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Effect of elevated CO_2 concentration on seedling growth rate and photosynthesis in *Hevea brasiliensis*

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To study the effect of elevated CO_2 concentration on plant growth and photosynthesis, two clones of *Hevea brasiliensis* were grown in polybags and exposed to elevated concentration (700 ± 25 ppm) for 60 days. There was higher biomass accumulation, leaf area and better growth when compared to ambient air grown plants. From A/Ci curves it is clear that photosynthetic rates increases with increase in CO_2 concentrations. After 60 days of exposure to higher CO_2 concentration, a decrease in the carbon assimilation rate was noticed.

1. Introduction

In the wake of global climate change increasing CO_2 concentration in the atmosphere and its influence on ecosystem has inculcated a great deal of research during the last two decades. When plants are exposed to elevated CO_2 concentrations growth and productivity increases substantially, especially in C_3 species (Kimball 1983; Long and Drake 1991). Though elevated CO_2 concentration influence various plant metabolic activities that favour higher growth rates, a higher photosynthetic rate is the main reason for biomass accumulation (Long 1991; Drake 1992). It is also evident that photosynthetic rate of C_3 species is limited under existing ambient CO_2 concentration (Farquhat *et al* 1980). Since *Hevea brasiliensis* is a C_3 species, elevated concentrations of CO_2 can influence the photosynthetic rates and help to enhance the growth rate.

This study is an attempt to assess the effect of elevated CO_2 concentration on the initial growth rates of polybag grown rubber plants at nursery stage and also to study the influence of elevated CO_2 concentration on photosynthetic rates. If we can increase the growth rates, it will also enable us to evolve a suitable technique to enhance growth rates of the polybag plants in nurseries. Enhancing the initial growth rates will help both in getting robust plants and in better establishment of plants when planted in the main field.

2. Materials and methods

The study was conducted in the Department of Crop Physiology, University of Agricultural Sciences, Bangalore, situated at 12°58″N, 17°35″E at an altitude of 930 M. Budded stumps of the clones RRII 105 and GT-1 were planted in polybag (55×25 cm). Treatments were imposed 60 days after establishing plants in the polybag when most of the leaves in the first whorl were matured. Fifteen polybag plants of each clone were exposed to 700 ± 25 ppm of CO_2 concentration and another similar set of plants were grown under ambient air CO_2 concentration (350 ppm) which served as control. Plants were exposed to elevated CO_2 concentrations for 60 days and growth rates were assessed.

Polybag plants were kept in trenches for exposing them to elevated CO_2 concentration. Trenches of 3 m long, 1·25 m wide and 0·6 m deep were dug in a place well exposed to sunlight. Control plants were also kept in another trench for maintaining identical growing con-

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ditions. The trench used for exposing plants to elevated CO_2 was covered with polythene structure and this structure served as poly house.

Higher CO_2 concentration were obtained by the organic matter decomposition method. Inside the trench a layer of well decomposed organic matter was spread uniformly all along the floor. A light weight metal frame of 1·6 m tall with gable roof was placed over the trench enclosing it. Using 125 μ thick polythene sheet, a cover was tailored to suit the size of the frame. This was erected over the trench and the trench was kept air tight. Before closing the trench, water was sprinkled on the organic matter to stimulate soil microbial activity. Polybag plants were also watered. Plants were exposed to elevated CO_2 between 3·30 pm and 11·00 am. For more details of the methodology see Devakumar *et al* (1996).

Photosynthesis measurements were made from four plants from each clone and on four leaves from each plant, using a portable photosynthesis system (ADC Ltd. London, UK) at ambient CO_2 concentration, before exposing the plants to higher concentration of CO_2 and after 60 days of exposure to elevated CO_2 concentration. Photosynthetic rates were also measured at different CO_2 concentrations above the ambient levels to develop CO_2 response curves (A/Ci curves). Different concentrations of CO_2 were obtained by the method described by Shesha Shayee *et al* (1992). All the measurements of photosynthesis were made between 8.30 and 11 am. Plants were harvested 60 days after exposing to elevated CO_2. Before harvesting, plant height, stem girth and leaf thickness were measured. Leaf thickness was measured using a thickness gauge (Walace, England, UK). Leaf area was measured using a portable leaf area meter (Li-3000, Li-cor Inc., Nebraska, USA). Leaf dry weight, and total dry matter were measured after drying in the oven at 70°C.

3. Results and discussion

From the CO_2 response curves it is evident that carbon assimilation rate increases with increase in CO_2 concentration (figure 1). From this it appears that photosynthetic rates will increase when plants are exposed to higher concentrations of CO_2, probably due to higher substrate availability for photosynthesis. From the carbon assimilation rates of plants before and after exposure to elevated CO_2 concentration (table 1) it appears that photosynthetic rates will be decreased after exposing to higher concentrations of CO_2 (for 60 days). For how long plants maintained higher photosynthetic rates after exposing to elevated CO_2 was not clear, but there are evidences in the literature that decrease in photosynthesis occurs (Webber *et al* 1994) especially in polybag grown plants for various reasons (Arp 1991; Long and Drake 1991). Net photosynthetic rates reported here are relatively smaller than those in *H. brasiliensis* from other parts.

Higher growth rates and biomass production was recorded in plants grown at 700 ± 25 ppm CO_2 concentration. Further, clonal response was significantly different to elevated CO_2 concentration. Leaf area increased significantly by 30·6% under elevated CO_2 in GT-1, while RRII 105 recorded 32·4% increase (table 2). In our earlier experiment also a similar response was noticed

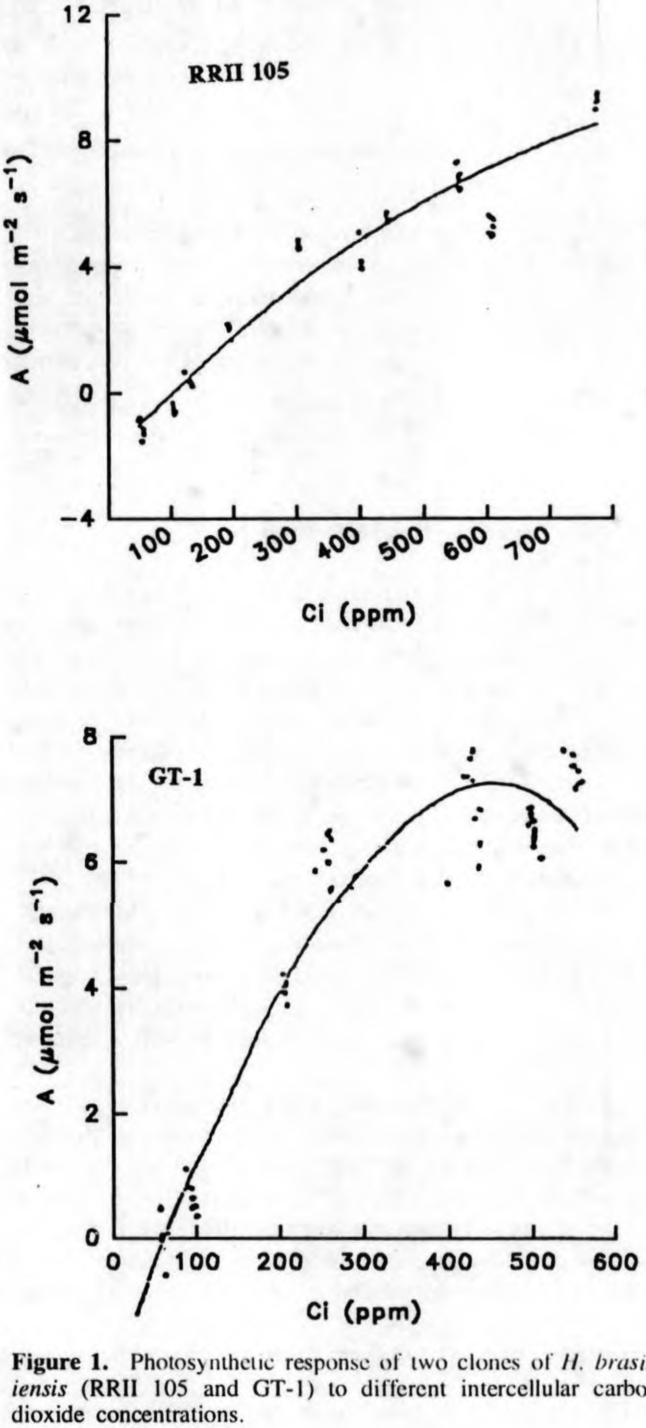

Figure 1. Photosynthetic response of two clones of *H. brasiliensis* (RRII 105 and GT-1) to different intercellular carbon dioxide concentrations.

in many forest tree species (Devakumar *et al* 1996). Higher leaf area production has been reported in many similar studies due to increase in number of branches, leaf number, increased tillering and due to increase in leaf expansion rates (Rogers *et al* 1983; Sionit *et al* 1981; Cure *et al* 1989). In *Hevea* leaves are produced in whorls as a characteristic feature. We did not notice any increase in the number of whorls due to elevated CO_2 concentration. Therefore increase in leaf area is mainly due to higher leaf expansion rates. When higher temperature is associated with higher concentration of CO_2 leaf area is further increased (Imai and Murata 1984; Ackerly *et al* 1992). Higher temperature was associated with higher concentration of CO_2 in our system (Devakumar *et al* 1996).

Total dry matter (TDM) varied significantly between clones and treatments. In GT-1, TDM increased by 15% in plants grown under elevated CO_2 concentrations while, RRII 105 had 21% increase over plants grown under ambient air CO_2 concentration. Stem girth which is a reflection of overall plant biomass accumulation capacity, increased in both the clones under elevated CO_2 condition. RRII 105 responded positively with 29% increase when compared to GT-1 which had 22%. Plant height did not show significant increase in the clone GT-1, on the other hand RRII 105 recorded 13.4% increase in response to elevated CO_2 concentration which was significantly different from the control plants (table 2).

Table 1. Photosynthetic rate ($\mu mol\ m^{-2}\ s^{-1}$) measured at 350 ppm before and after exposing the plants to higher concentrations of CO_2.

Clone	Plants grown under ambient air conditions (350 ppm)	Plants grown under elevated CO_2 conditions (700 ± 25 ppm)
RRII 105		
Before exposing to elevated CO_2	7·90	8·0
After exposing to elevated CO_2	7·81	4·2
GT-1		
Before exposing to elevated CO_2	8·2	8·1
After exposing to elevated CO_2	8·0	6·0

Such an increase in plant height, stem girth and total biomass production is largely due to higher photosynthetic rate and lower rates of respiration and photorespiration seen when plants are grown in a atmosphere of higher CO_2 concentration (Long and Drake 1992). Most of the carbon fixed in the process of photosynthesis is being expelled in the process of respiration. When respiration is curtailed, naturally it is available for anabolic processes of plant growth. In addition to this reduced stomatal conductance and transpiration rates are also found to occur under elevated CO_2 concentrations. This will help in better water use efficiency in terms of the amount of water consumed to produce a given amount of biomass on a land area basis compared to plants grown at normal ambient CO_2.

Leaf thickness increased in both the clones when exposed to elevated CO_2 concentration. Between the clones their was no noticeable change in this character. Increase in the leaf thickness could be attributed to increase in the number of layers in the palisade cells as shown by Thomas and Harvey (1983).

Leaf weight ratio was quantified to assess the allocation of biomass to foliage. This was found to increase significantly in plants grown under elevated CO_2 concentrations. Such an increase in the leaf weight ratio is an indication of allocation of higher biomass to photosynthetic surface area. This indicates that plants tend to increase their photosynthetic capacity by increasing the efficiency of the photosynthetic machinery when there is more substrate available for photosynthesis.

Table 2. Effect of elevated CO_2 on a few biometrics parameters in two clones of *H. brasiliensis*.

Clones and treatments	Dry matter (g/plant)	Leaf area (cm^2)	Steam diameter (cm)	Plant height (cm)	Leaf thickness (μ)	Leaf weight ratio
RRII 105						
Control	17·60	1156	2·91	37·02	12·52	0·357
Elevated CO_2	21·29	1531	3·77	42·00	14·42	0·453
GT-1						
Control	18·85	1674	2·91	31·60	11·22	0·395
Elevated CO_2	21·70	2187	3·55	31·70	14·25	0·631
CD at 5% treatment	0·85	32	0·11	0·91	0·92	0·021
Clone	0·63	29	0·09	0·63	0·95	0·025

In general, both the clones showed a positive response to elevated CO_2, but the extent of response was different between the clones. There was nearly 75% increase in assimilation rates in RRII 105 at elevated CO_2 concentration, whereas GT-1 had only 14% increase. Similarly, RRII 105 showed higher biomass production than GT-1. Therefore, it is possible to conclude that clones with higher carbon assimilation ability at higher concentrations of CO_2 would perform better under elevated CO_2 conditions as seen in the case of clone RRII 105.

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