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ENHANCING INITIAL GROWTH RATES OF YOUNG *HEVEA* PLANTS USING ELEVATED CO_2 CONCENTRATION, RELATIVE HUMIDITY AND TEMPERATURE

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It is well established that growing plants in an atmosphere with elevated CO_2 concentration increases *the biomass production of C_3 species. Elevated relative humidity (RH) would increase the leaf expan*sion rates. A mild increase in temperature in association with high concentration of CO_2 and high RH helps in further enhancing the growth. A combination of these three parameters was obtained using an indigenous technique and was employed to enhance initial growth rates of young *Hevea* plants.

Using this technique two *Hevea* clones *viz*: RRIM 600 and RRII 105 were exposed to elevated CO_2, RH and temperature for 90 days. Both the clones showed a positive response. In RRIM 600, mean plant stem diameter, leaf area, leaf number, height and biomass showed 17.5, 46.5, 43.9, 54.1 and 26.5 per cent increase respectively in plants exposed to elevated CO_2 over the ambient air grown plants. In RRII 105, biomass increased by 21 per cent and stem diameter, leaf area, leaf number and plant height showed 20, 13.4, 5 and 0.7 per cent increase over ambient air grown plants respectively. From this data it is possible to conclude that the combination of elevated CO_2, RH and temperature can increase the initial growth rates of young plants of *Hevea*.

INTRODUCTION

Rubber tree, the source of natural rubber has a commercial life span of nearly thirty years. Of this, first 7 to 8 years is the immaturity period, which is quite long compared to most of the plantation crops. Though there are efforts to reduce the immaturity period such as breeding for vigorously growing clones, enhancing the initial growth rates of young plants is a viable approach. If we can reduce the immaturity period by enhancing the initial growth rates right from nursery itself, it can add to improve the growth rates and may help to reduce the gestation period.

Growing plants under elevated CO_2 conditions is found to increase the biomass production considerably, especially in plants with C_3 type of photosynthetic pathway. Such a response has been proved in many species (Kimball, 1983). There are different methods to expose plants to higher concentrations of CO_2 using solardome glass house, controlled environment cabinets, open top chambers, free air CO_2 enrichment (FACE) etc. Unfortunately growing plants under elevated CO_2 is a very expensive proposition. Also not many plants can be accommodated in these systems except in FACE. All these methods are highly sophisticated and require addition of extremely huge quantities of external CO_2 to increase the concentration to desired levels. In this paper we will demonstrate an indigenous method to enhance the CO_2 concentration using which one can expose young *Hevea* plants to elevated CO_2 concentrations and slightly warmer temperatures, and also how this system can be successfully used to obtain better growth in young *Hevea* plants.

MATERIALS AND METHODS

Rectangular trenches of 3 m length, 1.25 m width and 0.6 m depth, were dug in a well exposed open piace to get uninterrupted sunlight. All the four sides of the cut ends of the trench were provided with a layer of brick lining to reinforce the edges. Into this trench a layer of well decomposed organic matter was spread uniformly all along the floor. Sixteen kilograms of organic matter was required for the trench of above dimension to obtain a CO_2 concentration of 700-750 ppm for 30 to 45 days (Fig. 1A).

A rectangular metal frame was fabricated to suit the size of the trench and cover the trench completely enclosing it. Frame was fabricated using hollow galvanized iron tube of 1.5 cm diameter. Height of the frame was 1.6 m with a gable roof. This frame provided support to the polythene cover. Using high density polythene sheet of 125 gauge, a cover was tailored to suit the size of the frame. Length of the polythene cover was 12 inches more than the frame so as to allow a free and flat fall on the ground after enclosing the metal frame. On this free lying polythene a thin layer of dry sand was poured to keep the complete system air tight (Fig. 1B).

In this system CO_2 released due to decomposition of organic matter put on the floor of the trench was trapped in the polythene chamber and accumulated to get a concentration of 700 - 750 ppm. Polybag budded plants were arranged in the trench in such a way that the leaves of adjacent plants did not overlap and cause mutual shading (Fig. 1B). Seedlings were exposed to elevated CO_2 between 3.30 pm to 11.00 am. Before closing the trenches organic matter was sprinkled with water. Polybag plants were also watered before closing the chamber. In this system apart from CO_2, relative humidity and temperature also builds up inside the chamber (Fig. 3).

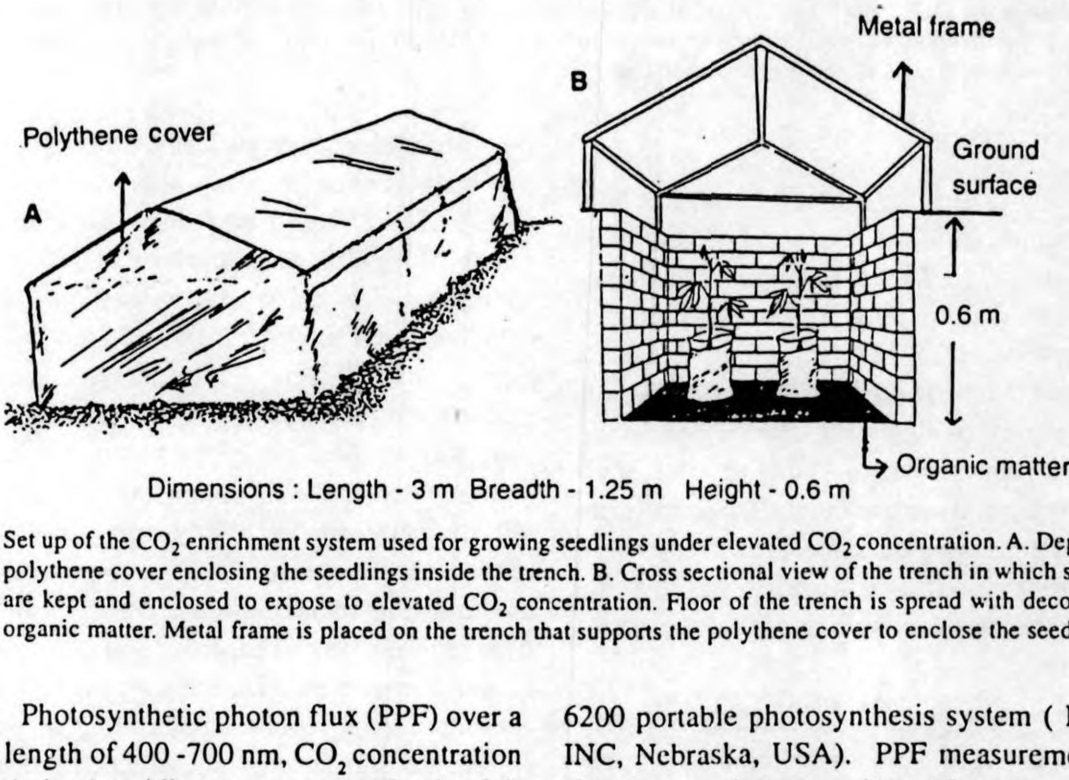

Fig. 1. Set up of the CO_2 enrichment system used for growing seedlings under elevated CO_2 concentration. A. Depicts the polythene cover enclosing the seedlings inside the trench. B. Cross sectional view of the trench in which seedings are kept and enclosed to expose to elevated CO_2 concentration. Floor of the trench is spread with decomposed organic matter. Metal frame is placed on the trench that supports the polythene cover to enclose the seedings.

Photosynthetic photon flux (PPF) over a wave length of 400 -700 nm, CO_2 concentration and relative humidity were measured using LI-6200 portable photosynthesis system (LI-Cor INC, Nebraska, USA). PPF measurement inside the trench was madè at 15 cm away from the roof of the polythene structure. Temperature inside the trench and ambient air were measured simultaneously. Leaf area was measured using portable leaf area meter (LI-3000, LI-Cor, INC, Nebraska, USA). Dry matter was measured after oven drying the plant material at 70°C till the three subsequent dry weights were constant.

RESULTS AND DISCUSSION

Carbon dioxide concentration inside the trench started building up after enclosing the trenches at concentration of 350 ppm and reached 700 - 750 ppm in less than an hour. It remained high all through the night and started falling after sun rise in the morning (Fig. 2A). Next day after sun rise photosynthetically active radiation started increasing gradually (Fig. 3A). This increase corroborates with the decrease in the CO_2 concentration inside the trench (Fig. 2B), suggesting the utilization of higher concentration of CO_2 by the plants in presence of sunlight for photosynthesis. CO_2 concentration never went below the ambient level. This suggests that there will be replenishment of CO_2 inside the trench from the organic matter while plants are photosynthesizing in the presence of sunlight. Temperature inside the trenches started increasing after sun rise (Fig. 3B). An average of 1.21° C rise was seen inside the chamber compared to ambient air up to 8.00 am, whereas this difference from 8.00 am to 11.00 am was 4.69° C. Because of this rise in temperature inside the trenches it was not possible to keep the trenches closed for longer periods after sunrise. Along with CO_2 and temperature, rise in relative humidity (RH) was also taking place inside the trench (Fig. 3C). RH built up in side the chamber within thirty minutes after closing and reached the saturation level. It remained so till the trenches were exposed to open air.

Using this system, polybag planted bud grafted seedlings of two clones of rubber were exposed to elevated CO_2, relative humidity and temperature. One month old polybag planted bud grafts were subjected to this treatment for ninety days and their responses were assessed. There was a positive response to elevated CO_2 in biomass production, in both the clones studied though the extent of response varied. From

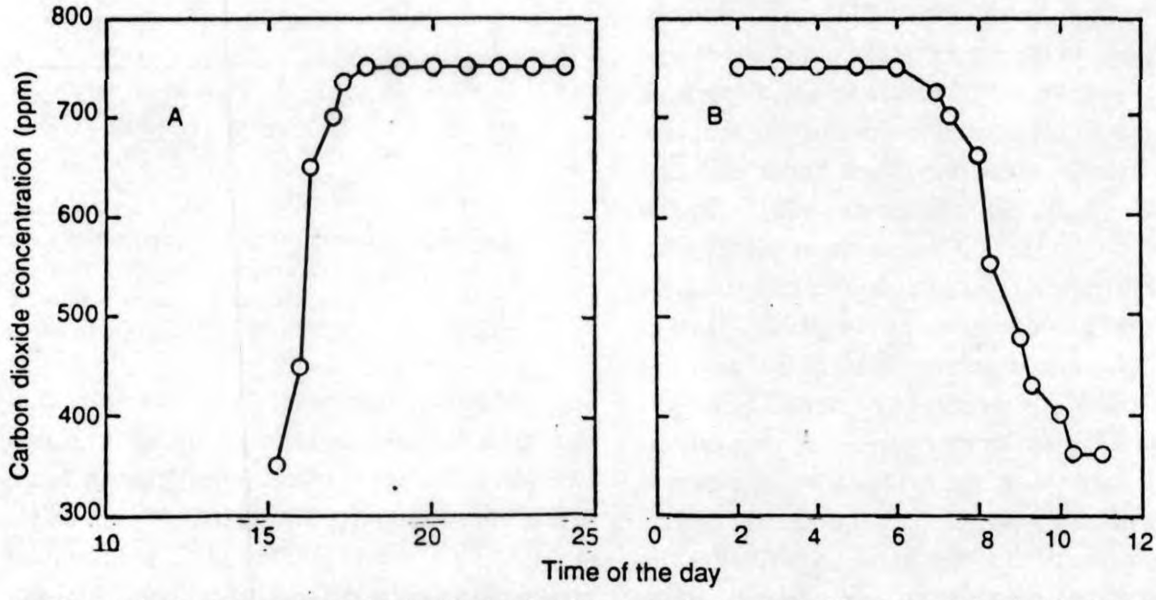

Fig.2. Changes in the CO_2 concentration inside the chamber; A. Build up of the CO_2 concentration inside the trench (15.30 to 6.00 h), B. Depletion of CO_2 concentration after 7.00 upto 11.00 h

this data, it is evident that growth rates were better under elevated CO_2 concentration (Fig. 4). Among the two clones RRIM 600 showed higher response than RRII 105 to elevated CO_2 in terms of biomass production. The total dry matter of RRIM 600 was 26.5 per cent more under elevated CO_2, compared to ambient air grown plants.

Table 1. Growth related characters of two *Hevea* clones grown under elevated CO_2 and ambient air recorded after ninety days of growth

Clone	Treatment	Stem diameter (cm)	Plant height (cm)	Leaf number
RRIM 600	Ambient air grown	0.94	94.1	18.5
	Elevated CO_2 grown	1.14*	107.15*	33.0**
RRII 105	Ambient air grown	1.13	80.6	30.5
	Elevated CO_2 grown	1.42*	90.21*	32.0^{NS}

** *Significant at 1 % probability*
* Significant at 5 % probability
NS: No significant difference

In this system, plants are making use of higher concentrations of CO_2 for carbon assimilation in the presence of light in the morning hours between 7.00 and 11.00 am. Evidences show that, it is possible to increase the biomass production by growing plants under elevated CO_2 (Kimball, 1983; Bazzaz, 1990). In the present method of CO_2 fertilization, plants were also experiencing relatively higher temperatures compared to ambient air grown plants. Imai *et al.* (1984) noticed enhancement of leaf area and whole plant dry weight at higher CO_2 associated with higher temperature. The proportionate increase in carbon assimilation at elevated CO_2 will rise with temperature (Long, 1991). He also found that elevated CO_2 will alter the magnitude of response of leaf canopy carbon gain to rising temperature and relative humidity which apparently enhanced growth. Therefore, higher temperature and humidity associated with higher concentration of CO_2 has helped in higher carbon assimilation and leaf expansion.

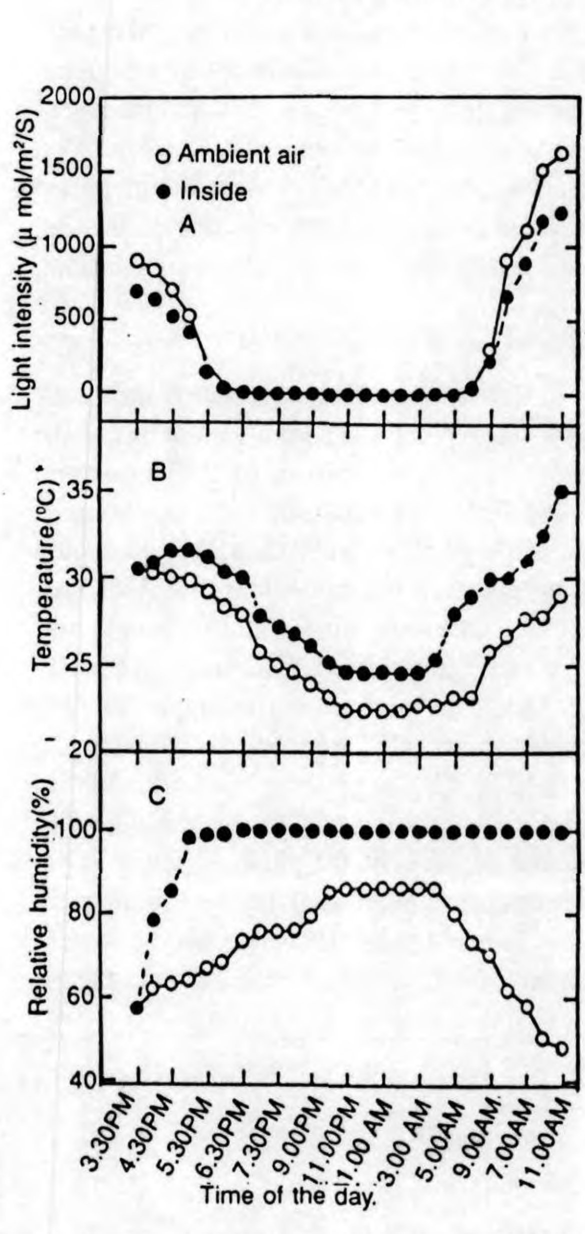

Fig. 3. Changes in light intensity (A), temperature (B) and relative humidity (C) in the ambient air (O) and inside the chamber for the period during which the seedings were exposed to elevated CO_2 concentration

Another important plant character that showed a remarkable increase under elevated CO_2 was leaf area per plant. Significant increase in leaf area was noticed in both the clones under elevated CO_2 when compared to ambient air grown plants (Fig. 5). RRIM 600 had 46.5 per cent increase in leaf area, while RRII 105 showed only 13.4 per cent under elevated CO_2. Leaf number was significantly high in elevated CO_2 grown plants, compared to ambient air grown plant, but it was not so in RRII 105. Similar

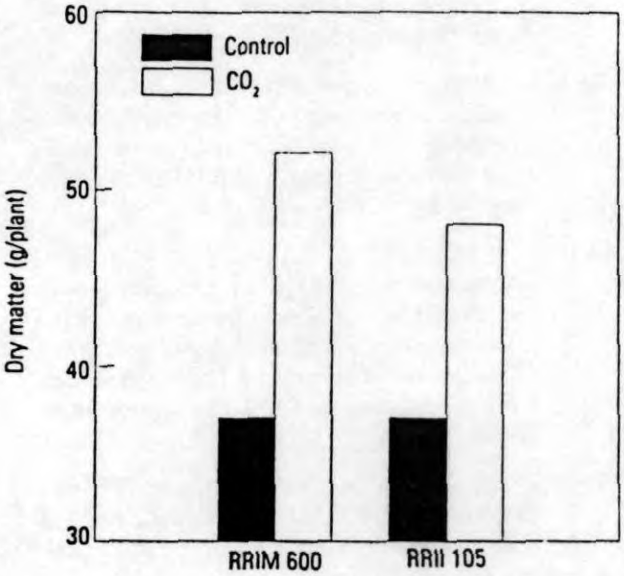

Fig. 4. Dry matter produced in polybag plants after three months of exposure to elevated CO_2 concentration and in ambient air

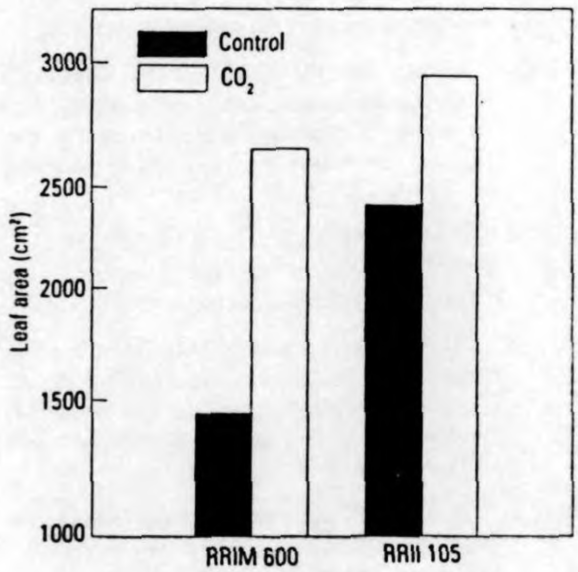

Fig. 5. Leaf area development per plant after three months of exposure to elevated CO_2 concentration and in ambient air

type of studies conducted under controlled conditions have reported increase in leaf area in plants grown under high concentrations of CO_2 (Masle *et al.*, 1993; Kimball, 1986 and Gifford *et al.*, 1985). When higher temperature is associated with elevated CO_2 concentrations, leaf area is further enhanced (Ackerly *et al.*, 1992). It is due to higher leaf initiation rate, leaf expansion and individual leaf area. Relative humidity is another important weather parameter that determines leaf growth. Relative humidity can reduce the vapor pressure deficits and thus help in maintaining high turgidity of the cells which provides a congenial condition for cell division, elongation and expansion. Plant height and stem diameter were significantly higher in elevated CO_2 grown plants in both the clones which is a reflection of higher growth rates under elevated CO_2 concentration (Table 1). Another possible reason for higher growth seen under this system could be due to lower dark respiration rates. According to Tanaka and Yamaguchi (1968) efficiency of respiration increases as a result of whole plant CO_2 enrichment. Respiration rates decrease at higher concentrations of CO_2 (Farrar and Williams, 1991; Bunce and Caulfield, 1991). Decrease in the respiration rates means decrease in the utilization of assimilates and the same may be made use of in growth processes.

The main advantage in this method is that, there is no need of adding CO_2 from an external source which reduces the total cost considerably. Construction of the system is within the scope of a small workshop and material required is easily available. This system can be effectively used to enhance the initial growth rates of the seedlings in the nurseries. This can help in growing robust seedlings that may perform better when field planted thus reducing the casualty.

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