Available online at www.elixirpublishers.com (Elixir International Journal)

Environment and Forestry

ISSN: 2229-712X

Elixir Environment and Forestry 178 (2023) 56908 - 56915

Growth, Chlorophyll and Carotenoids Contents of Tea (*Camellia sinensis* (L) O. Kuntze) Under Varied Light Intensity in Southwest Nigeria

Adeosun S.A.[1], Togun A.O.[2] and Adejumo S.A.[2]

[1] Department of Agronomy and Soils, Cocoa Research Institute of Nigeria, P.M.B 5244, Ibadan, Nigeria

[2] Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria

ARTICLE INFO

Article history:

Received: 14 October 2022;

Received in revised form: 2 May 2023;

Accepted: 25 May 2023;

Keywords

Tea Cultivars,
Light Intensity,
Vegetative Growth,
Chlorophyll,
Carotenoids,
Leaf Abscission.

ABSTRACT

The nutritive and anti-oxidative properties of tea have made it the most widely consumed beverage in many parts of the world. Warm climatic conditions arising from high light intensity however, constitutes a major constraint to tea cultivation in South-Western Nigeria. Reduction in the Light Intensity (LI) is therefore, fundamental to the possible expansion of tea production in this zone. A pot experiment was carried out to evaluate the effect of different light intensities on growth, leaf chlorophyll and carotenoids contents of two tea cultivars at two locations (Ibadan and Owena). The experiment was a factorial of eight treatments; Two tea cultivars (143 and 318), Four levels of light intensity- (25%=2.40x10^{4}lux, 45%=4.57x10^{4}lux, 65%=6.75x10^{4}lux and 100%=1.04x10^{5}lux: control). These were achieved by using sheds of 4, 2, 1 and 0 palm fronds layers, respectively. The experiment was laid out in completely randomized design with four replications. Data were collected on Number of Leaves (NL), Leaf Area (LA, cm^2), Plant Height (PH, cm), leaf abscission as well as chlorophyll and carotenoids contents (mg/g). The data were analyzed using descriptive statistics and ANOVA at $\alpha_{0.05}$. The result revealed that Cultivar 143 performed significantly better than 318 with 25.23±9.74NL, 665.93±297.54LA in Ibadan and 25.38±9.82NL, 898.23±670.34LA in Owena. Tea plants under 45 and 65% LI had higher NL, LA and PH compared to those grown under 25 and 100% LI in Ibadan and Owena. Highest leaf abscission (15.44±3.89 and 23.13±7.22 dropped leaves in Ibadan and Owena, respectively) was obtained in C143 under 100% LI; while the least (6.84±3.89 and 4.78±7.22 dropped leaves in Ibadan and Owena, respectively) was obtained in C318 under 45% LI. In Ibadan, chlorophyll and carotenoids increased from 1.11±0.83 and 0.30±0.15, respectively in C318 under 100% LI to 3.15±0.83 in C143 under 25% LI and 0.6±0.15 in C318 under 45% LI; while in Owena, chlorophyll and carotenoids increased from 1.05±0.87 and 0.29±0.30, respectively in C143 under 100% LI to 2.97±0.87 and 0.83±0.30 in C318 under 25% LI. Conclusively, light intensities of 45% (4.57x10^{4}lux) - 65% (6.75x10^{4}lux) enhanced optimal vegetative growth, reduced leaf abscission, increased chlorophyll and carotenoids accumulation of tea cultivar 143 which was more adaptable to Ibadan and Owena, Southwest Nigeria.

Introduction

Tea (*Camellia sinensis* (L) O. Kuntze) is one of the most important beverage crops in the world. Its beverage is highly reputed for its antioxidant properties when consumed. It has strong tap root, thick stem, thick dark green leaves with white flowers. Tea production is the economic mainstay of some countries like China, India, Kenya and Tanzania. China is rated as the world largest producer of tea with 1,467,467 metric tonnes in 2010 and 2,620,000 metric tonnes in 2018; while Kenya stood as the Africa largest and the world third largest producer of tea with 399,000 metric tonnes in 2010 and 432,400 metric tonnes in 2018 (FAOSTAT, 2010; Shahbandeh, 2020). Tea production in Nigeria is still at marginal level since it is confined to Mambilla highlands because of the cool weather. Meanwhile, in this area, land for tea production is limited by other agricultural practices and infrastructural demand. This has necessitated the need for the expansion of tea production to southern parts of the country. However, the high temperature occasioned by excessive light intensity especially during dry season is one of the most limiting abiotic factors of tea production in South-Western Nigeria.

Light is an absolute requirement for plant growth. It is the most imperative among all other ecological factors (Ghasemzadeh and Ghasemzadeh, 2011) serving as a source of energy for plant life (Sysoever *et al.*, 2010). Tea plant has been shown to be a light sensitive plant. Light influences many physiological processes in tea as in all green plants (Graham, 1998). Photosynthesis, respiration, transpiration, and translocation of photoassimilate, as well as development are some of the important physiological processes in *Camellia sinensis* affected by light intensity (Jannedra *et al.*, 2007; Too *et al.*, 2015). Meanwhile, tea yield potential is fully expressed under reduced light intensity or optimum temperature. Being a C3 plant, tea undergoes photorespiration and photoinhibition under excessive light intensity (Mohott

Tele:
E-mail address: seunfunmi1999@gmail.com

and Lawlor, 2002). Photoinhibition is a process whereby photosynthetic rate is reduced or completely hampered under excessive light intensity. Photoinhibition is initiated by excessive irradiation which causes stomata closure. Light intensity exerts direct and indirect effect on guard cells that control the opening and closing of stomata. According to Jannedra *et al.* (2007), stomata conductance is affected by light intensity as its opening is sensitive to several stimuli from external environment like light intensity, water availability, leaf temperature and Vapour Pressure Deficit (VPD). Apart from its effect on photosynthesis, light intensity also influences synthesis of photosynthetic pigments especially chlorophyll and carotenoids and other biochemical compound in tea. Wang *et al.* (2013) submitted that excessive sunlight resulted in low levels of chlorophyll and carotenoids in albino tea plant. Too *et al.* (2015) also found out that harvesting of tea when light was low enhanced high amount of theanin in tea leaves. There is dearth of information on the effect of light intensity on the growth performance and biochemical synthesis in tea in South-western Nigeria.

There are two main varieties of tea plant, namely, *Camellia sinensis var. sinensis* (also known as China variety) and *Camellia sinensis var. assamica.* (Assamica variety) (Bonheuer, 1991). In 1982, Cocoa Research Institute of Nigeria (CRIN) acquired 33 clones for commercial production among which five high yielding ones (35, 68, 143, 236 and 318) were identified, selected and released to farmers as commercial cultivars (Oloyede *et al*., 2014; Oloyede *et al*., 2017). Among the five clones, 143 and 318 have been successfully adapted to lowland ecologies of Nigeria. The C143 is highly branching with light green, shorter and broader leaves while C318 is less branching with highly pigmented, dark green and narrower leaves. Therefore, this trial was aimed at investigating the growth, chlorophyll and carotenoids contents of these mostly cultivated and lowland adapted tea cultivars, 143 and 318 under varied light intensity in Ibadan and Owena, Southwest Nigeria.

Materials and Methods

This pot experiment was conducted in Cocoa Research Institute of Nigeria (CRIN) stations, Ibadan and Owena, Southwest Nigeria. Ibadan is located on Latitude 07º 10'N, Longitude 03º 52'E Southwest Nigeria. Ibadan is characterized by two distinct seasons: rainy and dry seasons. The rainy season runs from March to October and is characterized by heavy rains, humid atmosphere and cloudy sky. The dry season runs from November to March and is characterized by little or no rainfall with hot and scotching sun. Part of the dry season is characterized by cold and dry harmattan wind. In Ibadan, annual rainfall ranges between 1100 and 1150 mm, average maximum and minimum temperature are 27.0 °C and 19.8 ºC, respectively; while relative humidity varies from 89% during raining season to 57% during dry season (CRIN Weather reports, 2012). Owena is located in Idanre LGA of Ondo State on Latitude 07º N and longitude 05º 7'E in the humid tropical rain forest zone of Nigeria and is characterized by two seasons, the rainy and dry seasons. The rainy season is characterized by heavy rainfall, humid atmosphere and cloudy sky. It runs from early March to late November. The annual rainfall is 1340-1804 mm. The dry season which is characterized by scanty rainfall, dry atmosphere and intense sun heat, runs from late November to early March. Relative humidity varies from 89% during raining season to 76% during dry season. The average maximum and minimum temperature are 29.9 ℃ and 20.7 ℃, respectively (OSAR, 2012).

The experiment was a 2 x 4 factorial comprising two tea cultivars (C143 and C318) raised in pots under four levels of light intensities [25% (2.40×10^4lux), 45% (4.57×10^4lux), 65% (6.75×10^4lux) and 100% light (1.04×10^5lux)] and laid out in completely randomized design with four replications.

Construction of sheds and determination of light intensities

Bamboo sheds of different layers of palm fronds were used to reduce light intensities to 65%, 45% and 25%. Three rectangular sheds of 10 m length, 2 m width and 2 m height made of bamboo and palm fronds were constructed. The top and sides of the sheds were covered with different layers of palm fronds depending on the light intensity. The light intensities were determined with the aid of Lux meter (LX1010BS model). The light intensities were measured three times per day (at 8.00 am, 12 noon and 4.00 pm) for seven days and the light intensity value for each shed was calculated by finding the means of the seven days readings. The percentage light intensity was determined by comparing the light intensity value inside the shed with the light intensity value in the open space using the equation below:

$$\%Light\ Intensity = \frac{Light\ Intensity\ inside\ the\ shed}{Light\ intensity\ in\ the\ open} \times 100$$

Pot filling and transplanting of tea cuttings

Top soil was collected from the forest land of CRIN Ibadan. The soil was allowed to dry and was sieved with 2 mm soil sieve. Plastic pots of 5-litre capacity were filled with 5 kg of the sieved soil. The plastic pots were perforated at the base to allow drainage of excess water from the soil.

Germinated tea stem cuttings were transplanted into the soil-filled pots at 6 - 8 leaves stage. The soil was watered to field capacity. The transplanted tea cuttings were later set in the already constructed light sheds.

Data collection

As from two Months After Transplanting (MAT), the following morphological parameters were measured on each plant per treatment on monthly basis: Number of leaves, leaf area, number of branches, plant height, stem diameter and number of dropped leaves (number of leaf abscission scars). Number of leaves, number of branches and number of dropped leaves were determined by visual count; plant height (cm) and stem diameter (cm) by meter rule and digital venier calipers, respectively. Plant height was measured from the soil surface to the terminal bud of the plants. Stem diameter was measured at the 4 cm height of the stem. Leaf area (cm^2) was determined by measuring the length and width of the 5^{th} and 6^{th} leaves from the apex of each plant. The area of the leaves (Length x Width) was multiplied by a predetermined Leaf Area factor of 0.61 giving the actual leaf area of each leaf. The leaf area of each leaf was multiplied by the number of leaves per plant to give leaf area per plant.

Determination of chlorophyll and carotenoids contents in tea leaves

The tea plants in the plastic pots were uprooted at 8 MAT. The soil in the plastic pots was poured out and the pots were refilled with the same soil. One stand of pre-germinated tea cuttings (143 and 318 cultivars) was planted into each of the plastic pots and were arranged in the same light sheds for the laboratory assay of the tea leaves for chlorophyll and carotenoids contents. At 6 MAT, fresh but matured leaves were randomly plucked from the tea plants in each treatment and replication. The leaves were assayed for chlorophyll and carotenoids content at the Soil and Plant Nutrition Laboratory of CRIN Ibadan. Tea leaf sample (1g) was weighed into 15 mL ethanol (96%) filled centrifuge tubes. The content of the centrifuge tube was heated in water bath at 78.4 ºC for 3 hours in order to extract the chlorophyll and carotenoids pigments in the leaf. The solution was allowed to cool and was read on Spectrophotometer, SPECTRUM LAB 752s: carotenoids at 440 mm wavelength; chlorophyll a and b at 665 nm and 649 nm wavelengths, respectively. The total chlorophyll and carotenoids in mg/g leaf fresh weight were determined using the Wintermans and Mots (1965) equations below:

Chlorophyll (a+b) = $(6.10 \times A_{665} + 20.04 \times A_{649}) \times 15/1000/FW$ (mg/g fw)

Where:

6.10, 20.04 = Constants; A_{665} = Absorbance coefficient 665 nm for reading chlorophyll a; A_{649} = Absorbance coefficient 665 nm for reading chlorophyll b; 15/1000 = Volume of supernatant; FW = Fresh weight of the leaf

Carotenoids = $4.69 \times A_{440} - 1.96 \times A_{665} - 4.74 \times A_{649} \times 10 \times 15/1000/ FW$ (mg/g fw)

Where:

4.49, 1.96, 4.74 = constants; A_{649}= Absorbance coefficient 440 nm for reading carotenoids; 10 = dilution factor; 15/1000 = Volume of supernatant; FW = Fresh weight of the leaf

Data analysis

All data collected were subjected to analysis of variance (ANOVA) using STAR (Statistical Tools for Agricultural Research) (2013) software. The significant means were separated with Tukey's Honest Significant Difference (HSD) Test (P=0.05).

Results and Discussion

The cultivars differed significantly (P=0.05) in their growth parameters both at Ibadan and Owena (Table 1; Figure 1). The 25.23 leaves and 5.02 branches of C143 were significantly higher than 19.99 leaves and 4.38 branches of C318 at Ibadan. In the same vein, 25.38 leaves and 898.23 leaf area of C143 were significantly higher than 20.74 leaves and 669.28 leaf area of C318 at Owena. Similarly, C143 was better than C318 in plant height and stem diameter, although the difference was not significant (P>0.05). The superior genetic and morphological characteristics of C143 as well as its ability to thrive under harsh tropical climate might be attributed to its better vegetative growth. It has been previously adjudged as high yielding, drought tolerant, more adaptable to the lowland and more vigorous in growth than C318 (CRIN, 1985; Omolaja and Iremiren, 2012).

Light intensities were significantly (P=0.05) different in enhancing vegetative growth of tea (Table 1; Figure 2). At Ibadan, 65% light increased number of leaves by 5.00, 26.12 and 35.90% compared to 45%, 25% and 100% light, respectively; number of branches by 6.64, 14.72 and 35.00%, and leaf area by 8.96, 31.48 and 5287.89%. Similarly, in Owena, 65% light increased number of leaves by 11.59, 12.75 and 2214.89% compared to 45%, 25% and 100% light, respectively; number of branches by 27.18, 25.66 and 130.00%, and leaf area by 21.91, 37.13 and 15212.23%. The 45 and 65% light intensities produced significantly (P=0.05) taller and thicker tea stems especially from 6 – 8 MAT. The variations observed in the performance of tea in response to varying light intensities shows that as important as light is to the growth and development of plant, there is a tolerable/optimum level for each species of plant. Low and high light intensities reduced the crop performance due to inactivation or disruption of the essential metabolic processes in plants. Stress resulting from different environmental factors generally has been reported to trigger production of Reactive Oxygen Species (ROS). A variety of ROS, including H_2O_2, superoxide, singlet oxygen, and the hydroxyl radical, are generated during stresses caused by environmental factors like UV, chilling, high light intensity, salt and pathogen attack. The cultivars however, responded differently under each light intensity and the performance was also based on location (Table 1). The highest number of leaves, number of branches, plant height and leaf area were observed in C143 under 65% light in Ibadan and Owena; while 100% light reduced these growth parameters to the lowest levels in both cultivars, and 318 produced the least number of leaves, number of branches, leaf area, plant height and stem diameter under this light intensity in Ibadan; while, 143 produced the least values of number of leaves, number of branches and plant height under the same light intensity in Owena. This underscores the beneficial effects of reduced light intensities on tea growth which could be as a result of moderate light quantum incident on the plants occasioned by the imposed artificial shade.

The subdued light must have precipitated optimal condition for photosynthesis by regulating leaf and canopy temperature (Jannedra *et al.*, 2007). The unhindered photosynthesis led to the expanded leaf area which enhanced the growth of other plant parts. This corroborates the findings of Hajiboland *et al*. (2011) and Wijeratne *et al.* (2008) who had previously reported enhanced growth of tea under moderate light intensities. Besides, enhanced seedling growth of coffee and increased leaf size of Sage (*Salvia officinalis* L.) were obtained under 50% light intensity (Famaye, 2002; Sadgheti *et al.,* 2018). Odeleye *et al.* (2001) also observed that soya beans plants grown under subdued light had more leaf area and grew taller as compared to plants grown in full day light.

Tea plants under 100% light intensity were consistently the poorest in all the growth parameters. This implies that very bright and scotching sun light significantly (P=0.05) reduced tea growth. This could be as a result of excessive evapo-transpiration which makes soil water less available for plant growth (Hopkin, 1995) and possible photo-inhibition that plant generally undergoes under high light intensities (Mohotti and Lawlor, 2002). Besides, the full light intensity also brought about lower water potential gradient between the soil and the plant root, leading to excessive water shortage in the plant i.e. higher Diffusion Pressure Deficit (DPD) as a result of higher Turgor pressure and lower Osmotic pressure culminating in cell wall plasmolysis, leaf wilting and abscission (Hopkin, 1995; Mohotti and Lawlor, 2002; Fatubarin, 2003).

Table 2 reveals that rate of leaf abscission varies significantly according to the different cultivars and light intensities. Cultivar 143 plants shed significantly more leaves than cultivar 318 plants in Ibadan and Owena. The 100% light caused highest leaf drop. The highest leaf drop of 12.20 and 18.80 in Ibadan and Owena, respectively, caused by 100% light were significantly higher than the least leaf drop of 7.66 and 5.33 caused by 45% light. This is probably because evapo-transpiration is higher under full light intensity. Stress induced leaf abscission might also be a kind of strategy to reduce water loss from transpiration under high light intensity and serve as tolerance mechanism (Taylor and Whitelaw, 2001; Sakamoto *et al*., 2008). Besides, high light intensity has been reported to reduce the endogenous concentration of IAA due to photodegradation (Michaeli *et al*., 2001). Depletion of IAA at the abscission zone (AZ) sensitizes the AZ to produce ethylene which results in activation of cellulase (cell wall degrading enzyme). Abscission then results from degradation of the cell wall substances surrounding cells in the AZ. Reactive Oxygen Species Production like H_2O_2 under abiotic stress has also been reported to trigger abscission in plant (Michaeli *et al*., 2001; Sakamoto *et al*., 2008). All these were confirmed in this study where, the 100% light increased leaf abscission by 49.51, 59.27 and 47.70% compared to 25%, 45% and 65% light intensities, respectively at Ibadan; and by 158.24, 252.72 and 241.82%, compared to 25%, 45% and 65% light, respectively at Owena. Besides, cultivar 143 under 100% light shed highest number of leaves in both locations; while cultivar 318 under 65% light at Ibadan and 45% light at Owena shed the least amount of leaves. Although, leaf drop was highest in C143 plants under 100% light; yet, they performed better than C318 plants under the high light intensity. The better growth performance of C143 in comparison with C318 under high light intensity corroborated CRIN (1983) that the former was more drought tolerant than the latter. The higher leaf abscission observed in C143 under high light intensity might probably be its drought tolerance and adaptability mechanism. Besides, it has smaller leaf size which reduce transpiration and excessive water loss via leaf surface especially, in dry season. This corroborates the submissions of Andrian *et al.* (2008) that closure of the stomata, wilting or rolling of leaves which result in reduction of water loss from plant increase their ability to survive drought condition.

It is apparent in Table 3 that the effects of different cultivars, locations and light intensities differ significantly (P=0.05) with regards to chlorophyll and carotenoids synthesis and accumulation in tea plants. Cultivar 318 was superior to 143 significantly (P=0.05) in terms of leaf chlorophyll content in Ibadan and Owena and also had more carotenoids at Owena; while C143 was slightly better than C318 in leaf carotenoids content at Ibadan, but the difference was not significant (P>0.05). This is evident in the greener pigmentation observed in C318 tea plants. However, lowest light intensity of 25% was significantly superior to other light intensities in enhancing chlorophyll and carotenoids synthesis in tea plants in both locations probably because extremely strong light intensity has been reported to often decrease chlorophyll content in plant leaves**.** Although, low light intensity has been reported to reduce the number of chloroplast/unit leaf area, but the few but bigger chloroplasts in these leaves results in high chlorophyll content. The reduction in chlorophyll content under high light intensity has also been blamed on the inhibition of chloroplast formation (Fu *et al*., 2012). At Ibadan, 25%, 45% and 65% light increased chlorophyll of tea by 166, 68 and 58%, respectively in comparison with 100% light; while they increased carotenoids content by 73, 45 and 39%, respectively. Similarly, at Owena, 25%, 45% and 65% light intensities increased chlorophyll of tea by 147.01, 88.89 and 46.15%, respectively in comparison with 100% light; while they increased carotenoids content by 163.33, 103.33 and 33.33%, respectively. The accumulation of chlorophyll and carotenoids in tea plants was significantly undermined under 100% light intensities. This is consistent with the findings of Wang *et al.* (2013) who submitted that high sunlight resulted in low levels of chlorophyll and carotenoids in albino tea plant. Similarly, Zhang *et al*. (2014) and Oliveira *et al.* (2014) observed that chlorophyll synthesis was enhanced under low light intensity in field grown tea. According to Li *et al*. (2016), the decrease in light intensity resulted in increase in the contents of chlorophyll a (Chl a), chlorophyll b (Chl b) and total chlorophyll (Chl a + b). Moreover, the interaction of cultivars with light intensities was apparent as the highest chlorophyll content was recorded by the interactions of C143 with 25% light, and highest carotenoids by interaction of C318 with 45% light; while the least chlorophyll and carotenoids occurred in the interaction of C318 with 100% light at Ibadan. However, at Owena, highest chlorophyll and carotenoids were obtained in C318 under 25% light, and the least occurred in C143 under 100% light. Cultivars 143 and 318 were not significantly (P>0.05) different in chlorophyll content under extreme light intensities of 25% and 100%; but C318 was significantly (P=0.05) better under moderate light intensities of 45 and 65%. However, C143 was significantly better than C318 in carotenoids under 100% light only at Ibadan. The reported hardiness and drought tolerance characteristics of C143 (CRIN, 1985; Omolaja and Iremiren, 2012) explains its higher chlorophyll and carotenoids contents under extreme light intensity of 100%.

Conclusion

The growth, chlorophyll and carotenoids contents of tea plant were significantly influenced by its cultivars and variation in the light intensities of its environment. The magnitude of influence of light intensities on tea was affected by its cultivars as C143 survived high light intensity better than C318. All vegetative growth indices were enhanced under moderate light intensities of 45 – 65% as extreme light intensity of 100% grossly undermined the growth of tea. The chlorophyll and carotenoids increased with decrease in light intensities. Hence, 25% light enhanced highest chlorophyll and carotenoids contents. The extreme light intensity of 100% reduced chlorophyll and carotenoids composition of tea as reduced light intensity of 25 – 45% enhanced chlorophyll and carotenoids. Although C318 was superior to C143 in chlorophyll under reduced light intensity, its potential for chlorophyll and carotenoids accumulation was undermined under extreme light intensity of 100%. It follows that for tea to thrive in the Southwest Nigeria, it must be grown under 45 – 65% light, and that cultivar 143 is more adapted to the area.

Table 1. Effects of cultivars and light intensities on number of leaves, number of branches and leaf area of tea plants at 8 MAT

Treatments		Ibadan			Owena		
Cultivars		NL	NB	LA (cm^2)	NL	NB	LA (cm^2)
C143		25.23a	5.02a	665.93a	25.38a	0.66b	898.23a
C318		19.99b	4.38b	602.09a	20.74b	1.70a	669.28b
Mean		22.57	4.70	634.01	23.06	1.03	783.76
Light Intensities (%)							
25		27.11a	4.62ab	678.27b	28.95b	4.17b	894.44b
45		27.80a	4.97a	818.42ab	29.25ab	4.12b	1006.06b
65		29.19a	5.30a	891.77a	32.64a	5.24a	1226.51a
100		6.36b	3.92b	15.19c	1.41c	0.04c	8.01c
Mean		22.62	4.70	600.91	23.06	0.51	783.76
Light Intensities (%) x Cultivars							
25	C143	29.19a	4.72a	729.91a	31.28a	3.93b	609.67a
	C318	25.03a	4.53a	753.80a	26.63a	4.40a	560.01a
Mean		27.11	4.63	781.55	28.96	4.17	584.84
45	C143	31.41a	5.38a	898.67a	33.50a	4.56a	749.41a
	C318	24.19a	4.56a	738.18b	25.00a	3.98b	504/38b
Mean		27.80	4.97	818.43	29.25	4.27	749.41
65	C143	32.88a	5.56a	948.02a	36.19a	6.13a	815.85a
	C318	25.50a	5.03a	847.82a	29.09a	4.61b	693.75b
Mean		29.19	5.30	897.92	32.64	5.37	754.80
100	C143	7.47a	4.44a	87.14a	0.56a	0.01b	151.29a
	C318	5.25a	3.41a	68.57a	2.25a	0.20a	117.57a
Mean		6.39	3.93	77.86	1.41	0.11	137.43

Means followed by the same letters in a column under each treatment are not significantly different by HSD (P=0.05) NL = Number of leaves; NB = Number of branches; LA = Leaf area; C143 = Cultivar 143; C318 = Cultivar 318; MAT = Months after transplanting

Table 2. Effects of cultivars and light intensities on rate of leaf abscission in tea plants at 8 MAT

Treatments		**Number of dropped leaves**	
Cultivars		Ibadan	Owena
C143		10.55a	10.70a
C318		7.60b	7.75b
Mean		9.07	9.23
Light Intensities (%)			
25		8.16b	7.28b
45		7.66b	5.33c
65		8.26b	5.50c
100		12.20a	18.80a
Mean		9.07	9.23
Light Intensities (%) x Cultivars			
25	C143	9.00a	7.72a
	C318	7.33b	6.84a
Mean		8.17	7.28
45	C143	8.49a	5.88a
	C318	6.84b	4.78a
Mean		7.67	5.33
65	C143	9.27a	6.09a
	C318	7.26b	4.91a
Mean		8.27	5.50
100	C143	15.44a	23.13a
	C318	8.97b	14.47b
Mean		12.21	18.80

Means followed by the same letters along a column in each treatment are not significantly different by HSD (P=0.05)
MAT = Months After Transplanting

Table 3. Effects of cultivars and light intensities on chlorophyll and carotenoids (mg/g fresh weight) in the leaves of tea plants at 6 MAT

Treatments		Ibadan		Owena	
Cultivars		**Total chlorophyll (mg/g fw)**	**Carotenoids (mg/g fw)**	**Total chlorophyll (mg/g fw)**	**Carotenoids (mg/g fw)**
C143		2.00b	0.45a	1.81b	0.51b
C318		2.13a	0.44a	2.19a	0.54a
Mean		2.06	0.44	2.00	0.53
Light intensities (%)					
25		3.14a	0.57a	2.89a	0.79a
45		2.01b	0.48b	2.21b	0.61b
65		1.90b	0.46b	1.71c	0.40c
100		1.20c	0.33c	1.17d	0.30d
Mean		2.06	0.44	2.00	0.53
Light intensities (%) x Cultivars					
25	C143	3.15a	0.57a	2.41a	0.74a
	C318	3.14a	0.56a	2.97a	0.83a
Mean		3.15	0.57	2.69	0.79
45	C143	1.87b	0.46b	2.01b	0.60a
	C318	2.15a	0.6a	2.41a	0.62a
Mean		2.01	0.53	2.21	0.61
65	C143	1.70b	0.43b	1.35b	0.39a
	C318	2.11a	0.48a	2.08a	0.41a
Mean		1.91	0.46	1.72	0.4
100	C143	1.29a	0.36a	1.05a	0.29a
	C318	1.11a	0.30b	1.29a	0.31a
Mean		1.20	0.33	1.17	0.3

Means followed by the same letters in a column under each treatment are not significantly different by HSD (P=0.05); MAT = Months after transplanting

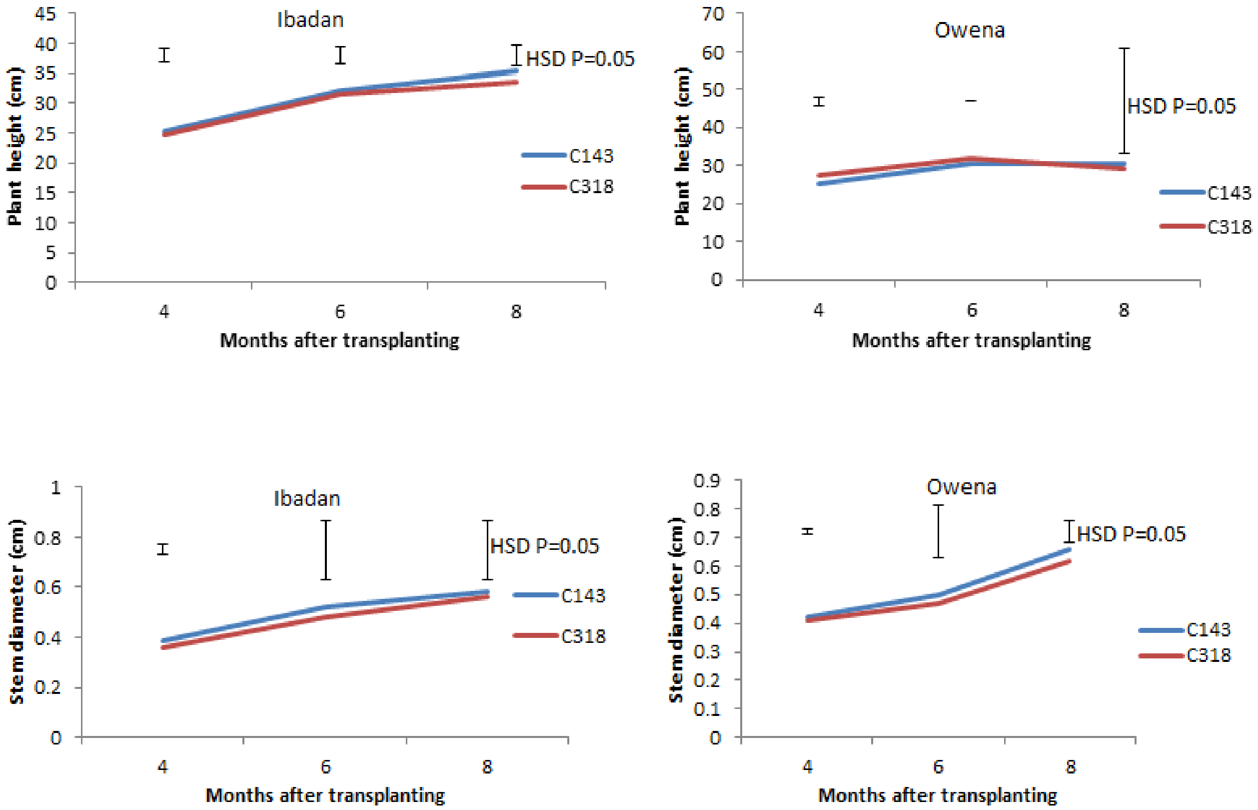

Figure 1. Main effect of cultivars on plant height and stem diameter of tea plants at Ibadan and Owena

MAT = Months after transplanting

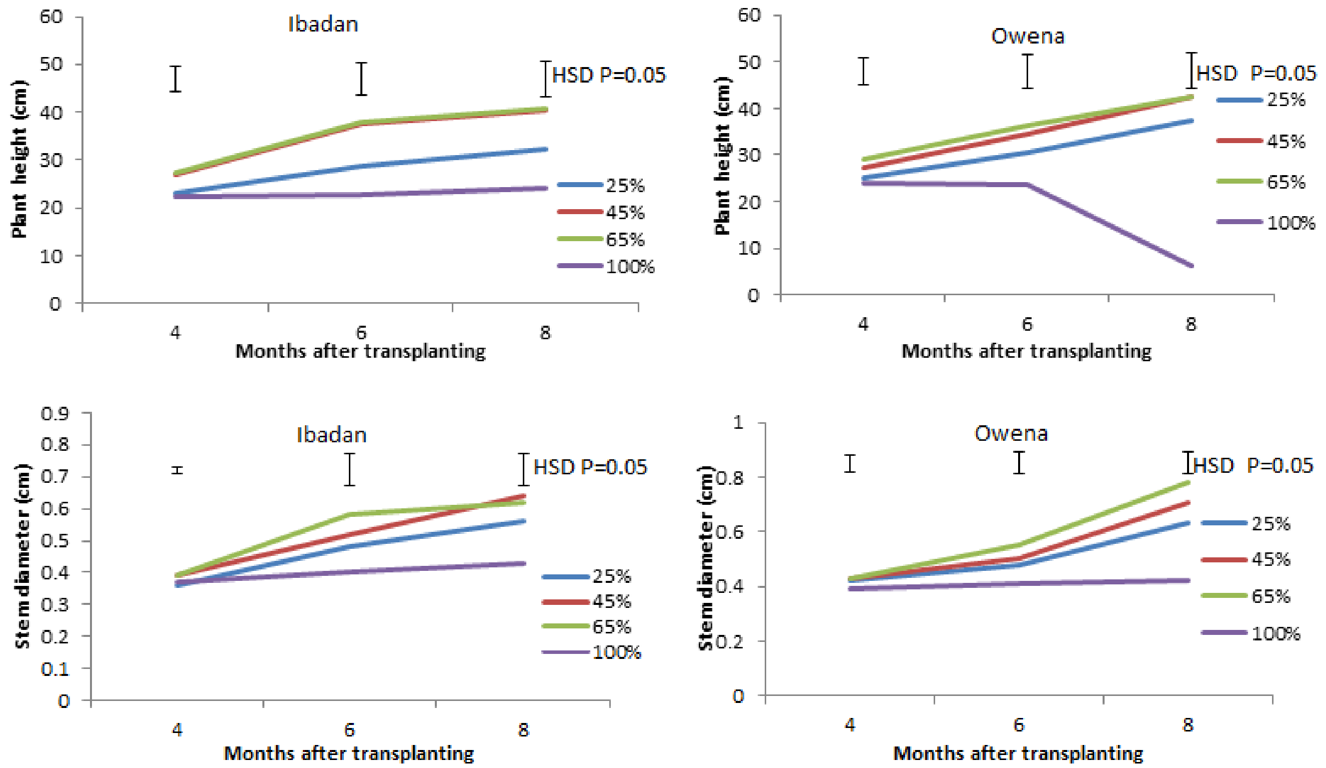

Figure 2. Main effect of light intensities on plant height and stem diameter of tea plants at Ibadan and Owena

MAT = Months after transplanting

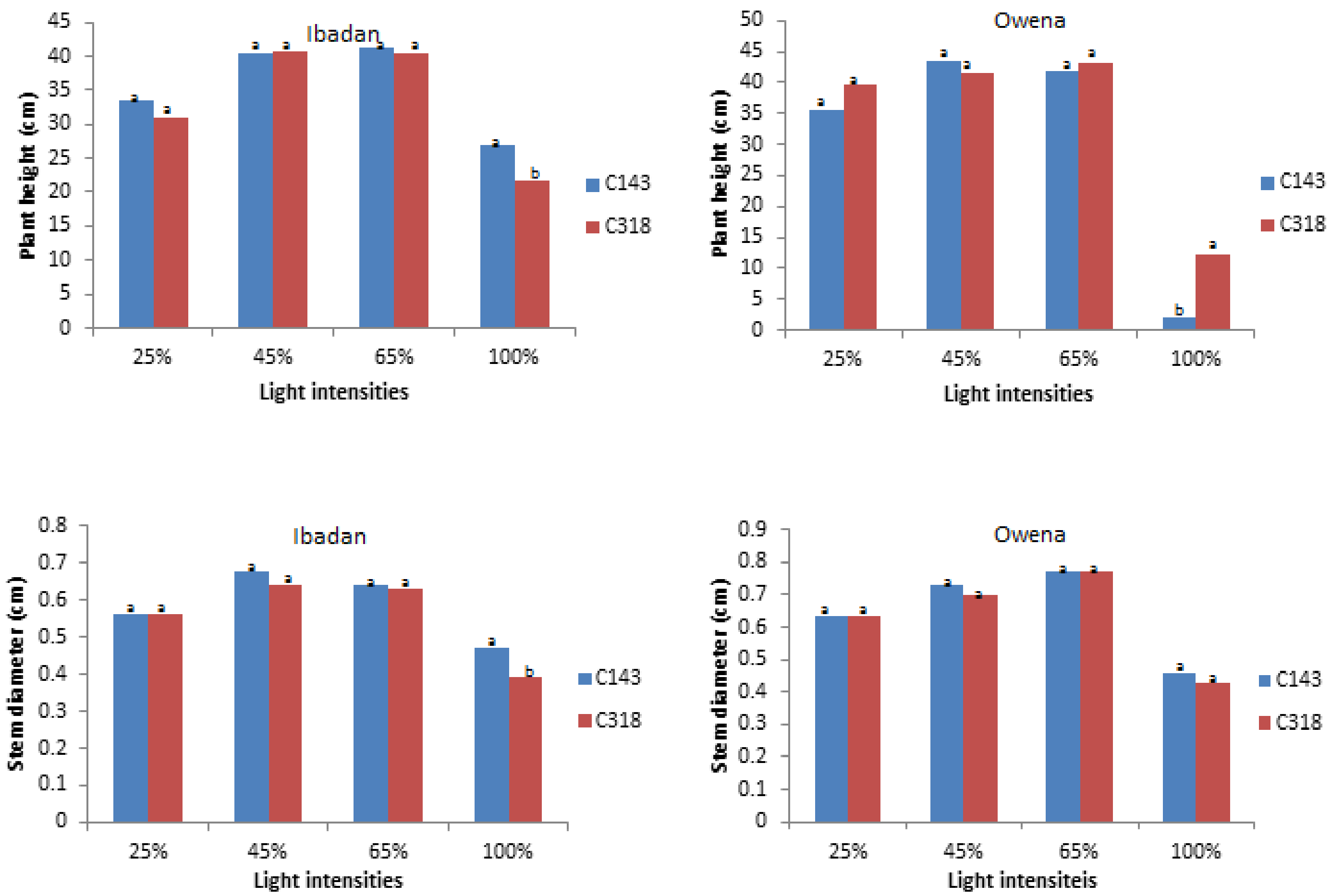

Figure 3. Plant height and stem diameter of tea cultivars under different light intensities at 8 MAT in Ibadan and Owena

Means followed by the same letters in each composite bars in each graph are not significantly different by HSD (P=0.05). MAT = Months after transplanting

References

Bonheure D. (1991).TEA.The Tropical Agriculturist. (Macmillan Ltd. 1991) Pp 1-54.

CRIN. (1983). Annual report of the Cocoa Research Institute of Nigeria (1983). Pp 47-56

CRIN. (1985). Annual report of the Cocoa Research Institute of Nigeria (1985) Pp 55-69

Cocoa Research Institute of Nigeria Weather reports, (2012) (Unpublished)

De Oliveira C. A., Oliveira W. C., Ribeiro, S. M. R., Stringheta P. C. and do Nascimento A. G. (2014). Effect of light intensity on the production of pigments in *Nostoc spp. European Journal of Biology and Medical Science Research.* Vol.2, No.1, pp.23-36

Famaye, A. O. (2002). Effect of shade regimes on growth of coffee species in Nigeria. *Moor Journal of Agricultural Research.* Vol. 3 No.2 2002 184-194

FAOSTAT (2010). Food and Agriculture of the United Nations-Production. P.1

Fatubarin A. (2003). Mineral nutrition in plants. *In: Plant Physiology.* Ilorin: Higher Education Hand Book Series, Nigeria. ISBN 978-36297-3-5.Pp 21-32.

Fu Weiguo, Li Pingping, Wu Yanyou (2012). Effects of different light intensities on chlorophyll fluorescence characteristics and yield in lettuce. *Scientia Horticulturae 135 (2012) 45–51*

Ghasemzadeh A. and Ghasemzadeh N. (2011). Effect of shading on synthesis and accumulation of polyphenolic compounds in ginger (*Zingiber officinale* Roscoe) varieties. *J. Med. Plant Res. 5:2435-2442*

Graham T. L. (1998). Flavonoid flavonol glycoside metabolism in Arabidopsis. *Plant Phys. Biochem. 36:135-144*

Hajiboland, R., Bastani S. and Rad S. B. (2011).Effect of light intensity on photosynthesis and antioxidant defense in boron deficient tea plants. *Acta Biologica Szegediensis. volume 55 (2):265-272.* http://www.sci.u-szeged.hu/ABS.

Hopkin, W. G. (1995): The Physiology of Plant under Stress. In: Introduction to Plant Physiology. Pp434-438

Janendra W. A., De Costa, M., Mohotti, A. J., Wijeratne M. A. (2007). Ecophysiology of Tea. *Braz. J. Plant Physiol. Vol. 19 no.4 pp.1-3*

Li, A.M., Li, S.H., Wu, X.J., Zhang, J., He, A.N., Zhao, G. and Yang, X. (2016) Effect of Light Intensity on Leaf Photosynthetic Characteristics and Accumulation of Flavonoids in Lithocarpus litseifolius (Hance) Chun. (Fagaceae). *Open Journal of Forestry, 6, 445-459. http://dx.doi.org/10.4236/ojf.2016.65034*.

Michaeli R., Philosoph-Hadas S., Riov J, Shahak Y., Ratner K., Meir S. (2001). Chilling-induced leaf abscission of Ixora coccinea plants. III. Enhancement by high light via increased oxidative processes. *Physiol Plant; 113:338-345*.

Mohotti, A. J., Lawlor, D. W. (2002). Diurnal variation of Photosynthesis and Photoinhibition in tea: effect of irradiance and nitrogen supply during growth in the field. *J. Exp. Bot. 53:313-322.*

Odeleye F. O., Togun, A. O. and Tayo, T. O. (2001). The effect of light intensity on the growth, development and yield of soyabean in southwest Nigeria. *African Crop Science Journal, Vol. 9, No. 3, pp557-590*

Oloyede, A. A., Olaniyi, O. O., Adeosun, O. A**.,** Muyiwa, A. A. and Akanbi, O.S.O. (2014). Variability of selected tea genotypes (*Camellia sinensis*) to stem cutting propagation in Nigeria. *Conference Proceeding: 38th Annual Conference of the Genetics Society of Nigeria. Pp546-551.*

Oloyede, A. A., Olaniyi, O. O. Adeosun, S. A. and Adeigbe, O. O. (2017). Effect of locations, clones on biochemical constituents of tea leaves in Nigeria. *Proceeding of the 51st Annual Conference of the Agricultural Society of Nigeria, Abuja 2017. Pp227-230.*

Omolaja, S. S. and Iremiren, G. O. (2012). Tea Improvement in Nigeria. Advance topics in sciences and technology in China, 2012, pp.323-342

OSAR. (2016). Ondo State Agro-Climatological Report, 2016 (Unpublished).

Sakamoto M, Munemura I, Tomita R, Kobayashi K. (2008). Involvement of hydrogen peroxide in leaf abscission signaling, revealed by analysis with an in vitro abscission system in Capsicum plants. *Plant J*; 56:13–27; PMID: 18557836; DOI: 10.1111/j.1365-313X.2008.03577.x

Sadgheti, R., Nemetolla, E., Ali N., Mostafa Y. and Mohamad M. M. (2018). Effect of light intensity on leaf morphology, photosynthetic capacity and chlorophyll content in Sage (*Salvia officinalis* L.). *Korean Journal of Agricultural Science and Technology Vol. 36 No. 1 2018. 246-257*

Shahbandeh M. (2020). Production of tea worldwide 2006-2018 by leading country. *Statista. https://www.statista.com/statistics/264188/production-of-tea-by-main-producing-countries-since-2006/.*

STAR, (2013). Statistical Tools for Agricultural Research.

Sysoeva, M.I. Marcovskaya, E.F. and Shibaeva, T.G. (2010). Plant under continuous light. *Plant Stress.4:5-17*

Taylor J. E., Whitelaw C. A. (2001) Signals in abscission. *New Phytol*; 151:323-39.

Too, J.C., Kinyanjui, T., Wanyoko, J K.~~,~~ and Wachira, F.N. (2015). Effect of sunlight exposure and different withering durations on theanine levels in tea (*Camellia sinensis*) *Food and nutrition Sciences, 2015, 6, 1014-1021.* http://www.scirp.org/journal/fns

Wang, K.R., Li, N.N., Su, Y.Y. and Liang, Y.R. (2013). Effect of sunlight shielding on leaf structure and amino acids concentration of light sensitive albino plant. *African Journal of Biotechnology. Vol. 12(36). Pp.5535-5539*

Wijeratne, T. L., Mohottti, A. J. and Nissanka, S. P. (2008). Impact of long term shade on physiological, anatomical and biochemical changes in Tea (*Camellia sinensis* (L) O. Kuntze). *Tropical Agricultural Research Vol. 20: 376-387*

Wintermans, J. F. and A de Mots. (1965). Spectrophotometric characteristics of chlorophyll a and b and their pheophytins in ethanol. *Biochem. Biophys. Acta Vol. 109: 448-453*

Zhang, Q., Yunchi, S., Ma, L. and Ruan J.Y. (2014). Metebolomic analysis using ultra-performance liquid chromatography-Quadruple-Time of light mass spectrometry (UPLC-Q-TOF MS) uncovers the effects of light intensity and temperature under shading treatments on metabolites in tea. 2014 Nov.12;9(11):e112572
doi:10.1371/journal.pone.01125.ecollection 2014