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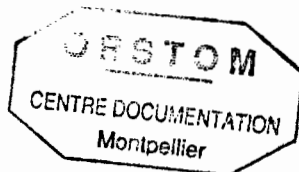
Laboratoire de Bioclimatologie

EFFECT OF LEAF AGE AND WATER DEFICIT
ON THE LEAF PHOTOSYNTHETIC RATE OF *HEVEA BRASILIENSIS*

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Effect of Leaf Age and Water Deficit on the Leaf
Photosynthetic Rate of *Hevea brasiliensis*

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ABSTRACT

In order to select *Hevea brasiliensis* clones better adapted to the climatic conditions of humid tropical regions of the southern Ivory Coast, leaf carbon assimilation rates (LCAR) were determined on leaves of three rubber clones: RRIM600, GT1 and Pb235. Measurements were taken during the leaf life span to follow the evolution of the potential photosynthetic capacity and to determine the effect of water stress which happens during 2 to 3 months of the short dry season.

LCAR versus light response curves for well watered plants showed a variation in the rates within clones. However, GT1 had maintained its highest steady state of photosynthesis capacity for 180 days, whereas RRIM600 had lost 22% of its highest photosynthetic rate only 60 days after it was reached.

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Water stress was found to reduce the LCAR in two ways: when soil water depletion was light, LCAR dropped slightly, and when water was supplied, the recovery was gradual. But, when water shortage was more drastic, LCAR was not far from the photorespiration point. When plants were watered, the LCAR never reached the initial values: it was reduced by 44% or more.

These results indicate that leaf photosynthesis depends not only on climatic conditions (mainly solar radiation and rainfall) but also on their impact during the leaf life span, confirming our earlier findings on rubber stands.

INTRODUCTION

An investigation was undertaken in order to understand the effect of some climatic conditions of the southern Ivory Coast such as solar radiation and water availability on canopy CO₂ assimilation rate during the foliage ontogeny.

Photosynthesis is the primary process which influences latex production. Samsuddin et al.^{1,2} and Ceulemans et al.³ have studied the leaf CO₂ assimilation rate (LCAR) of several clones of *Hevea brasiliensis*. They concluded that there are significant differences in the LCAR, largely dependent on the stomatal resistance to CO₂

diffusion. Gomez et al.⁴ have attributed these LCAR differences to the stomata density or to the dimension of the stomata itself.

If leaf photosynthetic characteristics constitute an important factor, it should not be considered at one particular time of the leaf development but over the whole life span. This means that during leaf ontogeny, climatic and physiological factors can induce some modifications in the LCAR.

This work gives some results on the evolution of rubber leaf photosynthetic activities and the effect of water stress on it, during the leaf life span.

MATERIALS and METHODS

Measurements were made on stumps of three clones of *Hevea brasiliensis*, namely GT1, RRIM 600 and Pb235 supplied by the Institut de Recherche du Caoutchouc (IRCA).

The stumps grew outside in bags filled with 35 kg of forest soil and they were watered every day. Leaf photosynthetic rate depends not only on genotype factors but also on environmental conditions. So, plant growth was followed, particularly the emergence of the flush and the

elongation of the leaves on the shoot. LCAR measurements were made on attached lower leaves (LBC 9 and older)⁵ from the 3rd and the 4th flush which grew in the same climatic conditions.

The attached leaflet was fixed horizontally in a water jacket assimilation chamber, supplied with CO₂ from atmospheric air at a flow rate of 165 l/h. The CO₂ concentration which was measured by a CO₂ Infrared Gas Analyser IRGA (type ADC) was generally 345 ± 5 ppm. The air coming from the ventilated chamber was led to another CO₂ IRGA, in an open system arrangement^{6,7}. Water vapour concentration and air temperature were controlled by 2 water baths: the first one had a bubbling system which maintained constant the water vapour condensation temperature, and the second controlled the air temperature before it was introduced in the chamber. The water vapour pressure was measured by a dew point hygrometer and the air and leaf temperatures by thermocouples. Light intensities were changed from low to high by varying the height of the 3 HPIodine/T lamps. A relationship was determined between light intensities and height by putting a quantum sensor (Lambda-LICOR) in the assimilation chamber. Irradiance was filtered with a 6 cm water layer to avoid that leaf temperature rose too much (+1,5°C) above air temperature.

Table 1: Means for stomatal and epidermal cells densities of rubber leaves used in the photosynthetic measurements.⁸

CLONE	Position on the flush	Leaflet area (cm ²)	Density stomata	epidermal	stomatal index
RRIM600	upper leaf	< 45	389± 37	1433± 184	21
	under leaf	> 45	544± 34	1539± 172	26
GT1	upper leaf	< 50	467± 78	1701± 147	22
	under leaf	> 50	568± 35	1478± 168	28
Pb235	under leaf	> 50	518± 51	----	--

RESULTS and DISCUSSION

Leaf growth is under the influence of some climatic parameters as solar energy and soil water availability which control the cell size. Stomatal arrangement on the epidermal leaf surface influence the gas (CO₂ and H₂O) diffusion rate. Leaf morphological characteristics studied in this experiment⁸ are summarised in Table 1.

Table 1.

Table 1 shows the tendency for RRIM600 and GT1 well watered plants to have lower stomata density for leaves of higher insertion than leaves of lower insertion on the flush. In order to take cell size into account, the ratio between the number of stomata per unit area and the sum of the number of epidermal cells and stomata for the same unit area (stomatal index)⁹ seems more important since the upper leaves on the flush, in both clones, had similar ratio (21), while the lower leaves had a higher ratio (26 to 28).

Because of the importance of these leaf characteristics, all the LCAR measurements were

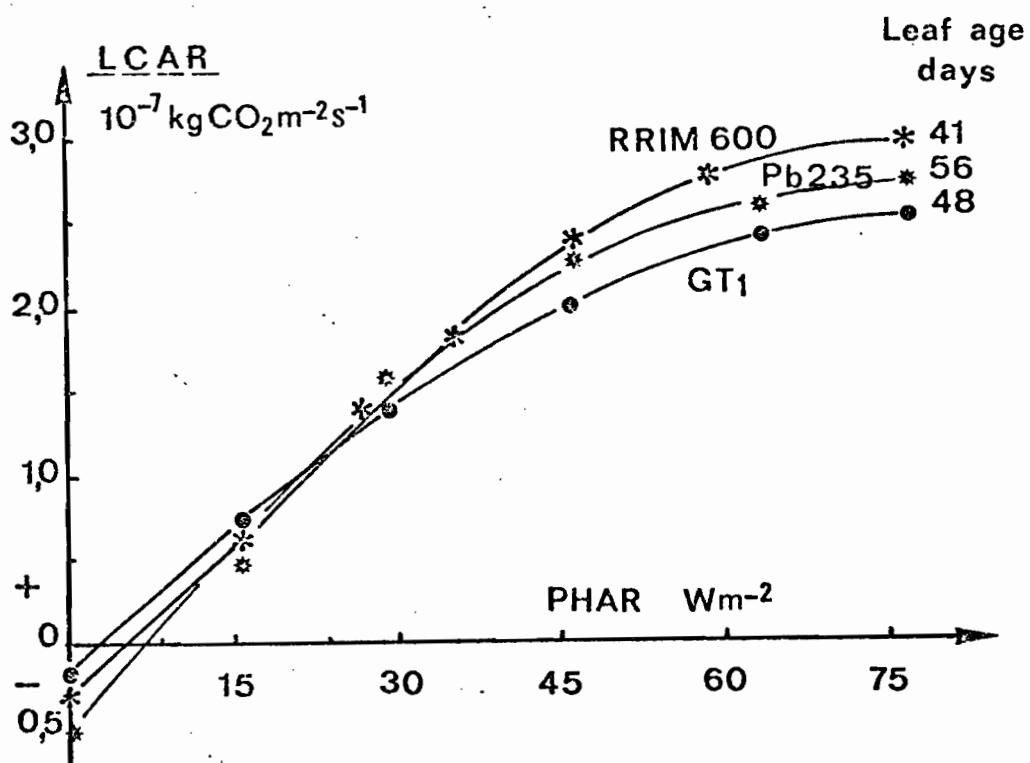


Figure 1: Responses to photosynthetic active radiation (PHAR) of leaf carbon assimilation rates (LCAR) of fully expanded RRIM600, GT1 and Pb235 rubber leaves.

made on the lower insertion leaves of flush on RRIM600, GT1 and Pb235. Figure 1 presents the photosynthesis versus light response curves for well watered plants: forty days old leaves (LBC 9 + 21 days) of RRIM600 show higher LCAR values than both GT1 and Pb235.

Figure 1.

Hevea leaves were light saturated between 75 and 100 Wm^{-2} of PHAR, the latter representing approximately a quarter of full radiation at midday in our climatic conditions during march to may, and a half of it during june to september.

But with high irradiance, steady-state values of both LCAR and transpiration were difficult to determine. The air, after going through the leaf chamber, presented larger oscillations in the CO_2 concentration under constant light conditions. Similar oscillations were also observed for the dew point temperature. These oscillations can be explained by the movement of the stomatal aperture attributable to an unbalanced water supply through the plant system despite a good water availability in the soil. The resistance to water uptake by roots is responsible for it.¹⁰

The results presented in Figure 1 are for young leaves, nevertheless, changes in LCAR during ontogeny have been reported previously. In fact,

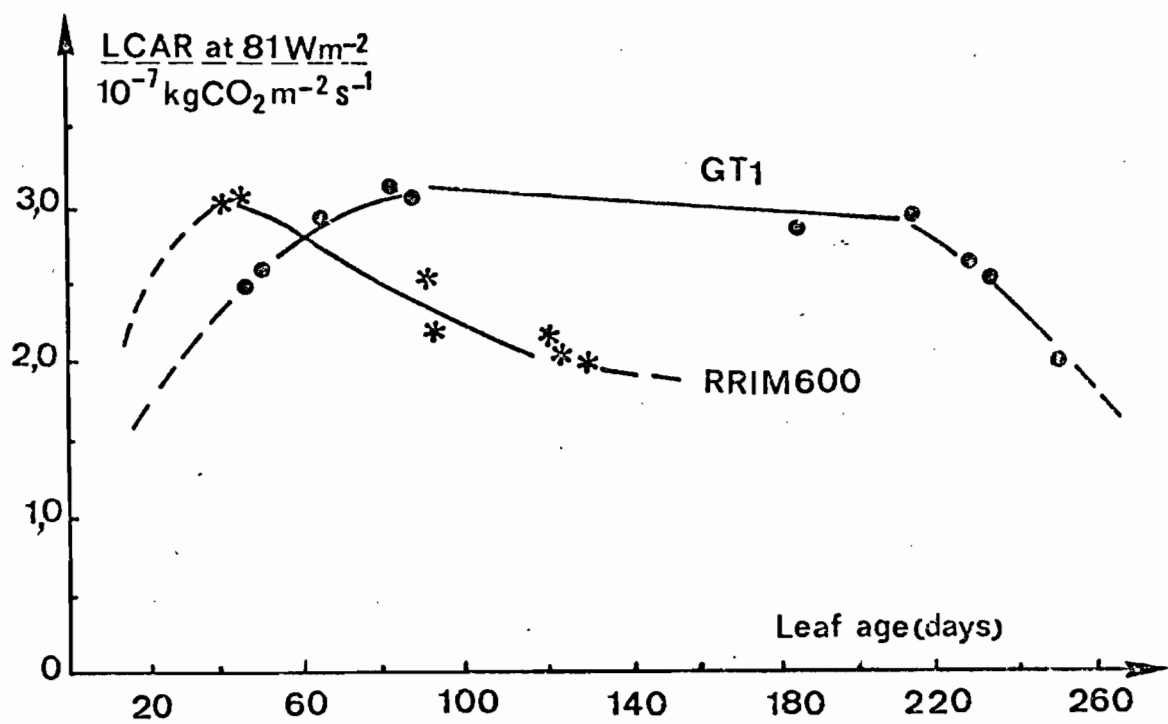


Figure 2: Evolution of LCAR at 81 W.m⁻² during the life span of attached leaves on the 4th flush of well watered RRIM600 and GT1 rubber plants.

dry matter production and thus latex production depend on the daily leaf photosynthetic activity throughout its life span (240 - 260 days).

Rubber stand leaves fall once a year, and twice or more for young stumps. This was the case with Pb235 leaves stopping LCAR measurements.

Figure II

Even though LCAR was maximum with young leaves as reported above (Figure I), the measured values of LCAR for RRIM600 fell about 30% 90 days later. Similar decrease in the LCAR has been reported earlier⁶. On the other hand, GT1 maintained its photosynthetic capacity during nearly 6 months when well watered. It is only after this period that a regular decrease of LCAR was noticed (Fig. II).

A water shortage occurring during this period of nearly constant LCAR has a decreasing effect on LCAR:

140 days after the leaf emergence of GT1, water stress was induced by withholding water supplies for 4 days (Figure III). A general reduction of 24% in the LCAR was recorded. When water supply is renewed, a quick recovery was observed but the initial value of LCAR was not reached, yet the wilting has not been excessive.

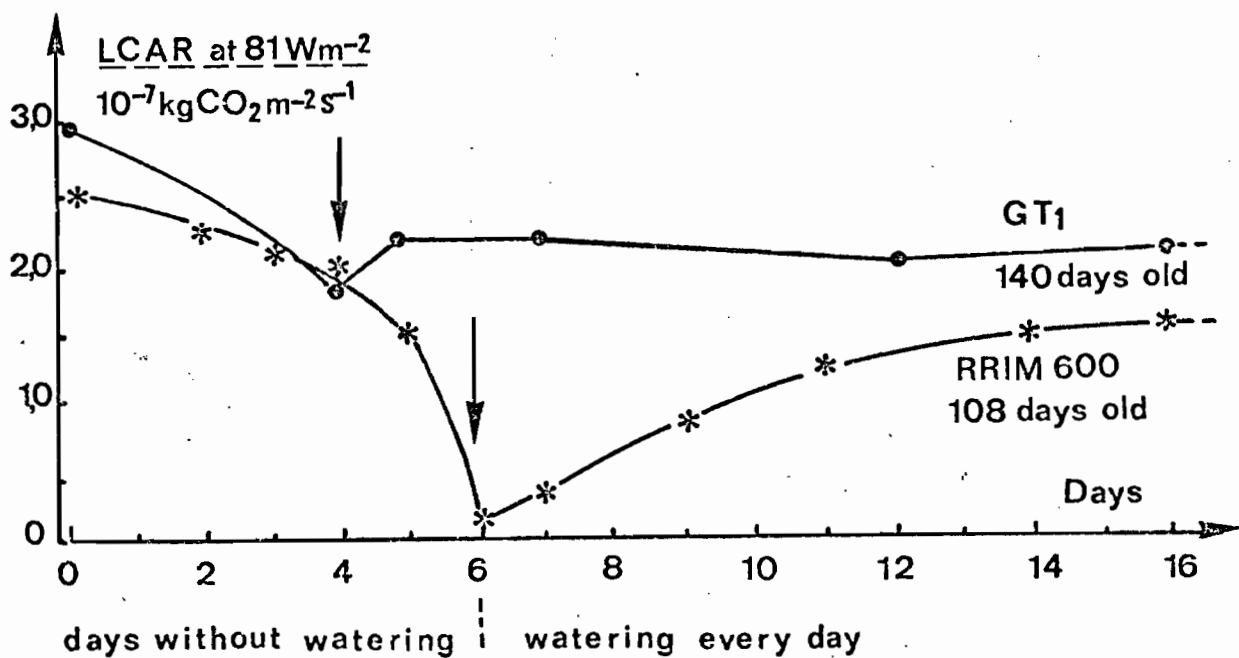


Figure 3: Evolution of the LCAR at 81 W.m^{-2} of RRIM600 and GT1 during a drying cycle and after watering. The leaf age corresponds to the period of a short dry season in southern Ivory Coast.

Figure III.

A similar experiment was conducted on 108 days old RRIM600 leaves, and the photosynthetic activity shows (Figure III) a reduction of 95%, after 6 days of water shortage. After watering the plants, a slow recovery was observed and 10 days later levelled off at 56% of the initial LCAR. This slow increase could be attributed to the regeneration of the capillary root-hair which were dessicated by the soil water depletion. The after effect of drought on the stomata were permanent and they opened less than their normal aperture, yet the leaves had completely recovered their turgidity. Glover ¹¹ made the same observations of the effects of drought on stomatal behaviour in maize crops without measurements of the maize LCAR.

The results have only a significant meaning if they are analysed on a global scale. In fact, growth and thus latex elaboration is the result of the total contribution of all tree leaves during their life span. Because other characteristics tied to the clones such as leaf angle, crown architecture and tree density population must be considered together to have the best view of the tree foliage assimilation rate (FAR).

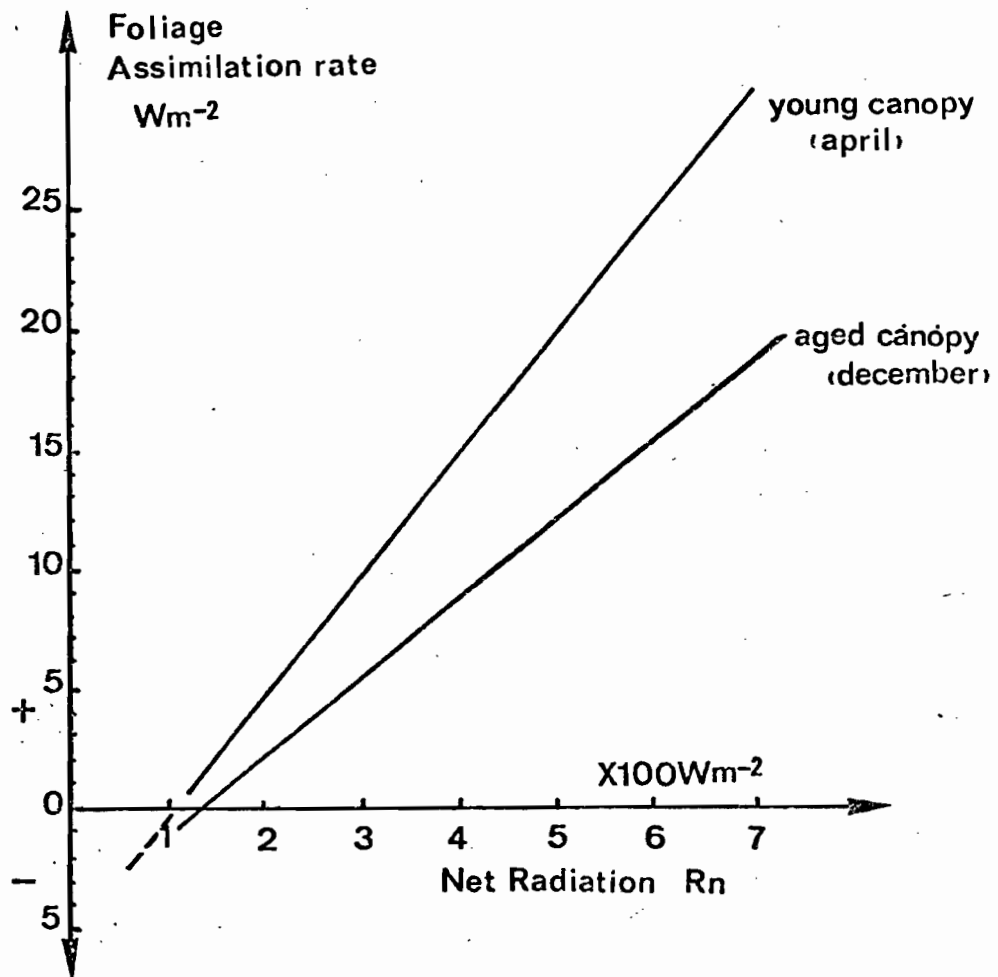


Figure 4: Relationship between instant net radiation and the foliage carbon assimilation rate of a GT1 rubber stand. Young and aged canopy correspond respectively to 30-60 days and to 260-290 days old leaves.

Field tests of laboratory developed relations between plant response and environmental conditions are needful. Micrometeorological methods have been used to study the CO₂ exchanges between a rubber canopy and the atmosphere¹². These measurements were conducted on a 24 m high GT1 rubber stand to try to understand the relation between meteorological factors and the foliage response as photosynthetic assimilation rate (FAR)

Figure IV.

The relationship, illustrated in Figure 4, between FAR response to net radiation for a rubber canopy is not as straightforward as that for a simple leaf: it does not show a decrease for higher values of net radiation. In fact, under outside conditions, FAR is not only influenced by solar radiation, but also by wind and air temperature and by the rubber foliage architecture. The global FAR was very high ($20 \text{ W.m}^{-2} = 1,8 \cdot 10^{-6} \text{ KgCO}_2.\text{m}^{-2}.\text{s}^{-1}$), this did not take the night respiration into account. When compared with the same well watered foliage, 8 to 9 months older (240-270 days), the photosynthetic energy fixation decreased by 35-45% for the same energy input. This reduction was attributed to the

effect of some physiological and climatic conditions which influence the photosynthetic carbon fixation when the leaves grow older¹². In fact, the senescence of leaves cannot be regarded as a stage of general decay but more like other physiological phases of development¹³ as we see it earlier.

CONCLUSION

Two factors -leaf age and water stress- have been more particularly studied because of their influence on the rubber photosynthetic activity which, in the southern Ivory Coast climatic conditions, controlled trees growth and latex production.

Leaf carbon assimilation rate depends on the leaf morphological characteristics. Stomatal densities are higher on lower inserted leaves on the flush, and the stomatal index are quite equal between studied clones.

Leaves of well watered GT1 plants maintained a higher leaf carbon assimilation rate (LCAR) during a longer period (6 months) than RRIM 600 which the LCAR fell 30% 90 days later after reaching their maximum values.

Water stress affects the LCAR depending on the drought importance: a light water stress induced

a decrease of 24% of LCAR; and a pronounced shortage reduced it to 44% of the initial value.

Foliage assimilation rates versus photosynthetic active radiation responses are different than from those obtained with leaves due to the tree foliage architecture. Trees subjected to varying degrees of drought during the short dry season show a decrease of the FAR. The geometrical properties of the tree crown constitute one the determinants influencing the FAR of the canopy system.

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