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Longevity and factors influencing photosynthesis in tea leaves

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Abstract

Quadratic relationship between the age of a tea leaf and the net photosynthetic rate (P_N) has been found. A progressive increase in P_N was recorded for four months. Then the P_N slowly declined, yet even seven-month-old tea leaves sustained a low P_N. In a tea shoot, the P_N increased from the first leaf onwards. Besides the physiological maturity and proximity, photon flux density (PFD) played an important role in reducing the P_N. The tea leaf P_N was influenced by cultivation procedures which in turn disrupted the quantum of PFD transmitted through the canopy.

Additional key words: *Camellia assamica* ssp. *assamica*; irradiance; leaf age and insertion; photon flux density; spectral distribution in canopy.

Introduction

P_N of tea leaves is influenced by the values of PFD, temperature, daylength, carbon dioxide concentration, genetic potential of given cultivar, physiological maturity, and by management practices (Raj Kumar *et al.* 1993a,b, Marimuthu *et al.* 1994). Earlier studies on the P_N of tea leaves and source-sink relations led to an extended pruning cycle in order to sustain the productivity (Manivel and Hussain 1982a,b). The P_N reaches its maximum at the leaf temperature of 30-35 °C and rapidly decreases beyond 37 °C; finally there is no net uptake of CO_2 at 42 °C (Hadfield 1976, Tanton 1982a,b). To lower the ambient temperature at canopy level, tea is cultivated under a regulated shade. Fully expanded mature leaf is an effective moderator against possible drought as compared to the tender leaves. In order to impart the drought tolerance, addition of mature leaves at the end of the crop season, particularly before the onset of a dry spell, is the recommended practice at north and south Indian tea

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plantations. These culturing operations result in desirably dense canopy architectures. Considering the importance of the maintenance leaves' P_N for health and productivity of the plant, the present investigation was carried out to bring information on the life-span of a tea leaf and factors influencing P_N at the bush level.

Materials and methods

Experiments were done at the UPASI Tea Research Institute, Experimental Farm, Valparai (1080 m a.s.l.) between 1995 and 1996. Tea clone UPASI-3 representing an "Assam" cultivar [*Camellia assamica* ssp. *assamica* (Masters) Wight] grown under a regulated shade provided by trees *Grevillia robusta* L. was selected for the studies. Shade trees were lopped off periodically at 8 to 9 m above the ground level, leaving three to four tiers of horizontal branches before pruning the tea plants. Twenty-three-year-old tea plants were last pruned during May 1995 at 55 cm above the ground level. All cultivating operations including manure supply and plant protection fixings were adopted according to the recommendations of the UPASI Scientific Department (Swaminathan *et al.* 1990).

From the experimental plots, ten bushes with a similar trunk diameter were chosen and observed for bud emergence from the twentieth day after pruning at an interval of two to three days. Until tipping (first harvest after pruning), emerged buds on the pruned frames were allowed to grow into "aperiodic shoots" consisting of six to seven fully expanded leaves and two to three tender leaves with a growing bud. After reaching the level of 65 cm above ground, the burgeon was tipped, and thereafter the plants were regularly harvested, adding a mother leaf before the onset of drought. The date of leaf unfolding was monitored periodically up to the termination of the experiment. The number of days between the date of unfolding and P_N monitoring was considered as the leaf age counted in days.

P_N of tea leaves in different age groups has also been studied with another set of UPASI-3 plants grown under a regular plucking. Uniformly growing tea shoots were tagged and plucked, leaving the mother leaf on the canopy. Tagged stumps with axillary buds were monitored regularly to calculate the age same as in the previous experiment. Spectral distribution of PFD within the crop stand was measured with a *LI-COR 1800* spectroradiometer (*LI-COR Instruments*, Lincoln, USA). Measurings were made at three levels, *i.e.*, the top canopy, 20 cm below the canopy, and at the ground level. The instrument scanned the range of 300 to 1100 nm at a 5 nm interval; measurements were taken with a cosine-corrected sensor attached to a fibre optic cable. At each level, a minimum of ten measurements were made, and the mean of spectral distribution of PFD was presented. All measurements were taken within an hour of solar zenith in November 1995 with the sun unobscured.

In all the cases, P_N of leaves was monitored within a week of unfolding, and observation continued thereafter periodically under field conditions using an infra-red gas analyser, and an open-type gas exchanger with the Parkinson leaf chamber (*ADC*, UK, models *LCA 3* and *PLC 3*, respectively). A minimum of ten leaves per set of identical physiological maturity were scanned from the fourth day of unfolding up to the 250th d. Obtained values were subjected to a statistical analysis (regression and ANOVA), and the interaction between leaf age and P_N was analysed using the statistical package *STATTECH-1*, version *2.0* (Murthy 1989).

Results and discussion

The metabolism of plants is influenced by a PFD in which they grow. Both the incident PFD and its quality changed significantly when filtered through the canopy at different levels (Fig. 1). When compared to the top canopy, PFD values underneath the canopy, both at 20 cm below and at the ground level, were reduced significantly and spectrally altered.

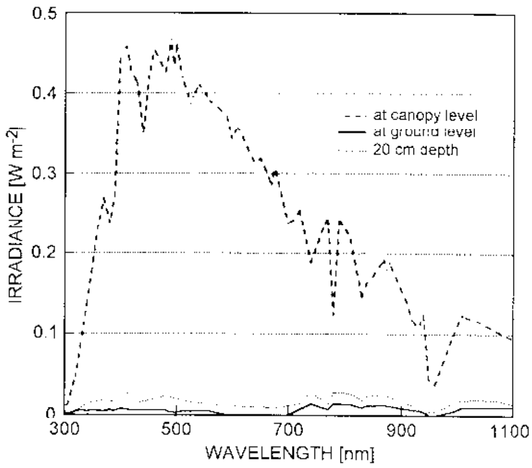


Fig. 1. Spectral distribution of radiation within a tea plant measured at top, 20 cm below the canopy, and at ground level.

Dependence of P_N on the leaf age showed a significant correlation at $P = 0.05$ %. This is in agreement with results on other plant species (see Šesták 1985). There was an initial linear increase in P_N with concurrent increase in the leaf age. Young tea leaves fixed relatively little atmospheric carbon dioxide while mature leaves recorded about 25 μmol(CO_2) m^{-2} s^{-1} (Fig. 2). Four months after unfolding the tea leaf P_N fell. However, tea leaves beyond seven- to eight- month-old fixed about 6 μmol(CO_2) m^{-2} s^{-1} which is adequate for sustaining the metabolic processes, contributing less to the reserve pool.

There is a gradient in leaf age from base to the tip of the shoot. As the lamina expands, P_N increases while respiration and growth decline. P_N increased from the first leaf onwards in a tea shoot (Fig. 3). 7- to 10-d-old first leaf subtending to the bud fixed 4 μmol, whereas the 60-d-old fourth leaf (mother leaf) fixed approximately 15 μmol(CO_2) m^{-2} s^{-1}.

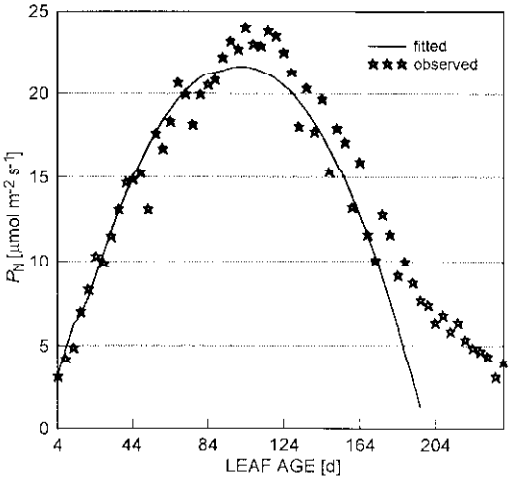
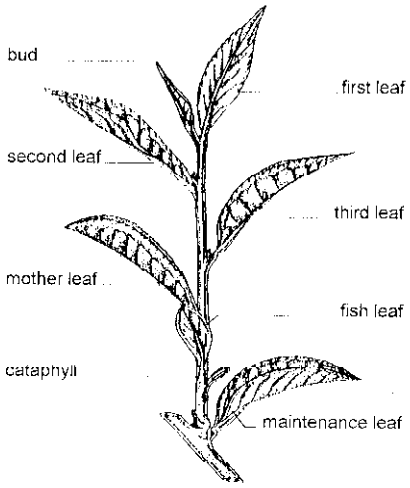


Fig. 2. Relation between age and net photosynthetic rate (P_N) of tea leaf: y = a + bx + cx - 2 (a = 1.419, b = 0.419, c = 0.023; x = age).



Leaf position	P_N [µmol m^{-2} s^{-1}]
First leaf	4.13
Second leaf	5.55
Third leaf	9.36
Mother leaf	15.24
Maintenance leaf	20.00
L.S.D.	1.92

Fig. 3. Net photosynthetic rate (P_N) of tea shoot. Note the decreasing trend in P_N activity with physiological maturity.

The PFD of the maintenance leaves depends on the canopy architecture, shade provided to the crop, and space between the plants of tea. The plants adapted to shade sustain a high P_N at a low PFD (Barua 1970). Such PFD may reduce P_N for the basal parts of a plant which may cause variation in phytochrome ratios (Lee and Patel 1987). Top 10 cm of the canopy contribute about 75 % of the productivity, and another 10 cm below this level support the balance by 20 to 25 % of the crop in tea. Though the leaves below these 20 cm of canopy under shaded conditions fix a very low amount of CO_2, they do not parasite upon other organs (Manivel and Hussain 1982a,b).

10 % of the PFD transmitted through the canopy is regulated by cultivation chores like plucking, tipping, and addition of new leaves on the canopy. This decreases the enzyme activity involved in photosynthesis which may affect overall cell metabolism (Boardman 1977). Maintenance leaves below the 20 cm canopy would not be a disadvantage *per se*, but the synthesis and maintenance of superfluous amounts would require an increased expenditure of energy; maintenance leaves below the 20 cm level of the canopy showed a greater carbon loss through increased respiration and a higher compensation irradiance. A partial defoliation of maintenance leaves, below 20 cm of the canopy, may cause a parallel increase in P_N and contents of photosynthetic enzymes (Boardman 1977).

Tea leaves attain peak efficiency and self-sufficiency in P_N when they are fully expanded and remain photosynthetically active for a longer period (Barua 1989, Manivel 1989). A drop in P_N is mainly due to the addition of a new leaf which increases the canopy density which in turn disrupts the PFD penetration. More than six-month-old tea leaves subtending top layer of new leaves showed relatively less carbon dioxide assimilation as a result of PFD paucity (Figs. 1 and 2). However, the same leaf, when irradiated, formed a significantly higher amount of photosynthates. When PFD value was between 900 and 1200 μmol m^{-2} s^{-1} the leaves aged beyond six months fixed relatively more CO_2 than a similar type of leaf with the PFD value reading <700 μmol m^{-2} s^{-1}.

Variation in P_N within a tea shoot may be attributed to its physiological maturity. Young tea leaves are heterotrophic in nature and depend on other sources for more photosynthates. Being autotrophic, the fully expanded fourth leaf supplies adequate amount of sugars to sinks. The third leaf is in transient stage, and hence it neither imports nor transports sugars (Marimuthu *et al.* 1994).

Cultivation practices like letting up and shade management increase the canopy thickness. In consequence, tea plants receive an inadequate amount of PFD. Partial defoliation of maintenance leaves and bush sanitation may enhance P_N under the given conditions.

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