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PHYSIOLOGICAL YIELD DETERMINANTS OF SUN AND SHADE LEAVES OF *HEVEA BRASILIENSIS* MUELL. ARG.

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ABSTRACT

Physiological yield determinants were measured in polybagged rubber plants grown in field conditions under different light regimes using a portable leaf area meter and a portable photosynthesis system. Treatment differences in CO_2 assimilation rates varied with the time of the day. CO_2 assimilation rates were significantly high during morning in the plants grown in full sunlight. Treatment differences were not significant with respect to leaf area and dark respiration rates. Possible reasons for differences in CO_2 assimilation rates and the contribution to dry matter production of the plant of sun and shade leaves are discussed.

Key words: yield determinants, sun and shade leaves, *Hevea brasiliensis*

INTRODUCTION

The amount of dry matter produced by a plant is mainly determined by the amount of light intercepted, the conversion efficiency of intercepted light and the rate of loss of dry matter produced (Kramer, 1986; Beadle et.al., 1985 and Nelson, 1988). These could be estimated by measuring the physiological yield determinants, i.e. total leaf area, CO_2 assimilation rate and dark respiration rate respectively. The total dry matter produced and the harvest index, i.e. the amount of dry matter partitioned towards the economically important part, governs the economic yield of a crop.

In many crops the majority of the leaves are under limiting light levels (Ort and Baker, 1988). Leaves get adapted to the environmental conditions under which they develop (Syversten, 1984). It has been shown that the anatomical and physiological characters of sun and shade leaves are different (Chazdon and Fetcher, 1984; Ashton & Barlyn, 1992).

As reported for other crops in a mature *Hevea brasiliensis* Muell. Arg. plantation most of the leaves are found under limiting light levels. The physiological yield determinants may be different in areas receiving full and limiting light levels in the canopy. Within the canopy the physiological yield determinants may vary depending on the light environment at different positions. Thus, the capacity for dry matter production by leaves in the light limiting areas of the canopy will have a significant influence on the economic yield of the crop. Measurements of CO_2 assimilation rates and dark respiration rates of attached leaves in the canopy of a tree demands complicated equipment and also the technical difficulties encounted under such conditions will affect the accuracy of measurements (Korpilathi, 1988). Therefore, in this study 3–4 months old *Hevea brasiliensis* Muell. Arg. plants grown in polybags were used to compare the physiological yield determinants when subjected to full and limiting light levels.

MATERIALS AND METHODS

Plant Material

Hevea brasiliensis Muell. Arg. plants of genotype RRIC 121 and grown in polybags (17.8 x 38.1 cm) were used for this study. Plants of same growth stage, i.e. two mature leaf whorls and a dormant bud were selected. Once the dormant buds developed into a mature leaf whorl under conditions provided, the leaves in these whorls were used for the study.

Experimental Area

An area (3m x 15m) close to the Plant Science Department Laboratories at the Rubber Research Institute of Sri Lanka, Agalawatta was chosen.

Shading

A wooden frame was built over the entire experimental area and was divided into 3 equal sections. Two sections were covered with 1 and 2 layers of coir matting to receive 40% and 25% of the incident light to the plants grown underneath, respectively. The third section was left uncovered for plants to receive 100% incident light. The light intensities were measured using a quantum sensor (LI–190 SR, LI–COR Ltd., Lincoln, Nebraska, U.S.A.). Ten plants were grown at each light level. The plants were spaced at 1.0mx0.8m in the experimental area.

Management Practices

Watering was done when required. Fertilizer was applied as recommended for polybagged plants by the Rubber Research Institute (Fertilizers to Rubber, Advisory Circular No.85, February 1980). Dithane M45 (10g in 4.5 liters of water) and Captan (10g in 3 liters of water) were sprayed alternatively at weekly intervals to control leaf diseases.

Measurements

CO_2 assimilation rates and related parameters

Six plants were selected from each treatment, at random. Measurements were made in the morning, i.e. 9–10 AM and in the afternoon, i.e. 2–3 PM on 2 leaves of a selected plant.

The CO_2 assimilation rates (A), stomatal conductance (gs), internal leaf CO_2 concentration (Ci) and light intensity (Q) were measured simultaneously using a commercial closed gas exchange system (LI–6200, LI–COR Ltd., Lincoln, Nebraska, U.S.A.), comprising a LI–6200 gas analyzer and LI– 6250 computer and software.

A medium size leaf chamber, adjusted to expose a constant area of the leaf, i.e. 10 cm^2 to light was used. Atmospheric air (Ca=340 ppm) was drawn into the system, by switching the analyzer pump with the leaf chamber kept open. Leaf–lets were clamped into the leaf chamber, to carry–out the measurements. Measurements were begun when a steady decline in CO_2 concentration was observed. The relative humidity of the system was maintained at 65–70% during measurements, by varying the air flow rate, through the magnesium perchlorate desiccant.

The apparatus was calibrated prior to measurements as described by Wells (1986).

Dark Respiration rates(Rd)

Measurements were made on leaves selected for CO_2 assimilation rate determination. Leaves were covered with black polythene for a period of 2–3 hours before the measurements were made at about 1800h. When measuring dark respiration rate (Rd), leaf chamber was covered with a black cloth to keep the leaf in darkness. Measurements were begun after a steady increase in the CO_2 concentration was observed in the system.

Leaf Area(LA)

Measurements were made on plants selected for the gas exchange measurements described above. The total leaf area of the leaves in the leaf whorl developed under the light level provided was measured by using a portable leaf area meter (Series LI-3000, LI-Cor Ltd., Nebraska, U.S.A.).

RESULTS

CO_2 Assimilation Rates (A)

Measurements made in the morning, i.e. 0900-1000h indicated that the CO_2 assimilation rates (A) are significantly high in plants grown under full light. The CO_2 assimilation rates are similar in plants grown under 40% and 25% of the incident light (Table 1). Measurements made in the afternoon, i.e. 1400h measurements shows that the treatment differences are not significant. The CO_2 assimilation rates are higher later in the day than these in the morning in plants grown under 40% and 25% of the incident light (Table 1).

Dark Respiration Rates (Rd)

The dark respiration rates are similar in *Hevea brasiliensis* plants grown under 100%, 40% and 25% of the incident light (Table 2).

Leaf Area (LA)

The total area of the leaves in a whorl is similar in plants grown under different light levels (Table 3).

Stomatal Conductance (gs)

The stomatal conductance is similar in plants grown under different light levels (Table 4). Nevertheless, there is tendency for it to be relatively low in plants grown under 25% of the incident light. Stomatal conductance is generally lower in the afternoon, in all 3 treatments (Table 4).

Internal Leaf CO_2 Concentration (Ci)

Internal leaf CO_2 concentration is significantly low in leaves developed under full sunlight. Generally the Ci values are relatively low in the afternoon in all 3 treatments (Table 5).

Table 1. *CO_2 assimilation rates (A) of Hevea brasiliensis leaves measured in the morning and the afternoon of the day. Measurements were made on genotype RRIC 121 and each value given is the mean of 12 observations*

Incident light (%)		CO_2 assimilation rate (A) (μmoles m^{-2} s^{-1})		Variance %	Mean CO_2 assimilation rate (A)
		9–10 a.m.	2–3 p.m.		
100		11.10	9.49	–15	10.3
40		5.08	6.01	+19	5.6
25		3.93	4.13	+ 5	4.0
	Significance	**	N.S.		
	F value	2.66			
	L.S.D.(5%)	4.075			
	Pr>F	0.0061			
	(**P<0.01)				

Table 2. *Dark respiration rates (Rd) in Hevea brasiliensis plants subjected to three different light levels and their statistical analysis. Measurements were made on genotype RRIC 121 and each value given is the mean of 12 observations.*

Parameter	Incident light (%)	Mean value
Rd (μmoles m^{-2} S^{-1})	100	0.88
	40	0.53
	25	0.85
	Significance	N.S.
	F.Value	2.15

Table 3. *Mean leaf area per whorl (La) in Hevea brasiliensis plants subjected to the different light levels and their statistical analysis. Each value given is the mean of 6 observations.*

Parameter	Incident light (%)	Mean
La (cm^2)	100	1389
	40	1425
	25	1307
	Significance	
	F.Value	N.S.
		0.41

Table 4. *Statistical analysis of the result of the stomatal conductance in Hevea brasiliensis grown under different light levels.*

Incident light (%)		Stomatal Conductance (gs) (moles m^{-2} s^{-1})	
		9–10 a.m.	2–3 p.m.
100		0.38	0.26
40		0.36	0.26
25		0.28	0.21
	F Value	0.87	0.91
	Significant	N.S.	N.S.

Table 5. *Statistical analysis of the results of the internal leaf CO_2 concentration (Ci) of Hevea brasiliensis leaflets measured in the morning and afternoon session of the day. Measurements were made on genotype RRIC 121 and each value given is the mean of 12 observations.*

Incident light (%)		Internal leaf CO2 concentration (Ci) (μmol mol^{-1})	
		9 – 10 a. m.	**2 – 3 p. m.**
100		260	253
40		294	280
25		294	288
	Significance	***	**
	F.Value	22.7	14.33
	L.S.D. (5%)	12.99	15.47
	Pr>F	.0002	.0012
	p	0.001	0.01

DISCUSSION

The CO_2 assimilation rates are high in plants grown in full light. Further, this difference with those grown under limiting light is more marked early in the day. In plants grown under limiting light, i.e. 40 and 25% of the incident light, the CO_2 assimilation rates are similar.

Therefore, the capacity for dry matter production is reduced markedly in leaves developed and photosynthesizing under limiting light levels.

In plants grown in full light the CO_2 assimilation rates are lower in the afternoon than those in the morning. Downton *et.al.*, (1987) and Kupers *et.al.*, (1986 a and b) have also made similar observations. In contrary to this, plants grown in limiting light levels maintain the CO_2 assimilation rates of early in the day even in the afternoon. Therefore, to get a more accurate estimate of the contribution of sun and shade leaves to productivity, the mean daily CO_2 assimilation rate or the daily

integral has to be studied. The diurnal variation pattern in the CO_2 assimilation rate of sun and shade leaves has to be established for this purpose.

In leaves receiving high light, the CO_2 assimilation rates tend to decline with time due to accumulation of ABA (Absicic acid) in the leaves (Downton *et.al.* 1987). The accumulation of ABA may not take place under limiting light and when the leaves are not under water stress. Therefore, the CO_2 assimilation rates found early in the day would be maintained in plants grown under limiting light.

The CO_2 assimilation rate decreases with decreasing light levels (Table 1). Differences in CO_2 assimilation rates are mainly caused either by stomatal or mesophyll limitations (Von Cammerer and Farquhar, 1984). In this study the stomatal limitation, as indicated by stomatal conductance, did not vary significantly with light levels. However, the internal leaf CO_2 concentration was significantly high in leaves developed under low light levels. This indicates that the CO_2 entering into the leaves were not been utilized for photosynthesis under such conditions. Thus it could be concluded that in plants grown under low light levels the mesophyll limitation has increased.

The capacity for light interception was compared in plants grown under different light regimes by studying the total leaf area per single whorl. The total leaf area per single whorl was found to be similar in plants grown under different light levels. Since no difference was found in leaf area in plants grown under different light levels, this parameter may not contribute significantly to differences in productivity of plants grown under different light regimes. Nevertheless, Nugawela (unpublished data) found that the area of a rubber leaf to increase when developed under limiting light levels over a long period of time. Dark respiration rate gives an estimate of dry matter loss from the plant. Hence it is an important factor determining productivity of plants. In this study the differences in dark respiration rates observed from plants grown under different light regimes were not significant. Respiration rates were measured in the field late in the day, i.e. 1800h in this study. Plants grown under 100% incident light received some light during measurements, resulting in low respiration rates. Similar dark respiration rates among the different treatments suggest that this too, may not contribute much towards differences in productivity when *Hevea* plants are grown under different light regimes.

It is evident that leaves developed under low light environments have low assimilation rates maintained throughout the day time. But still the mean CO_2 assimilation rate for the day is high in plants grown under high light. This will contribute to high productivity of these plants. Differences were not found in light interception efficiency and rate of loss of dry matter. These may not contribute to differences in productivity when plants are grown under low light regimes.

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