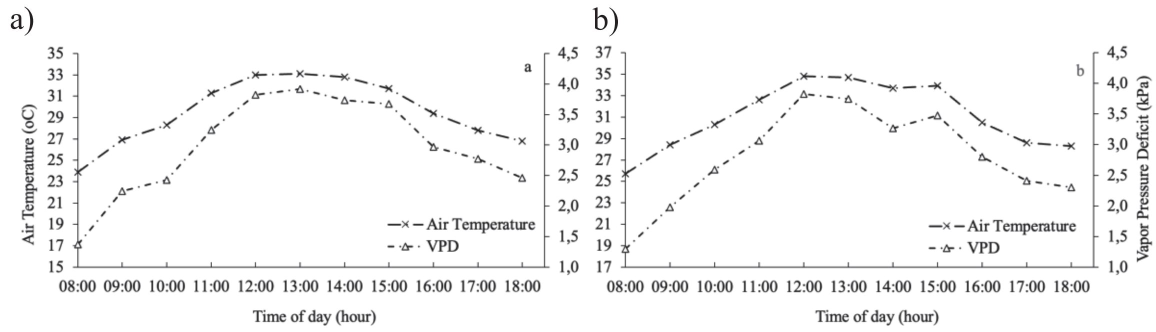

Fig. 1. Hourly air temperature and Vapor Pressure Deficit (VPD) changes on measurement date in a) 2019 and b) 2020.

Results and Discussion

Hourly air temperature and calculated VPD changes for measurement days in both years are presented in Fig. 1(a-b). According to the Fig. 1(a-b), daily air temperature and VPD values varied between 23.9-33.1ºC and 1.37-3.92 kPa, respectively in 2019 and between 25.7-34.8ºC and 1.30-3.83 kPa in 2020, respectively. Many researchers reported that the gas exchange parameters increased as the air temperature and vapor pressure deficit (VPD) increased [31, 32].

The results of one-way ANOVA, in which the effects of measurement hours on A, gs, Ci and E parameters for 2019 and 2020 were examined, are given in Table 2. As can be seen from the analysis results, the effects of measurement hours on all parameters were found to be significant at $p<0.01$ level for both years. Because of kenaf is in the Malvaceae family it has common characteristics with crops such as okra (*Hibiscus esculentum* L.) and cotton (*Gossypium hirsutum* L.) [33]. [34] determined that the effects of measurement hours on A, gs and Ci parameters in the cotton were statistically significant. In another study on pedunculate oak seedlings, [35] reported that the differences between diurnal measurements were statistically significant for A, E, gs and Ci parameters. It is seen that the results found in the previous studies are similar to the results found in this study. Diurnal changes of A, gs, Ci and E parameters for 2019 and 2020 are given in Fig. 2(a-d) and Fig. 3(a-d), respectively.

The intake of carbon dioxide from the environment for photosynthesis and the release of water vapor from the plant for transpiration are the two basic processes that take place between the leaf and the atmosphere [36]. Radiation is a well-known environmental driver of gas exchange, capable of causing 100 percent of the diurnal oscillation. T_{air} and VPD are frequently regarded as the second and third most significant environmental determinants of diurnal flow dynamics, respectively [4]. The stomatal conductance can change with short term changes of solar radiation [37]. The close relationship between A and gs is thought to help maximize A as a function of E during the day. There is also evidence to suggest that this relationship is driven by a signal produced by the mesophyll, to which guard cells sense and respond [35].

As a result of the measurements in 2019, the highest A values in kenaf plant were reached at 14:00 h (22.50 µmol CO_2 m^{-2} s^{-1}), 15:00 h (23.67 µmol

Table 2. The results of analysis of variance for both years.

Year	Source of Variation	df	Mean Square			
			Net photosynthesis rate	Stomatal conductance	Intercellular CO_2 concentration	Transpiration
2019	Blocks	2	0.264^{ns}	0.021^{ns}	1670.182^{ns}	1.154^{ns}
	Hour	10	27.296^{**}	0.094^{**}	2963.406^{**}	8.633^{**}
	Error	20	0.820	0.011	599.320	0.482
	$LSD_{0.05}$		0.87	0.08	23.90	0.67
2020	Blocks	2	2.449^{ns}	0.001^{ns}	607.245^{ns}	1.606^{ns}
	Hour	10	19.978^{**}	0.027^{**}	1114.741^{**}	19.865^{**}
	Error	20	2.587	0.007	231.810	1.078
	$LSD_{0.05}$		2.72	0.13	25.7	1.73

**Significance level at $p<0.01$, *ns* not significant

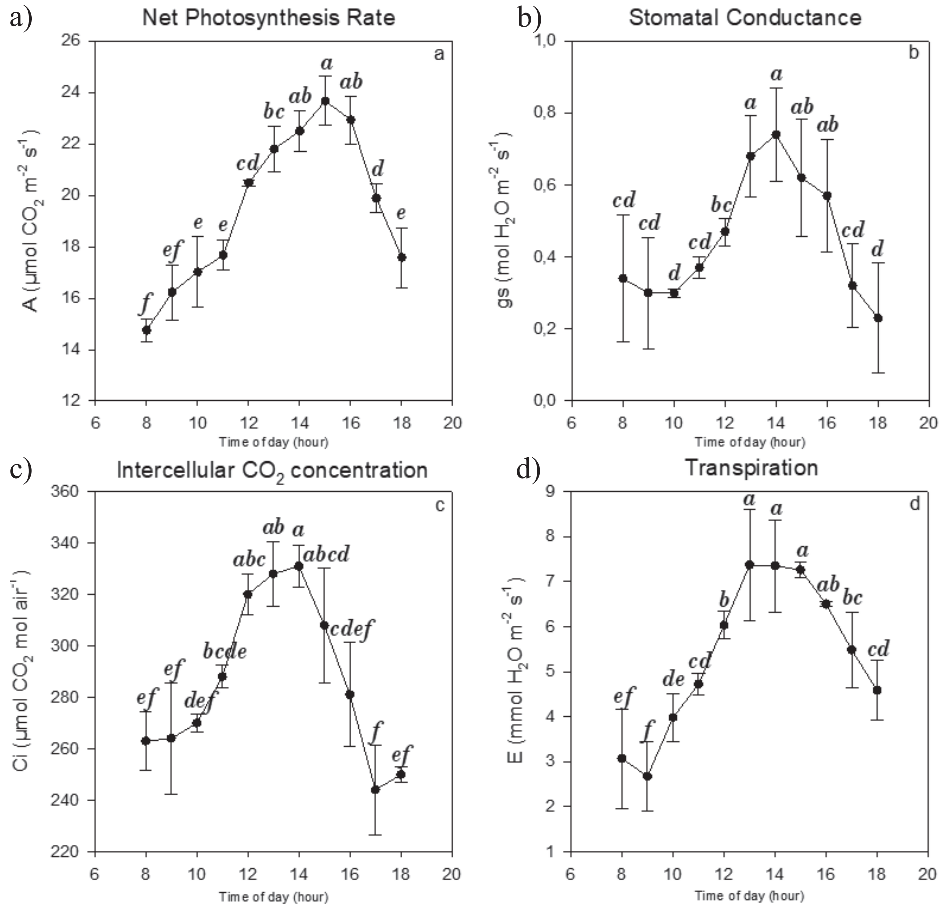

Fig. 2. Diurnal changes of net photosynthesis rate a), stomatal conductance b), intercellular CO_2 concentration c) and transpiration d) for 2019.

CO_2 m^{-2} s^{-1}) and 16:00 h (22.93 µmol CO_2 m^{-2} s^{-1}), while the lowest average values measured at 08:00 h (14.75 µmol CO_2 m^{-2} s^{-1}) and 09:00h (16.23 µmol CO_2 m^{-2} s^{-1}) (Fig. 2a). When the hourly changes of A values during the measurement day in 2020 were examined, the highest values were measured at 14:00 h, 15:00 h and 16:00 h as 22.30 µmol CO_2 m^{-2} s^{-1}, 22.23 µmol CO_2 m^{-2} s^{-1} and 21.97 µmol CO_2 m^{-2} s^{-1}, respectively whereas the lowest value was measured at 18:00 as 13.97 µmol CO_2 m^{-2} s^{-1} (Fig. 3a). Stomatal closure reduces gas diffusion conductance via stomatal conductance, resulting in a reduction in CO_2 assimilation rate [38]. The minimum values were observed in the morning in 2019 and in the evening in 2020, which are the hours when the arrival angles of the sun rays on the plants are more oblique. When the studies including seasonal measurements are examined, it is seen that the A values of the fully irrigated kenaf plant can reach up to 25-30 µmol CO_2 m^{-2} s^{-1} [11, 12]. In parallel with the obtained values, [13] reported that the maximum net photosynthesis rate for Tainung 2 cv. reached 19 µmol CO_2 m^{-2} s^{-1}, while it was 22 µmol CO_2 m^{-2} s^{-1} for Everglades 41 cv. [34] reported that they observed values approaching 30 µmol CO_2 m^{-2} s^{-1} in the hourly A measurements performed on 4 different cotton genotypes and that the Pima 32 genotype reached its maximum value of the 24 µmol CO_2 m^{-2} s^{-1}at 15:00 h.

When the hourly changes of gs values during the measurement day in 2019 were examined, it was determined that the highest and lowest average values were measured at 14:00h (0.74 mol H_2O m^{-2} s^{-1}) and 18:00h (0.23 mol H_2O m^{-2} s^{-1}), respectively, and gs reached the highest average values between 13:00 h and 16:00 h (Fig. 2b). In 2020, It was determined that the gs parameter reached its maximum values at 13:00 h (0.50 mol H_2O m^{-2} s^{-1}) and 14:00 h (0.58 mol H_2O m^{-2} s^{-1}) while the minimum values at 10:00 h (0.32 mol H_2O m^{-2} s^{-1}) and 18:00 h (0.27 mol H_2O m^{-2} s^{-1}) (Fig. 3b). The measurement time has been found to influence gs [39]. [12] stated that the values measured during the season in fully irrigated kenaf plants reached 0.95 mol H_2O m^{-2} s^{-1}. [13] declared that the highest gs values reached during the day were 1.3 mol H_2O m^{-2} s^{-1} and 1.75 mol H_2O m^{-2} s^{-1} for Tainung 2 and Everglades 41 cultivars, respectively. It is thought that the higher gs values obtained in the previous studies are due to different climatic conditions and the date of measurement. [34] determined the time interval in which the measurements carried out during the day for the cotton plant reached the maximum values as 13:00-15:00 h.

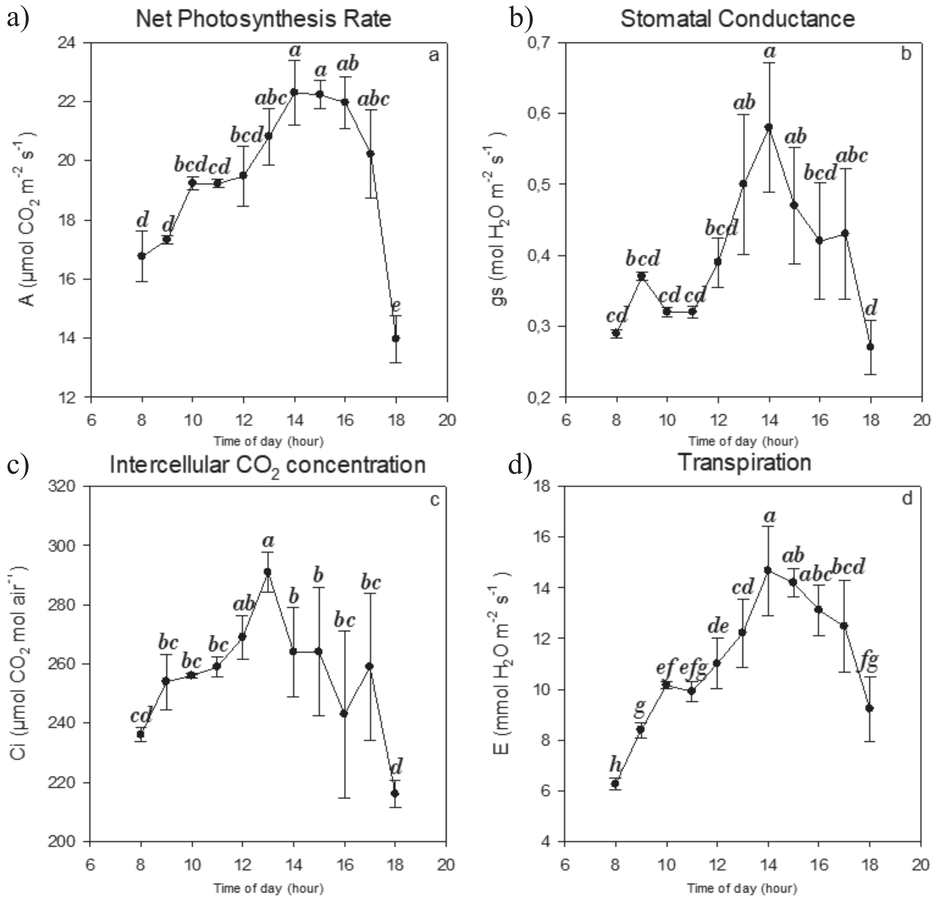

Fig. 3. Diurnal changes of net photosynthesis rate a), stomatal conductance b), intercellular CO_2 concentration c) and transpiration d) for 2020.

It is seen that Ci values in 2019 reached the highest averages at midday (12:00 h-14:00 h) and the maximum value of Ci was measured as 331 µmol CO_2 mol air^{1} at 14:00 h and the minimum value was measured as 243 µmol CO_2 mol air^{1} at 17:00 h (Fig. 2c). In 2020, the highest and lowest Ci values were measured at 13:00 h and 18:00 h as 291 µmol CO_2 mol air^{1} and 215.67 µmol CO_2 mol air^{1}, respectively (Fig. 3c). In a study with similar findings; [13] stated that the change interval of the Ci value between 08:00 h and 18:00h was between 250 and 320 µmol CO_2 mol air^{1} for Tainung 2 cv. and between 230 and 310 µmol CO_2 mol air^{1} for Everglades 41 cv. [40] measured hourly Ci values for maize during the day and they stated that it is achieved maximum values at noon. In addition, it was reported that the measured values in the study ranged from 100 µmol CO_2 mol air^{1} to 220 µmol CO_2 mol air^{1}. The differences with this study could be due to the different plant material.

Lastly, the E values of the kenaf plant had reached the highest averages between 13:00 h and 16:00 h, and the lowest values were measured at 08:00 h and 09:00 h in 2019 (Fig. 2d). The E parameter in the measurements carried out in 2020 reached the highest averages between 13:00 h (14.67 mmol H_2O m^{-2} s^{-1}) and 14:00 h (14.2 mmol H_2O m^{-2} s^{-1}) and the lowest value at 08:00 h as 6.25 mmol H_2O m^{-2} s^{-1} (Fig. 3d). [13] declared that the maximum E value obtained belonged to the measurement performed at 14:00 h and the measurements with the lowest averages were carried out between 08:00 h and 09:00 h. In the same study, the researchers reported that the daily average transpiration rate values obtained under full irrigation conditions were 7.07 mmol H_2O m^{-2} s^{-1} for Tainung 2 cultivar and 9.01 mmol H_2O m^{-2} s^{-1} for Everglades 41 cultivar, and showed that it could reach approximately 16.00 mmol H_2O m^{-2} s^{-1} for Tainung 2 cultivar at noon. The transpiration rate values obtained in this study were similar to the values obtained in the previous study. In another study in which similar results were obtained, the highest values for hourly measurements made in the cotton were reached between 12:00 h and 16:00 h [41]. Regulation of transpiration rate by stomata is an essential part of leaf energy balance and can be critical for maintaining an optimum or favorable leaf temperature for photosynthesis, particularly during periods of increased or high light intensity as seen during the diurnal cycle [9].

Relationships between gs, Ci and E parameters with A in kenaf plant for 2019 and 2020 are given in Fig. 3(a-c) and Fig. 4(a-c), respectively. Relationships has been determined between gs and E with A at $p<0.01$

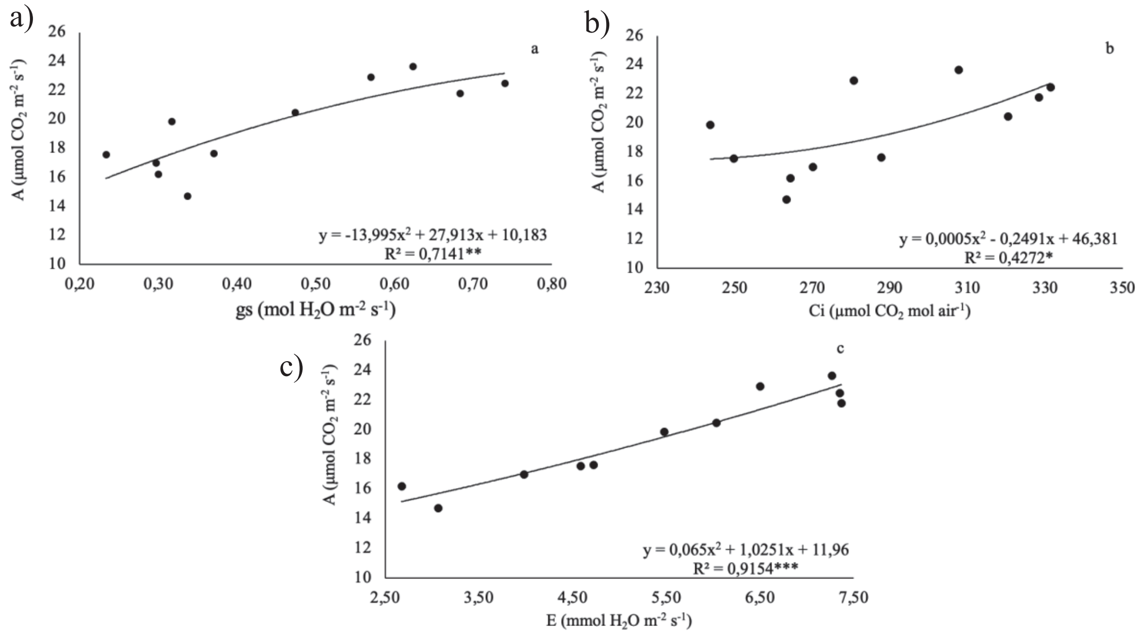

Fig. 4. Relations between stomatal conductance (gs), intercellular CO_2 concentration (Ci) and transpiration (E) with net photosynthesis rate (A) (a, b and c, respectively) for 2019.

significance level (R^2 = 0.71 and R^2= 0.91, respectively) and between Ci and A at $p<0.05$ significance level (R^2 = 0.43) for the measurements carried out in 2019, while it is seen that the determined relations between gs, Ci and E with A statistically significant at $p<0.01$ level (R^2 = 0.75, R^2 = 0.58 and R^2 = 0.73, respectively) in 2020. It can be said that especially the gs and E parameters can be used to estimate the hourly variation of the A parameter for the kenaf plant. [42] determined relationships at $p<0.001$ (R^2 = 0.865) significance level between the measured net photosynthesis rate and stomatal conductivity values for lemon trees. [43] determined linear relationships between A and Ci values, as a result of the measurements made on Prunus domestica trees during the day for two different treatments (R^2 = 0.82 and R^2 = 0.90). [44] determined

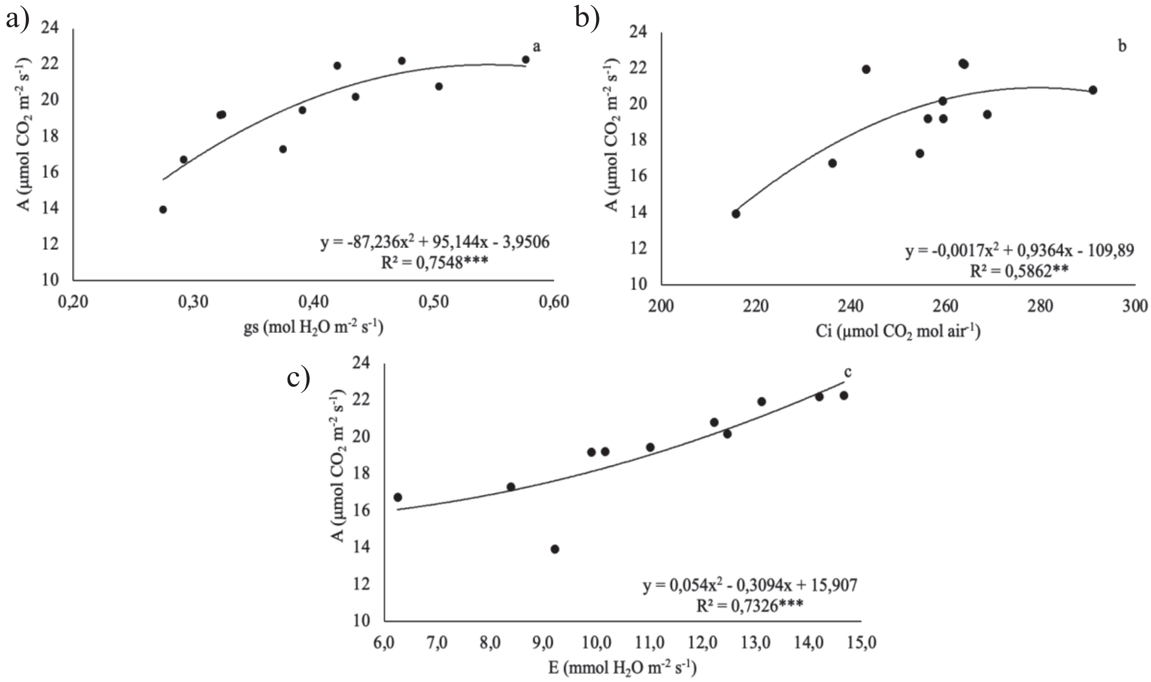

Fig. 5. Relations between stomatal conductance (gs), intercellular CO_2 concentration (Ci) and transpiration (E) with net photosynthesis rate (A) (a, b and c, respectively) for 2020.

that the A parameter has statistically significant correlations with the gs (R^2= 0.67) and E (R^2 = 0.71) parameters as a result of seasonal measurements made in cotton. [34] concluded that there is a statistically significant ($p<0.05$) fourth-order polynomial relationship between A and Ci values in cotton. [45] determined a statistically significant correlation between A and Ci values in tomato and they concluded that when A values increase, Ci values increase.

Conclusions

Kenaf is a fiber crop with high potential of biomass yield due to its high net photosynthesis rate. Hence, it is important to follow the physiological characteristics during the cultivation and to have information about diurnal physiological changes. As a result of the study, it was determined that the different measurement hours affected all parameters significantly ($p<0.01$). Net photosynthesis rate, stomatal conductivity, intercellular CO_2 concentration and transpiration rate parameters varied between 14.75-23.67 μmol CO_2 m^{-2} s^{-1}, 0.23-0.74 mol H_2O m^{-2} s^{-1}, 243-331 μmol CO_2 mol air^{-1} and 2.67-7.37 mmol H_2O m^{-2} s^{-1}, respectively in 2019 and between 13.97-22.30 μmol CO_2 m^{-2} s^{-1}, 0.29-0.58 mol H_2O m^{-2} s^{-1}, 217-278 μmol CO_2 mol air^{-1} and 6.25-14.67 mmol H_2O m^{-2} s^{-1}, respectively in 2020. In particular, the relationships that made it possible to predict the hourly change of net photosynthesis rate using the stomatal conductivity and transpiration rate parameters were revealed. Information on the responses of leaf gas exchange parameters to weather changes occurring during the day in kenaf plant in sub-humid climate conditions is extremely limited. These relationships and the obtained hourly measurement values can assist in the development of crop growth models for use in large-scale regional studies in the sub-humid climate zone.

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Conflict of Interest

The authors declare no conflict of interest.

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