Impact of different shades and light intensities on physiological changes in tea plant

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Introduction

The tea plant (*Camellia sinensis* L.) is grown in more than 52 countries in the tropical and subtropical regions of the world and is considered a significant source of revenue. It is a shade-loving plant that had originated in the forest under-story and it is usually grown as a mono-crop under shade trees throughout its lifetime [1]. There are a lot of positive effects of having shade trees in tea fields, including protecting tea plants from high temperature, direct solar radiation and acting as a wind barrier [2]. Varying responses in terms of productivity under different shade conditions have been reported in several studies [3, 4], leading to a controversy over the need for suitable shade management in tea plantations. However, the photosynthetic characterization of tea leaves under different shade levels with different light intensities is not well understood, although it has been studied in other tropical trees such as *Theobroma cacao* [5]. Hence, to enhance photosynthesis with different light intensities and shade levels, knowledge of the physiological parameters of tea leaves is important to identify superior traits that could be incorporated in developing proper shade management strategies. Therefore, the objectives of this study were to examine the photosynthetic behaviour and some related physiological parameters of mature tea bushes under different levels of shade with different light intensities.

Methodology

The experiment was conducted at Thalgaswella Estate, Galle, Sri Lanka (Low Country, 6^{o} 15' N, 80^{o} 16$^{'}$ E and 40 amsl). Two newly identified high shade tree species namely, *Derris microphylla* and *Cassia siamea* and the recommended high shade tree species *Albizia moluccana* were planted with the spacing of 6 m × 6 m in the three different plots having young tea plants, cultivar TRI 2026. The treatments were arranged in Randomized Complete Block Design (RCBD), each plot having 4 shade trees and approximately 25 tea bushes. The spacing of tea plants was 1.2 m × 0.6 m. Both three high shade species and tea plants were planted during September 2019. In each plot, 5 leaves were plucked from each randomly selected 5 bushes and the rate of photosynthesis (A_n), stomatal conductance (g_s) and transpiration rate (E) were measured using a portable photosynthesis meter (CIRAS-3, IRGA). Measurements were carried out initially under actual light intensity that prevailed under different shade tree species and subsequently under saturating light intensity (1200 $\mu molm^{-2}s^{-1}$) by providing artificial light. Instantaneous water use efficiency (WUE) was calculated as the ratio between net photosynthetic rate and transpiration rate.

Results and Discussion

Variations in different physiological parameters measured under different shades under natural light intensity are shown in table 1. The rate of photosynthesis was significantly different between different shade treatments. The highest value was observed in *D. microphylla* shade treatment (11.75 $\mu molCO_2m^{-2}s^{-1}$) while, the lowest was observed in *C. siamea* (6.24 $\mu molCO_2m^{-2}s^{-1}$). Moreover, stomatal conductance, transpiration rate and photosynthetic water use efficiency were reported significantly different among shade treatments under natural light intensity. The highest values for all these three physiological parameters were obtained in tea leaves grown under *D. microphylla* shade under natural light

conditions. The values were 288.27 $mmolH_2Om^{-2}s^{-1}$ (g_s), 5.88 $mmolH_2Om^{-2}s^{-1}$ (E) and 2.60 Kg/m^3 (WUE) respectively. On the other hand, the stomatal conductance was lower in *A. moluccana* shade treatment (202.86 $mmolH_2Om^{-2}s^{-1}$) and the photosynthetic water use efficiency was lower in *C. siamea* shade treatment (1.42 Kg/m^3).

Table 1. Variations in different physiological parameters of tea plants grown under different shade tree species under natural light conditions.

Species	A_n ($\mu molCO_2m^{-2}s^{-1}$)	g_s ($mmolH_2Om^{-2}s^{-1}$)	E ($mmol\ H_2Om^{-2}s^{-1}$)	WUE (Kg/m^3)
Derris microphylla	11.75 ± 0.69^a	288.27 ± 5.12^a	5.88 ± 0.03^a	2.06 ± 0.01^a
Cassia siamea	6.24 ± 0.69^c	225.06 ± 4.75^b	4.84 ± 0.02^b	1.42 ± 0.03^b
Albizia moluccana	9.12 ± 0.88^b	202.86 ± 4.77^b	5.21 ± 0.03^b	1.86 ± 0.02^a
Pr	<0.0001	0.0004	0.0059	0.0002

The values are represented as means ± standard error (n=5). Means having the same letter as superscript in a row are not significantly different at $\alpha = 0.05$, $\mathbf{A_n}$ Rate of Photosynthesis ($\mu molCO_2\ m^{-2}\ s^{-1}$), $\mathbf{g_s}$ Stomatal conductance ($mmolH_2Om^{-2}s^{-1}$), **E** Transpiration rate ($mmolH_2Om^{-2}s^{-1}$), **WUE** Photosynthetic water use efficiency (Kg/m^3).

Table 2. Physiological parameters of tea plants grown under different shade tree species under saturating light (1200 $\mu molm^{-2}s^{-1}$).

Species	A_n ($\mu molCO_2m^{-2}s^{-1}$)	g_s ($mmolH_2Om^{-2}s^{-1}$)	E ($mmol\ H_2Om^{-2}s^{-1}$)	WUE (Kg/m^3)
Derris microphylla	15.69 ± 0.09^a	284.76 ± 5.96^{ab}	5.72 ± 0.07^a	2.75 ± 0.03^{ab}
Cassia siamea	12.90 ± 0.08^b	260.32 ± 4.15^b	5.12 ± 0.06^a	2.56 ± 0.05^b
Albizia moluccana	15.45 ± 0.07^a	308.67 ± 3.81^a	5.45 ± 0.08^a	2.87 ± 0.04^a
Pr	0.0009	0.0003	0.1527	0.0353

The values are represented as means ± standard error (n=5). Means having the same letter as superscript in a row are not significantly different at $\alpha = 0.05$, $\mathbf{A_n}$ Rate of Photosynthesis ($\mu molCO_2\ m^{-2}\ s^{-1}$), $\mathbf{g_s}$ Stomatal conductance ($mmolH_2Om^{-2}s^{-1}$), **E** Transpiration rate ($mmolH_2Om^{-2}s^{-1}$), **WUE** Photosynthetic water use efficiency (Kg/m^3).

Table 2 shows the different physiological parameters of tea plants measured under different shade tree species under saturated light conditions. Significant differences were observed in the rate of photosynthesis, stomatal conductance and photosynthetic water use efficiency. In contrast, the transpiration rate of tea leaves did not show significant variations among treatments. The highest photosynthesis rate was observed in tea leaves grown under *D. microphylla* shade treatment (15.69 $\mu molCO_2m^{-2}s^{-1}$) and *A. moluccana* shade treatment (15.45 $\mu molCO_2m^{-2}s^{-1}$), while the lowest was recorded under *C. siamea* shade (12.90 $\mu molCO_2m^{-2}s^{-1}$). Comparatively, tea plants grown under *A. moluccana* had the highest stomatal conductance (308.67 $mmolH_2Om^{-2}s^{-1}$) and photosynthetic water use efficiency (2.87 Kg/m^3) while, *C. siamea* treatment denoted the lowest values; 260.32 $mmolH_2Om^{-2}s^{-1}$ and 2.56 Kg/m^3, respectively.

Conclusion

The study revealed that photosynthesis rate, stomatal conductance, transpiration rate and photosynthetic water use efficiency were significantly different among different shade tree treatments under natural light conditions whereas, photosynthesis rate, stomatal conductance and photosynthetic water use efficiency significantly varied under saturating light. Tea plants grown under *D. microphylla* shade trees showed better performances in terms of their physiological parameters tested in this study under natural light conditions while under saturating light, the recommended *A. moluccana* shade denoted improved values. Moreover, saturating light conditions had a positive impact on physiological changes in tea plants grown at Thalgaswella Estate, Galle, Sri Lanka than the natural light conditions.

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