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SHADE EFFECTS ON PHOTOSYNTHESIS OF CINNAMON (*CINNAMOMUM VERUM J.PRES*)

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ABSTRACT

Light response of net photosynthesis in cinnamon plants grown under four levels of growth irradiances ranging from 12%-100% day light was measured by exposing to photonflux densities of 0-1840 µmol m^2s^{-1}. Photosynthetic rate at light saturation derived from the data fitted to a quadratic model showed an increase from 5.14 - 7.25 µmol $m^{-2}s^{-1}$. Light required for 50% light saturation of photosynthesis also increased with the increase of growth irradiance. Light compensation point and dark respiration derived by fitting the data from 0-81 µmol $m^{-2}s^{-1}$ photon flux density to a linear model, and dark respiration measured directly increased with the increase of growth irradiance. The plants under 12% daylight had the highest quantum efficiency. The percentage increase of photosynthetic rate from growth irradiance to that at light saturation was greatest at 12% day light growth irradiance. The size of leaves, the leaf area per unit fresh and dry weight of leaves and leaf area per unit dry weight of plants were decreased with the increase of growth irradiance. These results indicate the C_3 nature of photosynthesis and the characteristics of shade adapted photosynthesis in cinnamon.

Key words: *Cinnamomum verum/zeylanicum,* dark respiration, growth irradiance, *Hevea* (rubber), light compensation point, photonflux density, photosynthetic rate, quantum efficiency

INTRODUCTION

Cinnamon (*Cinnamomum verum J.Pres - Lauraceae*) is commercially grown as a monocrop in full sunlight in moist lowlands of Sri Lanka for its bark. It is also seen growing under the shade of large trees and found to be suitable as an intercrop under coconut (Gunatillake, 1986). Some small farmers obtain economic yields by growing them under mature rubber (*Hevea*) trees. The shade under the rubber canopy depends on the age and the clone of the tree. Cinnamon seems to thrive under the partial light conditions of fully grown rubber trees (Pathiratna, 1994): Thus, it is quite possible that cinnamon, though considered a sun-loving plant also possesses mechanisms to maximise its CO_2 assimilation under low light conditions.

Some plants adapted to sunny habitats can also can acclimatize to grow under low photon flux densities by adopting ways of optimising photosynthesis under shade (Powles, 1984). These include morphological adaptations and physiological adjustments of photosynthesis (Boardman, 1977; Ashton & Berlyn, 1992). Morphological changes include thinner leaves that result in larger total leaf areas and lower root shoot ratio (Ashton & Berlyn, 1992).

Physiological characters of shade adapted leaves are, increased quantum efficiency and low light compensation point (Tenhunen *et al.*, 1976). Shade grown plants are also capable of using irradiance at higher levels than the irradiance under which they are grown (Prioul & Bourdu, 1973; Chabot *et al.*, 1979).

This study attempts to assess the nature and the extent of any adaptation of cinnamon to maximise photosynthesis under shade conditions.

MATERIALS AND METHODS

Experiment 1

Laboratory measurements

Six month old seedlings of cinnamon, grown in polythene bags containing a potting mixture of soil and coir dust in the ratio of 3:1, were subjected to different growth irradiances for five months before the measurements were taken. Shade levels of 48%, 28%, 12% daylight was obtained by using 1,2 and 3 layers of coir mesh laid over wooden frames. These three along with the 100% daylight treatment were replicated thrice and each replicate had 10 plants. Three plants from each replicate were selected at random for measurements. Plants were fertilized monthly and watered regularly. The day and night temperatures were 30 ± 2°C and 24 ± 2°C respectively and the average rainfall during the period was 2000 mm. The day length was around 12 hrs.

Plants removed to the laboratory for light response measurements in attached leaves, were kept in dark for about 1 h before the measurements. The illumination for measuring the light response was provided by a quartz-iodide light source (Model

250H, Scholly Fiberoptik, Donzlingn, GRG) and the light intensity was reduced from 1849 - 0 μmol $m^{-2}s^{-1}$ by using thin white cloth as natural filter. The leaves selected for measurements were subjected to photon flux densities of 1849, 727, 416, 286, 161, 81, 64, 33, 23 and 0 μmol $m^{-2}s^{-1}$ reduced successively. The measurements were repeated for four days within a week.

Field measurements

CO_2 assimilation rates in 5 mature healthy attached leaves from each treatment was measured at 1000, 1200 and 1400 hrs while the plants were in the field. Three such measurements on bright sunny days were taken. Dark respiration measurements in three plants from each treatment were also made separately.

A portable photosynthesis system (Series LI 6200, LI-Cor Inc USA) fitted with a quantum sensor (LI-190SR LI Cor Inc USA) was used for all these measurements.

Calculation of light compensation point, dark respiration and quantum efficiency of photosynthesis was made from linear regressions of data between light levels 0-81 μmol $m^{-2}s^{-1}$.

The photosynthesis at light saturation and the irradiance required for 50% saturation were calculated from a standard rectangular hyperbola model (Hay & Walker, 1989). The linear regression and the rectangular hyperbola model were done separately for each replicate and values derived from them were subjected to ANOA.

After the completion of these measurements the plants were uprooted and the leaf number, leaf areas and fresh weights of leaves were taken. The plant material was dried at 72°C overnight for dry weight determination. Leaf areas were measured using a portable leaf area meter (Series LI 3000 - LI Cor Inc USA).

Experiment 2

This field investigation was made in a smallholding where rubber (*Hevea*) had been interplanted with cinnamon land at 8.2m x 2.4 m. Five cinnamon bushes at random, from each of the four areas *viz*. cinnamon only, cinnamon under 2½, 5 and 8 years old rubber trees of clone RRIC 100 were selected. These cinnamon plants (bushes) were about 40 years old. The light received above the cinnamon canopy under rubber was measured at 16 random spots from each plot at 930, 1200 and 1430 hrs of the day and the measurement was repeated on three bright sunny days. Concurrent measurement of light intensity in an adjacent open area was taken for comparison. These measurements were made using the two quantum sensors described earlier. Photosynthetic rates in five well exposed mature attached leaves of Cinnamon from each plot were measured at 1000, 1200 and 1400 hrs of the day and repeated for three days. Dark respiration rates in two leaves from each plot was measured after dusk and repeated for two days using the same portable photosynthesis system. Subsequently, these plants were harvested and total leaf area, leaf fresh and dry weights were recorded.

RESULTS

Experiment 1

The rate of photosynthesis at light saturation significantly increased from 5.14-7.25 μmol $m^{-2}s^{-1}$ with artificial increase of growth irradiance from 12 - 100% day light. The mean daily photosynthetic rates when measured in the field also increased significantly from 2.49-4.50 μmol $m^{-2}s^{-1}$ under the same growth irradiances (Fig. 1a). Photosynthetic rate either at light saturation or daily mean did not seem to increase between growth irradiance of 48% and 100% day light. The light requirement for 50% saturation increased significantly from 256 - 528 μmol $m^{-2}s^{-1}$ in the same range of growth irradiances (Fig. 1b). The light compensation point in plants under 12% day light was 17.30 μmols $m^{2-}s^{-1}$ which increased significantly to 64.83 μmol $m^{-2}s^{-1}$ at 100% day light (Fig. 1c). The dark respiration rates estimated from the linear regression and direct measurement increased from 0.33-1.17 μmol $m^{-2}s^{-1}$ and 0.39-1.52 μmol $m^{-2}s^{-1}$ respectively within the same growth irradiances (Fig. 1d). However, there was no significant increases of light requirement for 50% saturation, light compensation or dark respiration between growth irradiances of 28% and 48%.

The variation in the quantum efficiency with the increase in growth irradiance though not significant showed a decreasing trend from 0.0234 to 0.0186 with the change of growth irradiance from 12%-100% (Fig. 2a).

The percentage increase of the photosynthetic rates from growth irradiance (PAR at growth irradiance was taken as the daily mean measured at 900, 1200 and 1400 hrs) to that at light saturation was greatest in the plants grown under 12% daylight and it decreased significantly with the increase in growth irradiance from 48% - 100% and from 12% - 28% (Fig. 2b).

The leaf area per unit plant dry weight increased with the decrease in growth irradiance but without significant differences between 100% and 48% or 28% and 12%. Leaf area per unit leaf dry weight and fresh weight also increased with the decrease of growth irradiance under artificial shade (Fig. 2c). The size of the

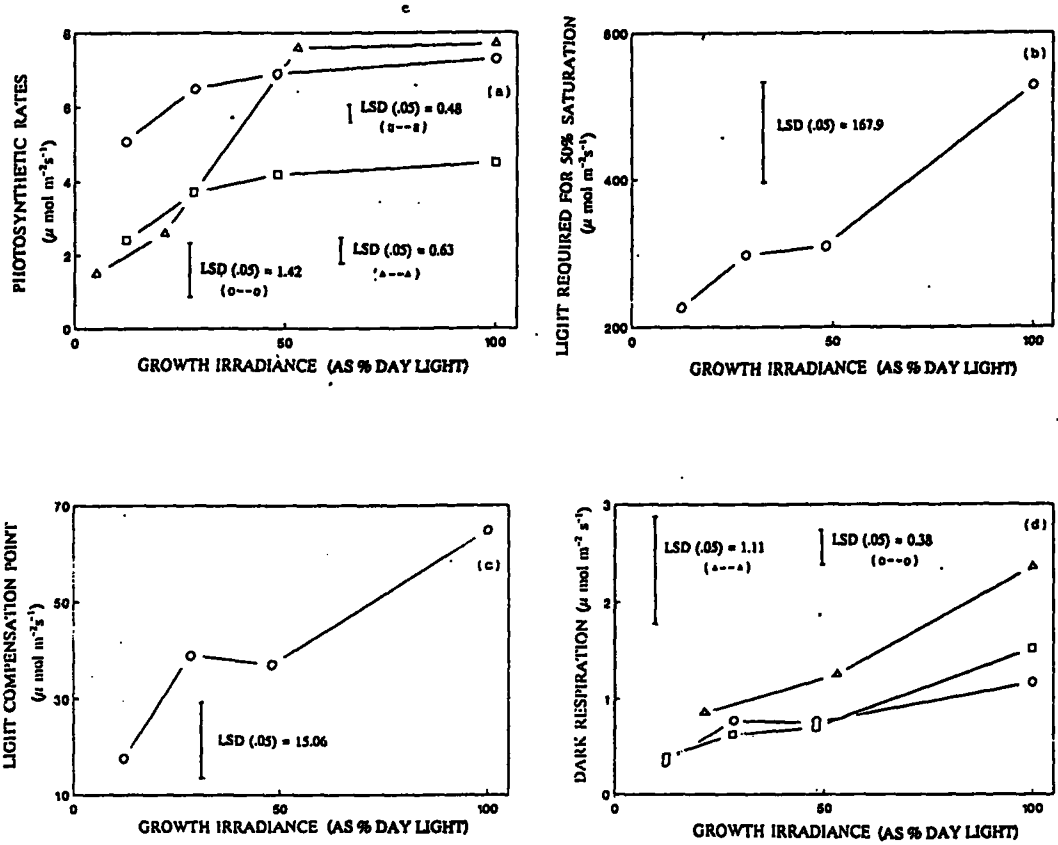

Fig. 1. Effect of growth irradiance (a) on the photosynthetic rate at saturating light derived from the light response curve (O--O) and daily mean photosynthetic rate measured in the field (□--□) (growth irradiances 12%,28%,48%,100% day light); daily mean photosynthetic rate of plants under rubber trees (△--△)(growth irradiances 5%,21%,53% and 100% day light; (b) on the light required for 50% saturation in plants under artificial shade (growth irradiances 12%,21%,48% and 100% day light); (c) on the light compensation point in plants under artificial shade (growth irradiances 12%,28%,48% and 100% day light) (d) on dark respiration in plants under artificial shade derived from linear regression(O--O),direct measurement (□--□) (growth irradiances 12%,28%,48% and 100% day light) and in plants under the shade of rubber trees (△--△) (growth irradiances 21%,53% and 100% day light)

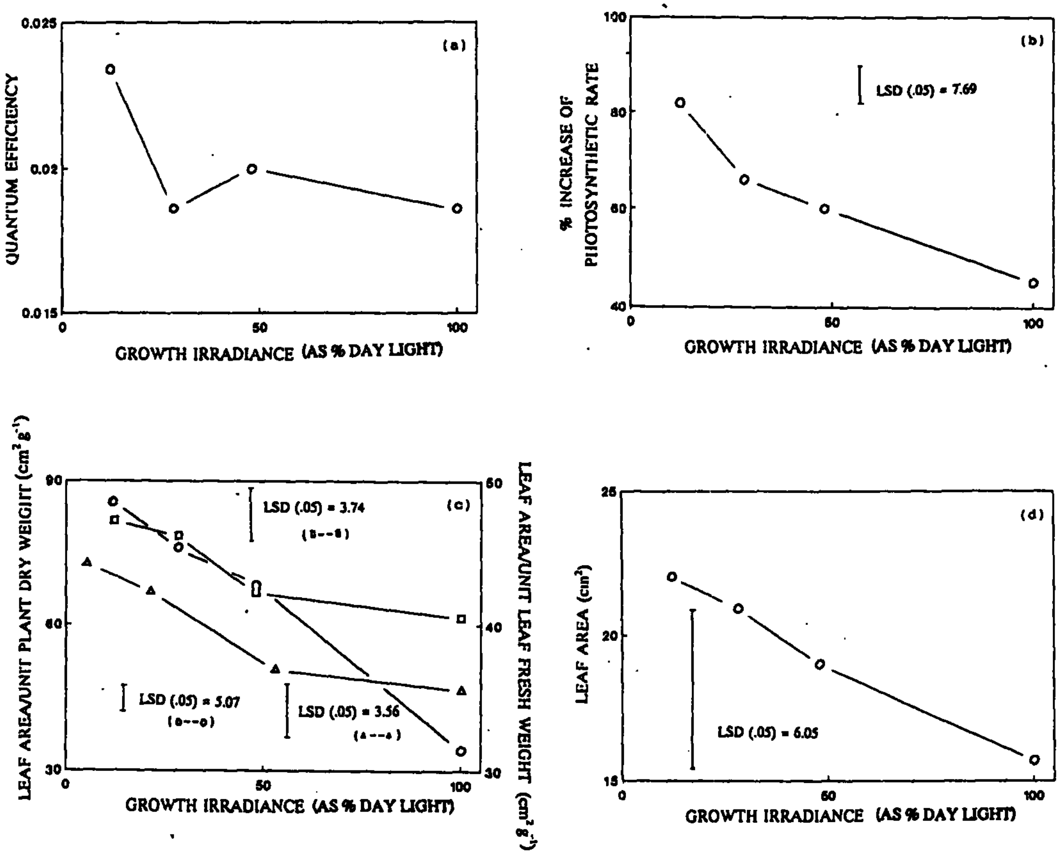

Fig. 2. Effect of growth irradiance (a) on quantum efficiency of plants under artificial shade (growth irradiances 12%,28%,48% and 100% day light) (b) on the percentage increase of photosynthetic rate at growth irradiance to that at light saturation in plants under artificial shade (growth irradiances 12%,21%,53% and 100% day light)(c) on leaf area per unit plant dry weight(O--O) and leaf area per unit leaf fresh weight (□--□) of plants under artificial shade (growth irradiances 12%,28%,48% and 100% day light); leaf area per unit leaf fresh weight (△--△) of plants under the shade of rubber trees (growth irradiances 5%,21%,53% and 100% day light) (d) on the mean leaf area in plants under artificial shade (growth irradiances 12%,28%,48% and 100%).

individual leaves also declined with increase of growth irradiance under artificial shade, the effect being significant only between the growth irradiance of 100% and 12% (Fig. 2d).

Experiment 2

The cinnamon plants under the shade of rubber trees also showed a similar increase in the mean daily photosynthetic rate *i.e.* from 1.53-7.36 μmol $m^{-2}s^{-1}$ with growth irradiance ranging from 5%-100% daylight (Fig. 1a). There was also a significant increase of dark respiration from 0.85 - 2.36 μmol $m^{-2}s^{-1}$ in plants under the shade of 21% - 100% (Fig. 1d).

The leaf area per unit fresh weight of leaf also showed a similar decrease, but not significantly either between 100% - 53% or 21% - 5% (Fig. 2c).

DISCUSSION

Plants under shade divert a large proportion of photosynthates for the production of leaves (Boardman, 1977) and is indicated by the large ratio of leaf area to total plant dry weight (Fig. 2c). The larger leaf area per unit dry and fresh weight of leaves is due to the production of thinner leaves. This is particularly due to a narrower palisade tissue (Friend, 1984). These morphological and anatomical changes as well as of the photosystem and enzymatic activity in response to shade could account for the reduced rates of dark respiration, low light compensation point and a higher quantum efficiency (The quantum efficiency values recorded in this study are comparatively low from the values reported elsewhere, Ehleringer & Pearcy (1983) in shade grown plants (Figs. 1c, 1d, 2a and 2c) as photosynthetic characteristics of many species are influenced by the light intensity under which they are grown (Boardman, 1977; Ashton & Berlyn, 1992). These adaptations are commonly reported for other crops (Friend, 1984; Cartechini & Palliotti, 1995).

These plants also showed a higher percentage increase in photosynthetic rate from the irradiance to that at light saturation with the increase in shade level. This indicates the possibility of cinnamon to make use of high intensity light for short periods of time (sun flecks) for photosynthesis as in other shade plants (Boardman, 1977; Friend, 1984; Pearcy, 1990). The ability of the plants under only 5% day light in the rubber land to grow and produce a considerable amount of dry matter is a clear indication of this. Under normal circumstances, this light would not be sufficient for reasonable growth. But the sun flecks that fall on the cinnamon plants with the movement of the branches and twigs of rubber trees would have provided sufficient light for photosynthesis. CO_2 exchange rates in some crops under light flecks may correspond to those under continuous light (Poni *et al.*, 1993; Intrieri *et al.*, 1995). If our light measurements were daily totals instead of instantaneous measurement it would have been possible to account for the effect of these short term sun flacks.

It is also evident from field measurements that there is light saturation of photosynthesis at 48% and 53% day light in plants under artificial shade and under the shade of rubber trees respectively suggesting the C_3 nature of photosynthesis in this crop. Further the shade adaptation characteristics exhibited in these results show the ability of cinnamon plants to grow even under light levels lower than 48% day light, a feature that may have derived from its native habitat in the moist forests of the central hills of Sri Lanka (Purseglove *et al.*, 1981). These findings therefore show the possibility of intercropping commercial cinnamon successfully under rubber and needs further studies to develop this system to obtain maximum benefits.

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REFERENCES

Ashton, P M S and Berlyn, G P (1992). Leaf adaptations of some *Shorea* species to sun and shade. *New Phytologist* **121**, 587-596.

Boardman, N K (1977). Comparative photosynthesis in sun and shade plants. *Annual Review of Plant Physiology* **28**, 355-377.

Chabot, B F, Jurik, T W and Chalot, J J (1979). Influence of instantaneous and integrated light flux density on leaf anatomy and photosynthesis. *American Journal of Botany* **66**, 940-945.

Cartechini, A and Palliotti, A (1995). Effect of shading on vine morphology and productivity and leaf gas exchange characteristics in grapevines in the field. *American Journal of Enology and Viticulture* **46**, 227-234.

Ehleringer, J and Pearcy, R W (1983). Variation in quantum yield for CO_2 uptake among C_3 and C_4 plants. *Plant Physiology* **73**, 555-559.

Friend, D J C (1984). Shade adaptation of photosynthesis in *Coffea arabica*. *Photosynthesis Research* **5**, 325-334.

Gunatillake, H A J (1986). Cinnamon under coconut. *Coconut Bulletin* **3**, 7-8.

Hay, R K M and Walker, A J (1989). *An introduction to the physiology of crop yield*. Longmans Scientific and Technical Publications. 249 pp.

Intrieri, C, Zerb, G, Marchiol, L, Poni, S and Caiado, T (1995). Physiological response of grapevine leaves to light flecks. *Scientia Horticulturae* 61, 47-59.

Pathiratna, L S S (1994). Cinnamon as a prospective intercrop for rubber *(Hevea)* in Sri Lanka. MSc Dissertation University of Reading. England.

Pearcy, R W (1990). Sunflecks and photosynthesis in plant canopies. *Annual Review Plant Physiology and Plant Molecular Biology 41*, 421-453.

Poni, S, Marchiol, L, Intrieri, C and Zerbi, G (1993). Gas exchange response of grapevine leaves under fluctuating light. *Vitis* 32, 137-143.

Powles, S B (1984). Photoinhibition of photosynthesis induced by visible light. *Annual Review of Plant Physiology* 35, 15-37.

Prioul, J L and Bourdu, R (1973). Graphical display of photosynthetic adaptability to irradiance. *Photosynthetica* 7, 405-407.

Purseglove, J W, Brown, E G, Green, C L and Robbin, S R J (1981). *Spices* Vol.1. Longmans, London. 100-174 pp.

Tenhunen, J D, Weber, J A, Yocum, C S and Gates, D M (1976). Development of a photosynthesis model with an emphasis on ecological applications, II Analysis of a data set describing the P_m surface. *Oecologia* 26, 101-119.

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