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Effective Leaf Area – An Efficiency Index of Canopy Foliage to Estimate Crop Productivity of Tea *(Camellia sinensis (L) Kuntze)*

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ABSTRACT. By studying the leaf and light distribution pattern within the maintenance foliage of tea canopy, the Effective Leaf Area (ELA) or the proportion of canopy leaf area which is effective in producing drymatter was estimated. This was about 42% of the total leaf area. The rate of transpiration, diffusive resistance of stomata and Net Photosynthesis Rate (NPR) indicates that the maintenance leaves are most efficient when they are about 12 weeks old. However, they play an active role for about 24 weeks as a source of drymatter producer of the tea canopy. Using the estimated value for ELA and NPR the productivity of tea bush was estimated. This was 4805 kg ha^{-1} yr^{-1}, which can be considered as a realistic estimate for a high yielding clone like TRI 2023 under low elevation growing conditions in Sri Lanka.

INTRODUCTION

The estimation of crop productivity of tea was attempted before, either by using theoretical estimates (Huxely, 1975) or by making actual measurements (Othieno, 1976; Laycock and Othieno, 1978). The estimated values based on theoretical assumptions were generally 3–4 times higher than the highest values recorded under different environments. However, it was not possible to give adequate explanations for these productivity gaps. In perennial woody plants such as tea, it is extremely tedious to make actual measurements to estimate productivity. The perennial nature of woody stem and root systems make it very complicated to carry out accurate measurements on total bio–mass at regular intervals. Very high plant to plant variation even in a clonal population may require large samples for any reasonable estimate.

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There are several parameters which can be used to express the size of canopy foliage, such as LAI, LWR and LAR which give an idea about the magnitude of the leaf component of the canopy foliage. On the otherhand, LAD takes into account both the magnitude of leaf area and its persistence in time (Watson, 1947). In effect, it represents the leafiness of the crop's growing period. However, none of these parameters give an idea about the relative efficiency of leaf area in the canopy foliage in dry matter production. Although there are other parameters such as NAR, which indicates the relative efficiency of the canopy foliage as a whole, the very high dependence on external environment (Watson, 1947) limit its validity as a useful parameter, particularly for estimation of crop productivity.

The main objective of this study was to estimate the "effective leaf area" or the proportion of canopy leaf area which is effective in producing dry matter and use this parameter as an index to estimate the productivity of tea.

MATERIALS AND METHODS

Two experiments were conducted in a tea plantation at 30m *amsl* in the wet zone of Sri Lanka, using well grown plants of tea clone TRI 2023 in its third pruning cycle.

Experiment 1. Sixteen plots, each consisting 16 bushes were used. Detailed measurements on light distribution pattern within the canopy foliage was made in the plots using two large tube solarimeters ie. one for total radiation and one for infra red radiation (Sceiez *et al*, 1964 and Sceiez, 1965). The difference between these two measurements give the amount of photosynthetically active radiation (PAR). Based on the light distribution pattern within the canopy foliage, leaves were removed at different layers *viz.* plucking surface to 5cm below the plucking surface, 5 – 15cm, 15 – 25cm and 25cm to ground level to assess the leaf area and leaf dry weight.

Experiment 2. A Plot of 150 bushes in close proximity to experiment 1 was selected. Immediately after plucking, 100 well exposed mother leaves were labelled. Approximately, two leaves per plant in the center region were labelled and for easy identification, a stick was placed just adjacent to each mother leaf. When the new shoot emerged from the axillary bud and developed into pluckable size, shoot consisting two leaves and a bud was removed leaving a well developed mother leaf. This procedure was continued for a period of 42 weeks. At the end of this period, the rate of transpiration and the diffusive resistance of stomata was measured using a steady state porometer. Then shoots were detached while keeping the cut ends in water to measure the leaf area and leaf dry weight and the rate of net photosynthesis (NPR) using a laboratory system especially developed for tea (Wadasinghe, 1988).

RESULTS AND DISCUSSION

The top most 5cm layer of the canopy intercepts about 38% of PAR and this was as much as 86% within first 15cm layer. The leaves below 25cm from the plucking surface receive less than 2% of the PAR. This pattern of light distribution in cultivated tea is generally in agreement with Hadfield's (1964), measurement of light within a stand of mature tea using Megatron photocell.

The distribution and characteristics of maintenance leaves at different depths of the canopy are given in Table 1. Both leaf area and leaf dry weight within first 5cm layer was low compared to its leaf number, in which most of it was eventually removed by plucking. The leaf area in the next 10cm layer (between 5 - 15cm) amounted to 23% of the total leaf area. Therefore, about 48% of the leaf area, which is within the first 15cm layer traps about 86% of PAR. The next 10cm layer consists of about 14% of the total leaf area, which interferes about 12% of PAR. However, about 38% of the leaf area, which is in between 25cm from plucking surface and ground level receive less than 2% of PAR.

Leaf area of individual leaf gradually increased with depth of canopy, but leaf dry weight of the lower most layer was about 23% less than the 10cm layer just above it (Table 1). This may suggest that the lower most leaves consume some of the stored materials in the leaves in situ for its maintenance as these leaves are almost completely shaded and they never import any carbohydrate food from upper leaves even under starved condition (Manivel and Hussain, 1982).

The life span of maintenance leaves of tea varied from 24 weeks to more than 42 weeks. While 6% of the leaves dropped at 30 weeks of age. 54% of the leaves senesced and dropped when the age of leaves were about 36 weeks and about 24% of leaves remained intact even after 42 weeks.

Table 1. Characteristics of maintenance leaves within different layers of the canopy

Canopy depth from plucking surface cm	Total leaf area dm^2	Leaf area per leaf dm^2	Leaf dry weight per g
0 - 5	104 (25)*	0.15	0.12
5 - 15	99 (23)	0.16	0.17
15 - 25	60 (14)	0.24	0.25
25 - g.l.	161 (38)	0.31	0.20
Total	424		

* Percentage values over total are given in parentheses.
** g.l. - ground level

The rate of transpiration decreased with increase in leaf age (Figure 1). The highest rate of transpiration was observed in leaves 12 weeks old, then it declined slowly upto about 24th week and rapidly thereafter. The rate of transpiration was 5mg cm^{-2} sec^{-1} when the leaves were about 12 weeks old. Diffusive resistance of stomata followed an opposite trend, giving lowest resistance when leaves were about 12 weeks old.

The rate of net photosynthesis (NPR) also showed a similar trend (Figure 1). Mother leaf was at its maximum NPR at the time the new shoot is removed and NPR gradually declined with increase in leaf age. However, the decline was marginal upto about 24th week.

Considering the rate of transpiration, diffusive resistance of stomata, NPR and senescence of maintenance leaves, it is evident that tea leaves play an active role as a source of dry matter producer till about 24 weeks old. Majority of leaves below 25cm from the plucking surface are presumably more than 24 weeks old and further, they are heavily shaded

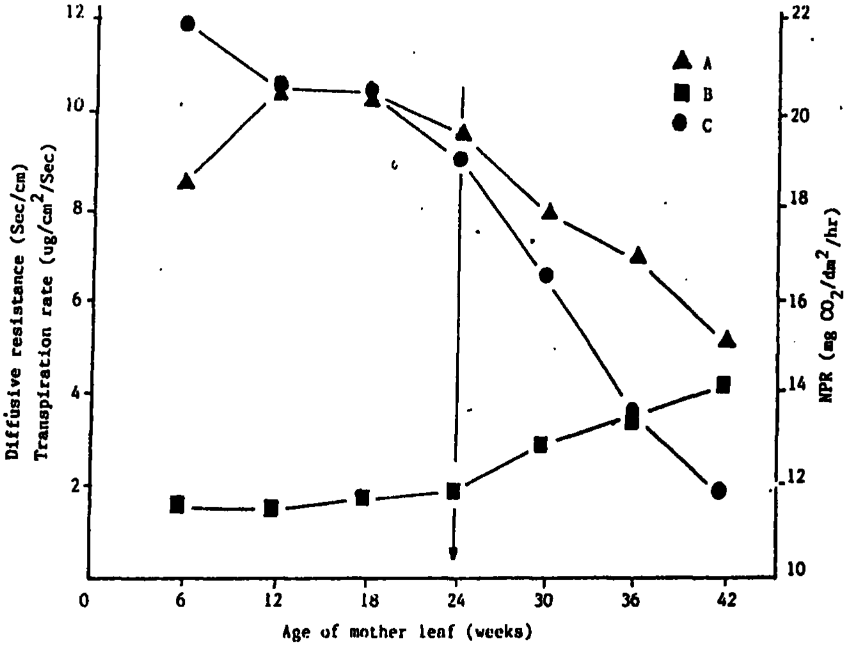

Fig.1. Transpiration rate (A), Diffusive resistance of stomata (B) and Rate of net photosynthesis -NPR- (C) at different ages of mother leaves.

by leaves above. Therefore, these leaves are very inefficient, at least in respect to dry matter production. This is in agreement with Pethiyagoda (1965) and De Silva and Waidyanatha (1966), who suggested that lower most leaves of the canopy may not be very important for contributing to harvest yield.

Using some of the information obtained from the two experiments described here, the effective leaf area and crop productivity was estimated based on the following assumptions.

a) The average NPR of canopy leaves is 20mg CO_2 dm^{-2} h^{-1}.
b) Average of 4 hours of photosynthetic activities per day.
c) There is no limitation of soil moisture and plant nutrients.

Table 2. Estimation of effective leaf area

Canopy depth from plucking surface cm	Leaf area dm^2	Percentage of leaf area exposed to light	Effective leaf area dm^2
0 - 5	104.05	100	104.05
5 - 15	98.69	62	61.19
15 - 25	59.96	14	8.39
25 - g.l.	160.96	2	3.22
Total	423.66		176.85

* g.l. - ground level

Only 41.17% of the total leaf area can be considered as effective in dry matter production. Therefore, total dry matter production = 176.85xaxb mg ha^{-1} $plant^{-1}$. (where a = average NPR and b = 30/44, conversion factor for mg CO_2 into mg carbohydrate.)

Assuming 13,000 plants per hectare of tea the total dry matter production will be equal 45771 kg $ha^{-1}yr^{-1}$.

If harvest index is 10% (Tanton, 1977) and ash content of plucked shoots is 5% (Eden, 1976), the economic yield is 4805 kg ha^{-1} $year^{-1}$ of made tea, which can be considered as a realistic estimate for a good stand of well managed high yielding clone like TRI 2023 under low elevation growing conditions.

The effective leaf area, which is a very useful index to estimate the crop productivity could be estimated by studying the leaf and light distribution pattern within the canopy foliage and NPR of canopy leaves. It has been shown that changing the natural growth habit of tea plant to a form of bush, the productivity of tea has been significantly reduced (Wadasinghe, 1988). This may be a result of reduced effective leaf area due to very dense canopy formed by changing the growth habit of tea plant from a tree type to a bush form. Therefore, the productivity of cultivated tea plant may be greatly improved by changing the growth habit in such a way it will allow more light penetration into the canopy, which will improve the effective leaf area.

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