



## CORRELATION BETWEEN CO<sub>2</sub> ASSIMILATION RATES AND OTHER GAS EXCHANGE PARAMETERS OF *Hevea* WITH REFERENCE TO COMMENCEMENT OF TAPPING

H. K. L. K. GUNASEKERA <sup>a\*</sup>, W. A. J. M. DE COSTA <sup>b</sup> AND A. NUGAWELA <sup>c</sup>

<sup>a</sup> Department of Agricultural and Plantation Engineering, Faculty of Engineering Technology,  
The Open University of Sri Lanka, Sri Lanka.

<sup>b</sup> Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

<sup>c</sup> Rubber Research Institute of Sri Lanka, Sri Lanka.

### AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

#### Article Information

DOI: 10.56557/JOGAE/2022/v14i47799

Received: 29 May 2022

Accepted: 04 August 2022

Published: 12 August 2022

Original Research Article

### ABSTRACT

The present study was supplement to a longer experiment to determine the feasibility of early commencement of tapping of two *Hevea* genotypes i.e. RRIC121 and RRISL 211. The main objective of this study was to develop a correlations between CO<sub>2</sub> assimilation rates and other leaf gas exchange parameters of *Hevea* with reference to the commencement of tapping. Tapped and untapped trees of two *Hevea* genotypes, i.e. RRIC121 and RRISL 211 at the same age were selected for the study. All cultural practices were performed according to the Rubber Research Institute of Sri Lanka. To evaluate the significance of differences between all possible pairs of treatment means, mean separation of treatments was performed with Duncan's Multiple Range Test (DMRT). The strength of the relationships between yield and photosynthetic gas exchange parameters was estimated by linear correlation analysis. The leaf gas exchange parameters were measured under optimal environmental conditions clearly showed the intercellular CO<sub>2</sub> concentration (Ci) gradually decrease with increasing light intensity in both clones. The same trend was observed in the different canopy layers under both tapping treatments. The highest leaf-air vapour pressure deficit (lvpd) was shown in the leaves of the upper canopy and lowest in the bottom canopy layer. Furthermore, the water use efficiency (WUE) of clone RRISL 211 was higher than that of clone RRIC 121 under tapping. This was primarily because of the greater photosynthetic rates of RRISL 211, rather than lower transpiration rates. When considering the correlation analysis of gas exchange parameters of *Hevea*, CO<sub>2</sub> assimilation rate (A) had highly significant correlations with gs, Tr and intensity of PAR. However, the absence of a correlation between PAR and WUE showed that, when PAR increases both A and Tr increase in similar magnitudes. Therefore, WUE remains approximately constant. The presence or absence of correlations in gas exchange parameters of tapped and untapped treatments were broadly similar to the overall correlation analysis. In the tapped treatments, because of tapping, the photosynthetic rate is stimulated relative to the transpiration rate. The positive latex yield response to WUE and lvpd of top leaves

\*Corresponding author: Email: hkgun@ou.ac.lk;

indicates that, in top leaves when ivpd increases transpiration also increases accordingly. Hence WUE and ivpd increase latex flow within the tree and finally increase the latex yield with increasing latex volume. On the other hand, latex yield has a negative correlation with gs. The study findings clearly revealed that, in top leaves reduced Ci increases the CO<sub>2</sub> gradient and uptake of CO<sub>2</sub> for more photosynthesis, which increases the latex yield. Faster utilization of absorbed Ci may enhance the yield potential.

**Keywords:** Rubber; CO<sub>2</sub> assimilation; correlation; gas exchange parameters; canopy layers; tapping.

## 1. INTRODUCTION

Rubber (*Hevea brasiliensis*) can be considered as an ideal crop for testing the relation of photosynthetic characteristics to yield, since a close link exists between the economic yield, i.e. latex and sucrose supply [1]. Thus, understanding the physiological and biological processes involved in canopy photosynthesis could help increase crop yield [2]. Rubber (*Hevea brasiliensis* Muell. Arg.) is “a latex producing species belonging to the family Euphorbiaceae. Natural rubber is biosynthesized initiating from the end product of the photosynthetic process of the rubber tree” [3]. “The rate of latex production in the latex vessels of *Hevea* has been related to the supply of sucrose from the adjacent sieve tubes [4]. This suggests that a close link exists between the CO<sub>2</sub> assimilation capacity and the economically important component of the rubber tree” [1]. “The photosynthetic characters of leaves at different canopy positions are acclimatized to their own micro-environment. The major differences in photosynthetic activity in sun and shade adapted leaves within a canopy are correlated with differences in the concentration of the electron transport chain, photosystem activity and photosynthetic enzyme activity” [5]. “Therefore, it appears that canopy photosynthesis is naturally optimized by partitioning of photosynthetic capacity among the leaves with respect to natural light exposure. Thus gas exchange characters of a leaf from a particular canopy position cannot be considered necessarily to represent the photosynthetic characters of the entire canopy. Hence, estimating canopy photosynthesis has become an important aspect of plant productivity research” [2,5]. However for tree crops, a model that describes light attenuation within the canopy and the use of light response curves for leaves at different canopy positions to determine the CO<sub>2</sub> assimilation potential may be the only practical alternative to estimate canopy photosynthesis. Studies on canopy photosynthesis and yield have shown a clear positive correlation between them [6]. “The variation of leaf photosynthetic characteristics with depth in the canopy is an important factor to consider in the prediction of canopy photosynthesis. The sum of the collective effect of all leaves must be obtained to predict the canopy light use” (Norman and Arkebauer, 1991).

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site and Plant Material

The present study was supplement to a longer experiment to determine the feasibility of early commencement of tapping of two *Hevea* genotypes i.e. RRIC121 and RRISL 211. The experiment was conducted in the Dartonfield Estate at the Rubber Research Institute, Agalawatta, Sri Lanka, located in the agro ecological zone WL1. Two *Hevea* genotypes (mature trees of same girth) with contrasting yield potential, i.e. RRIC 121 and RRISL 211 were selected for the study.

#### 2.1.1 Experimental design and treatments

Four tapped and four untapped trees of *Hevea* from each of the two genotypes were selected for the study. Trees tapped at  $\frac{1}{2}$  S d/3 + E, i.e. the highest yielding treatment, was selected for this study.

Each day, leaflets were sampled from two trees (tapped and untapped) from each genotype and the following sequence was adopted to measure their gas exchange characteristics. Gas exchange measurements were made on twelve leaves on any given day. Sequence was reversed on the second day and measurements were taken on four days.

Sequence for measurements of Amax of tapped (T) and untapped (UT) trees of clones RRISL 211 and RRIC 121

1	RRISL 211	T/t	2	RRIC	121	T/t
3	RRISL 211	UT/t	4	RRIC	121	UT/t
5	RRISL 211	T/m	6	RRIC	121	T/m
7	RRISL 211	UT/m	8	RRIC	121	UT/m
9	RRISL 211	T/l	10	RRIC	121	T/l
11	RRISL 211	UT/l	12	RRIC	121	UT/l

T- tapped tree, UT-un-tapped tree, t- top strata of the canopy, m-middle strata of the canopy, l-lower strata of the canopy

#### 2.1.2 Protocol to use detached leaves for gas exchange measurements

With the Portable Infrared Gas Analyzer, IRGA (Model LI – 6400, LICOR Inc., Lincoln, NE, USA), reaching the leaves of mature rubber canopy for the measurements of CO<sub>2</sub> assimilation was extremely

difficult. According to Korpilathi [7], use of detached leaves in the measurements of CO<sub>2</sub> assimilation affects the accuracy. However, similar photosynthetic rates in attached leaves of field grown trees and detached leaves have been reported [8,9,1].

### 2.1.3 Detached leaves for the gas exchange measurements

The canopy of each tree was visually divided into three strata as top, middle and bottom. Then twigs were cut from each stratum with a sharp knife and immediately put into a bucket of water. Thereafter, the middle leaflet of a healthy, bright green, mature leaf was separated (about 2 cm above the leaf base) from the petiole using a sharp blade and it was cut across the lamina under water. A further cut was made very closely after 2 minutes to remove any latex coagulated at the cut end of the leaf lamina. Then they were immediately put into a small beaker with their cut ends dipped in water and were taken to the laboratory under an air tight container. The leaves sampled were kept for about two hours in controlled environment, i.e. at 30°C with low light ca.100 μ mol m<sup>-2</sup> s<sup>-1</sup>. These detached leaves were used for gas exchange measurements as per the sequence described previously.

## 2.2 Gas Exchange Measurements

Using an open system, portable Infrared Gas Analyzer, IRGA (LI – 6400, LICOR Inc., Lincoln, NE, USA), CO<sub>2</sub> uptake by leaves was measured at different light levels. An in-built artificial light source, 6400 – 02B Red/Blue (LICOR Inc., Lincoln, NE, USA), was used to provide the varying levels of incident PPFD. While taking the measurements of leaf photosynthesis, other related gas exchange parameters, i.e. transpiration rates (E), stomatal conductance (gs), intercellular CO<sub>2</sub> concentration (Ci) and leaf temperature (T) were also recorded simultaneously.

### 2.2.1 CO<sub>2</sub> assimilation rate (A)

Photosynthetic and transpiration rates were measured by the LI – 6400 system based on differences in the mole fraction of CO<sub>2</sub> and H<sub>2</sub>O of the outlet (analysis cell) and inlet (reference cell) air streams flowing through the leaf cuvette. The net CO<sub>2</sub> assimilation rate, A (μmol m<sup>-2</sup> s<sup>-1</sup>) is given by the formula given below [10].

$$A = \{ F ( Cr - Cs ) / 100 S \} - Cs E$$

Where, F, Cr, Cs, S and E are respectively molar flow rate of air entering the leaf chamber (μmol s<sup>-1</sup>), mole

fraction of CO<sub>2</sub> in the inlet of analysis cell (μmol CO<sub>2</sub> mol<sup>-1</sup> air), mole fraction of CO<sub>2</sub> in the outlet of analysis cell leaf area (cm<sup>2</sup>) and transpiration (mol H<sub>2</sub>O m<sup>-2</sup> s<sup>-1</sup>).

### 2.2.2 Transpiration rate (E)

The equation that the LI – 6400 uses for computing transpiration rate (E) is,

$$E = \frac{F ( ws - wr )}{100 S ( 1000 - ws )}$$

where

F = flow rate (μmol s<sup>-1</sup>)  
ws & wr = sample and reference water mole fractions (mmol H<sub>2</sub>O mol<sup>-1</sup> air)  
S = leaf area (cm<sup>-2</sup>)

### 2.2.3 Stomatal conductance (gs)

The equation that the LI – 6400 uses to compute stomatal conductance to water vapour (gsw) is,

$$gsw = \frac{1}{1/gtw - kf / gbw}$$

where,

gbw = boundary layer conductance to water vapour (mol H<sub>2</sub>O m<sup>-2</sup> s<sup>-1</sup>) from one side of the leaf  
gtw = total conductance to water vapour (mol H<sub>2</sub>O m<sup>-2</sup> s<sup>-1</sup>)  
kf = stomatal ratio

The stomatal conductance to water vapour (mol H<sub>2</sub>O m<sup>-2</sup> s<sup>-1</sup>) is obtained from the total conductance by removing the contribution from the boundary layer.

### 2.2.4 Intercellular CO<sub>2</sub> concentration (Ci)

The equation that the LI – 6400 uses for computing intercellular CO<sub>2</sub> concentration (Ci), (μmol CO<sub>2</sub> mol<sup>-1</sup> air) is,

$$Ci = \frac{( gtc - E/2 ) Cs - A}{gtc + E/2}$$

where,

gtc = total conductance to CO<sub>2</sub>

### 2.2.5 Water use efficiency (WUE)

The CO<sub>2</sub> and transpiration rates at saturating light levels were used in determining water use efficiency (WUE) as:

$$WUE = \frac{\text{Photosynthetic rate (A)}}{\text{Transpiration rate (E)}}$$

## 2.3 Data Analysis

“Analysis of Variance (ANOVA) was carried out using the SAS (SAS Institute, Inc., Carry, NC, USA) statistical package. To evaluate the significance of differences between all possible pairs of treatment means, mean separation of treatments was performed with Duncan’s Multiple Range Test (DMRT). The strength of the relationships between yield and photosynthetic gas exchange parameters was estimated by linear correlation analysis” [11].

## 3. RESULTS

### 3.1 Correlation between CO<sub>2</sub> Assimilation Rates and Other Gas Exchange Parameters

#### 3.1.1 Correlation coefficients at the overall canopy level

The CO<sub>2</sub> assimilation rate (A) had highly significant correlations with gs, Tr and PAR. The CO<sub>2</sub> assimilation rate and Ci were significantly negatively correlated while WUE and A were highly significantly and positively correlated. WUE and gs had highly a significant negative correlation while Ci and WUE had highly significant negative correlation. Furthermore, WUE and lvpd had a highly significant positive correlation. PAR and Tr had a positive relationship while PAR and Ci had a negative relationship. lvpd and Tleaf had a strong positive correlation although there was no significant correlation between PAR and WUE (Table 1).

#### 3.1.1.1 Correlations between tapped and untapped treatments

When correlation analysis was done separately for tapped and untapped treatments (Table 2), presence or

absence of correlations between gas exchange parameters was broadly similar to the pattern showed in the overall correlation analysis. There were only few variations in the magnitude of the correlations between the two situations, i.e. tapped and untapped treatments.

For example the correlation coefficient between A and gs was higher in the untapped treatment than in the tapped treatment. The same was observed for the correlations between A and Tr rates. There were strong significant correlations between lvpd and Tleaf of the tapped treatment than the untapped treatment while that between Ci and PAR was higher in the tapped treatment than in the untapped treatment. There was a significant positive correlation between PAR and Tleaf in the untapped treatment but no such correlation could be observed either in the tapped treatment or in the overall data set. In both tapped and untapped treatments, WUE and correlation coefficients of A, gs and Ci were similar to the pattern showed in the overall correlation analysis. In the tapped treatment, correlation coefficients of Tr, lvpd, Tleaf and PAR were similar to the pattern showed in the overall correlation analysis. On the other hand, in the untapped treatment correlation coefficients of those parameters showed the opposite pattern (Table 2).

#### 3.1.1.2 Correlations between latex yield and gas exchange parameters of different leaf layers of Hevea

##### 3.1.1.2.1 The top leaf layer

When the overall data set (i.e. all combinations of clones, tapping treatments and replicates) is considered, latex yield showed positive correlations with WUE and lvpd of the top leaves. On the other hand, the overall latex yield was negatively correlated with gs and Ci. When only the tapped treatment was considered, latex yield was positively correlated with

**Table 1. Linear Correlation coefficients between CO<sub>2</sub> assimilation rate (A), stomatal conductance (gs), intercellular CO<sub>2</sub> concentration (Ci), transpiration rate (Tr), leaf-air vapor pressure deficit (lvpd), leaf temperature (Tleaf), water use efficiency (WUE) and PARi for the overall data set**

	A	Gs	Ci	Tr	Lvpd	Tleaf	PARi	WUE
A	-	0.37***	-0.62***	0.33***	0.12*	0.12*	0.72***	0.27***
gs		-	0.24***	0.92***	-0.12*	0.04 <sup>ns</sup>	0.27***	-0.30***
Ci			-	0.20***	-0.23***	-0.20***	-0.35***	-0.42***
Tr				-	0.11*	0.08 <sup>ns</sup>	0.22***	-0.01 <sup>ns</sup>
lvpd					-	0.98***	-0.04 <sup>ns</sup>	0.95***
Tleaf						-	-0.02 <sup>ns</sup>	0.96***
PARi							-	0.08 <sup>ns</sup>
WUE								-

ns, non-significant at P = 0.05; \*significant at P = 0.05; \*\*significant at P = 0.01; \*\*\*significant at P = 0.001

**Table 2. Linear Correlation coefficients between CO<sub>2</sub> assimilation rate (A), stomatal conductance (gs), intercellular CO<sub>2</sub> concentration (Ci), transpiration rate (Tr), leaf-air vapor pressure deficit (lvpd), leaf temperature (Tleaf), water use efficiency (WUE) and PARi of tapped treatment (above the diagonal) and untapped treatment (below the diagonal)**

A	gs	Ci	Tr	Lvpd	Tleaf	PARi	WUE
A	-	0.18**	-0.66***	0.15*	0.17*	0.15*	0.72***
gs	0.58***	-	0.32***	0.91***	-0.06 ns	-0.03 ns	0.28***
Ci	-0.63***	0.15*	-	0.25***	-0.25**	-0.21**	-0.25***
Tr	0.55***	0.94***	0.13 ns	-	0.13 ns	0.09 ns	0.21**
lvpd	-0.04 ns	-0.20**	-0.12 ns	0.10 ns	-	0.99***	-0.06 ns
Tleaf	0.11 ns	0.09 ns	-0.07 ns	0.12 ns	0.18*	-	-0.05 ns
PARi	0.73***	0.25**	-0.64***	0.24**	0.02 ns	0.26**	-
WUE	0.52***	-0.23**	-0.89***	-0.26**	0.01 ns	0.05 ns	0.59***

ns, non-significant at P = 0.05; \*significant at P = 0.05; \*\*significant at P = 0.01; \*\*\*significant at P = 0.001

**Table 3. Linear correlation coefficients between latex yield and gas exchange parameters of the top leaf layer**

Gas exchange parameters	Overall	Tapped treatment	RRISL 211	RRIC 121
A	0.19 ns	0.39 ns	0.48 ns	-0.02 ns
gs	-0.34 ns	-0.15 ns	-0.26 ns	-0.47 ns
Ci	-0.26 ns	0.21 ns	-0.37 ns	-0.18 ns
Tr	-0.09 ns	0.17 ns	0.15 ns	-0.34 ns
lvpd	0.32 ns	0.52 ns	0.42 ns	0.24 ns
Tleaf	0.02 ns	0.18 ns	-0.06 ns	0.12 ns
WUE	0.42 ns	-0.08 ns	0.46 ns	0.39 ns

ns, non-significant at P = 0.05; \*significant at P = 0.05; \*\*significant at P = 0.01; \*\*\*significant at P = 0.001

**Table 4. Linear correlation coefficients for relationships between latex yield and gas exchange parameters of the middle leaf layer**

Gas exchange parameters	Overall	Tapped treatment	RRISL 211	RRIC 121
A	0.05 ns	0.49 ns	0.02 ns	0.23 ns
gs	0.30 ns	0.36 ns	0.61 ns	-0.11 ns
Ci	0.34 ns	0.61 ns	0.60 ns	0.01 ns
Tr	0.33 ns	0.37 ns	0.65 ns	-0.06 ns
lvpd	-0.007 ns	-0.09 ns	-0.22 ns	0.24 ns
Tleaf	-0.03 ns	-0.11 ns	0.34 ns	-0.25 ns
WUE	-0.41 ns	-0.26 ns	-0.57 ns	-0.24 ns

ns, non-significant at P = 0.05; \*significant at P = 0.05; \*\*significant at P = 0.01; \*\*\*significant at P = 0.001

lvpd and photosynthetic rate of the top leaves. On the other hand, there was no significant correlation between latex yield and WUE. Within the clone RRISL 211, latex yield was positively correlated with lvpd, A and WUE of the top leaves while the latex yield of RRISL 211, showed a negative correlation with gs of the top leaves. In contrast to RRISL 211, within the clone RRIC 121 there was no significant correlation between latex yield and A of the top leaves. However, similar to RRISL 211, latex yield of RRIC 121 also showed positive correlations with WUE and lvpd and negative correlations with gs and transpiration rate of the top leaves (Table 3).

### 3.1.1.2 The middle leaf layer

In the middle canopy layer, a consistent and clear relationship could not be observed between latex yield and lvpd. In contrast to the situation in the top canopy layer, a positive correlation could be observed between latex yield and stomatal conductance in the middle leaves. The only exception to this trend was shown in RRIC 121. In contrast to the situation in top leaves, latex yield showed a consistent negative correlation with WUE in the middle leaves. Moreover, latex yield showed positive correlations with Ci of the middle leaves. The tapped treatment showed a positive correlation between latex yield and A in the middle leaves (Table 4).

**Table 5.** Linear correlation coefficients between latex yield and gas exchange parameters of the bottom leaf layer

Photosynthetic parameter	Overall	Tapped treatment	RRISL 211	RRIC 121
A	0.41 ns	0.05 ns	0.66 ns	0.21 ns
gs	0.48 ns	0.02 ns	0.76*	0.36 ns
Ci	0.30 ns	-0.19 ns	0.39 ns	0.33 ns
Tr	0.51*	-0.007 ns	0.79*	0.40 ns
lvpd	-0.29 ns	0.15 ns	-0.51 ns	-0.15 ns
Tleaf	-0.14 ns	0.18 ns	-0.53 ns	-0.01 ns
WUE	-0.31 ns	0.03 ns	-0.47 ns	-0.30 ns

ns, non-significant at  $P = 0.05$ ; \*significant at  $P = 0.05$ ; \*\*significant at  $P = 0.01$ ; \*\*\*significant at  $P = 0.001$

### 3.1.1.3 The bottom leaf layer

The correlations between latex yield and WUE, gs, Ci and lvpd were largely similar between bottom and middle layers. However, in contrast to the top and middle leaves, there was a negative correlation between latex yield and lvpd in the bottom leaves. In both clones, latex yield showed a positive correlation with A of the bottom leaves. The correlation coefficient between latex yield and A was greater in RRISL 211 than that in RRIC 121 (Table 5).

## 4. DISCUSSION

The study findings clearly revealed that the CO<sub>2</sub> assimilation rate (A) had highly significant correlations with gs, Tr and intensity of PAR (Table 1). These correlations can be easily explained by the basic theories of gas exchange and photosynthetic light response. Increasing PAR triggers a chain of reactions with increased photosynthetic rates, which required greater stomatal opening (i.e. increased stomatal conductance) resulting, in turn, in greater transpiration rates. In general, lvpd and WUE have an inverse relationship. But in this study, when lvpd increased WUE also increased. This could have been due to the increase of T<sub>leaf</sub> (with increasing lvpd), which probably promoted photosynthesis to a greater extent than transpiration. According to Kozlowzki (1975), plant dry matter production is dependent on the efficiency of water use of the crop. The negative response of WUE to gs indicated that when stomata partially close, the leaf transpiration rate decreases more than photosynthetic rate, thus increasing WUE. However, the absence of a correlation between PAR and WUE showed that, when PAR increases both A and Tr increase in similar magnitudes. Therefore, WUE remains approximately constant. The presence or absence of correlations in gas exchange parameters of tapped and untapped treatments were broadly similar to the overall correlation analysis. In the tapped treatment, because of tapping, the photosynthetic rate is stimulated relative to the transpiration rate. Samsuddin and Impens (1979)

compared CO<sub>2</sub> assimilation rates of four *Hevea brasiliensis* clones and concluded that although significant differences in yield potential exist, the CO<sub>2</sub> assimilation rates were comparable. They speculated that clonal differences in the cumulative carbon production of individual leaves, partitioning of assimilates towards the latex production and canopy architecture were the determinants of yield differences. Subsequent studies have shown significant positive correlations between yields and CO<sub>2</sub> assimilation rates in clones with a higher partitioning of assimilates towards latex production (Samsuddin, 1979). According to Zeltich [6], canopy photosynthesis measured for several crops has shown a very weak correlation with yield. The positive latex yield response to WUE and lvpd of top leaves indicates that, in top leaves when lvpd increases transpiration also increases accordingly. To increase latex flow within the tree and finally increase the latex yield with increasing latex volume. On the other hand, latex yield has a negative correlation with gs. Increasing gs may cause excessive transpiration rates, which could lead to a reduction of photosynthesis due to water stress. The contribution from the middle canopy layer to overall canopy photosynthesis is less. Probably middle and bottom leaves rely more on the CO<sub>2</sub> that is accumulating within the canopy. According to Chazdon and Fetcher [12], the internal leaf CO<sub>2</sub> concentration was significantly higher in leaves developed under low light levels. This indicates that most of the CO<sub>2</sub> entering the leaves was not being utilized for photosynthesis under such conditions. On the other hand, the top leaves rely on a CO<sub>2</sub> supply from outside environment. Therefore, CO<sub>2</sub> concentration gradient has to be higher for higher uptake from outside [13,14].

## 5. CONCLUSION

In the tapped treatments, because of tapping, the photosynthetic rate is stimulated relative to the transpiration rate. The positive latex yield response to WUE and lvpd of top leaves indicates that, in top leaves when lvpd increases transpiration also

increases accordingly. Hence WUE and ivpd increase latex flow within the tree and finally increase the latex yield with increasing latex volume. On the other hand, latex yield has a negative correlation with gs. In top leaves reduced Ci increases the CO<sub>2</sub> gradient and uptake of CO<sub>2</sub> for more photosynthesis, which increases the latex yield. Therefore, the study findings revealed that, a clear positive correlation between CO<sub>2</sub> assimilation rates and the leaf gas exchange parameters of *Hevea* with reference to the exploitation.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Nugawela A. Gas exchange characteristics of *Hevea* genotypes and their use in selection for crop yield. Ph.D. Thesis, University of Essex, England; 1989.
2. Monsi M, Uchijima Z, Oikawa T. Structure of foliage canopies and photosynthesis. Ann. Rev. Ecol. Syst. 1973;4: 301-327.
3. Tupy J. Some aspects of sucrose transport and utilization in latex producing bark of *Hevea brasiliensis*. Planta. 1985;27:51-64.
4. Gomez JB. Physiology of latex (Rubber) production. Malaysia Rubber Research and Development Board, Kuala Lumpur, Malaysia. 1983;71-98.
5. Beadle CL, Long SP, Imbamba SK, Hall DO, Olembo RJ. Photosynthesis in relation to plant production in terrestrial environments. Tycooly International, Oxford; 1985.
6. Zelitch I. The close relationship between net photosynthesis and crop yield. Bio Science. 1982;32(10): 796-801.
7. Korpilathi E. Photosynthetic production of scots pine in the natural environment. Acta Forestalia Fennica. 1988;202:1-71.
8. Aylett GP. Irradiance interception, leaf conductance and photosynthesis in Jamaican Upper Montane Rain Forest Trees. Photosynthetica. 1985;19 (3):323-337.
9. Pereira JF, Splitstoesser WE, Ogren WL. Photosynthesis in detached leaves of cassava. Photosynthetica. 1986;20(3):286-292.
10. Von Caemmerer S, Farquhar GD. Some relationships between the biochemistry of photosynthesis and the gas exchange of leaves. Planta. 1981;153:376-387.
11. Snedecor GW, Cochran WG. Statistical methods, 6<sup>th</sup> edn. Iowa State University Press, Iowa, USA; 1976.
12. Chazdon RL, Fetcher N. Photosynthetic light environments in a low land tropical rain forest of Costa Rica. Journal of Applied Ecology. 1984;72:553-564.
13. De Costa WAJM. Principles of crop physiology: Towards an understanding of crop yield determination and improvement. University of Peradeniya, Sri Lanka. 2000;189-377.
14. Long SP, Incoll LD, Woolhouse HW. C4 photosynthesis in plants from cool temperate regions, with particular reference to *Spartina townsendii*. Nature. 1975;257:622- 624.