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Influence of Light Intensity on the Photosynthesis and Phenolic Contents of *Mangifera Indica*

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Abstract: Light is an important environmental factor that have an influence on a plants photosynthesis and production of secondary metabolites like phenolic compounds and flavonoid. *Mangifera indica* from the family *Anacardiaceae* is known to have bioactivity due to its phenolic and flavonoid contents. The objective of the study is to determine the influence of light on the photosynthesis and phenolic contents of *M. indica*. Photosynthesis of the plant was measured using a portable photosynthesis system referred to as LICOR- 6400. Photosynthetic pigments as well as phenolic and flavonoid contents were quantified using a UV-VIS spectrophotometer. The outcome derived from the study shows that sun exposed leaves of the studied plant were having the maximum photosynthesis, saturation and compensation points ($P < 0.05$). Moreover, sun exposed leaves were having higher carotenoid, phenolic and flavonoid contents but lower chlorophyll contents. This leads to a conclusion that sun leaves of *M. indica* contribute the highest photosynthesis and phenolic contents to the plant.

Keyword: Flavonoid, light intensity; *Mangifera indica*; phenolic; photosynthetic pigment.

1.0 Introduction

Mangifera Indica (Mango) is a fruit plant belonging to the *Anacardiaceae* family. It is widely distributed in the world, even though it is native to Indian subcontinent. Mango is well known to contain some active ingredient that contribute to its traditional medicine application. Shah et al. [1] reported the use of mango tree and its part as food and as drug. Different part of the tree can be extracted and use as antibiotic. Other uses of the tree include the utilization of the wood to make lumber which can be used to make ukuleles and furniture [2]. Studies on mango are mainly concerned about their nutritional [3], antioxidant, antiviral, antidiabetic, anthelminthic, ant parasitic, antidiarrheal, and anti-inflammatory [4][5][3][1][6][7][5][8][9]. Moreover, *M. indica* can be used as a probiotic ingredient [3].

Environmental factors like light play an important role in the accumulation of phenolics in plants. This is due to the fact that phenolics are produced in response to adverse conditions, like insect attack, UV radiation, as well as drought and parasite attack. Moreover, biomass accumulated by a particular plant is also affected by the level of light intensity received by the plant [10]. The photosynthesis of a plant depends on the light received by the plants [11], due to this the pigment content of a particular plant changes depending on the level of light available to the plant. For example, Chl a, Chl b and Carotenoid contents of *Lactuca sativa* was highest when the plant was grown under blue LED light while Chl a/b ratio was highest under red LED light [12]. Because light intensity affects a plants photosynthesis, the net assimilation rate (A_{net}) of *L. sativa* was highest under red light compared to blue LED light [12].

Phenolic contents of *Lactuca sativa* was highest when the plant was grown under white LED light [12]. Another study by Ballester et al. [13] revealed that blue LED light do not influence the phenolic contents of fruits. Total phenolic content of *Brassica oleracea* was highest under red LED [14]. In addition to this, *Zea mays* sprouts that germinate under light have more phenolic content than those that germinate under dark conditions. This is also true for the flavonoid content of the plant [15].

The objective of this research is to determine the influence of varying light

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intensity on the photosynthesis and phenolic contents of *Mangifera indica*.

2. Materials and method

2.1 Determination of the effect of light of the plant photosynthesis

Sun and shade leaves of *M. indica* were used for this study. Prior to the study, a branch of sun and shade leaves were cut out of the plant, inserted into a flask of water, recut under water, and then incubated at ambient conditions for 24 hours. After the incubation, the portable photosynthesis system was assembled and set to the desired parameters, where flow rate was 500 µmol m^{-2} s^{-1}, CO2 and relative humidity were ambient while photosynthetic active radiation was variable from 2000 µmol m^{-2} s^{-1} to 0 µmol m^{-2} s^{-1}. Readings were recorded and then used to construct a photosynthetic light response curve. Moreover, parameters like A_{net}, maximum photosynthesis (A_{max}), apparent quantum yield (A_{qy}), light saturation point (LSP) and light compensation points (LCP) were deducted after fitting the curve according to Marshall & Biscoe [16].

2.2 Determination of the photosynthetic pigment contents

Photosynthetic pigments were determined spectrophotometrically were leaf sample were suspended in ethanol and quantified according to Lichtenthaler & Buschmann [17] after recording the absorbance of Chl a at 664.2nm, Chl b at 648.6 nm and carotenoid at 470nm respectively.

2.3 Plant material

Sun exposed and shaded mango tree leaves were sampled and harvested. 100g was measured and dried in an oven at 45°C for 42 hours. Sample was extracted based on Chai et al. [18] by grinding the dried leaves into powder. Furthermore, the dried powder was mixed with 2000 ml of ethanol and then incubated for 2 hours. The plant mixture was then filtered with a Whatman filter paper prior to centrifuging at 12000 rpm, at 4°C for 10 minutes. The supernatant was stored at low temperature and later used for determining total flavonoid and phenolic contents of the plants.

2.4 Determination of the total flavonoid contents

Total flavonoid content of *M. indica* was quantified using UV-vis spectrophotometer. The procedure was based on the aluminium chloride calorimetry method [6]. Plant extract was prepared and reaction mixture was developed by mixing plant extract with $AlCl_3$ and potassium acetate. Absorbance was recorded at 420 nm. Calibration curve was generated using Quercetin. Furthermore, results were expressed as mg/g quercetin equivalents (QE).

2.5 Determination of the total phenolic contents

Total phenolic content present in *M. indica* were quantified using UV-vis spectrophotometer [19]. The procedure was based on the folin-chiocalteau reagent. Quantification was done using UV-visible spectrophotometer. The leaf extract was first extracted and then the reaction mixture was developed using the reagent and $NaCO_3$. Absorbance was recorded at 760 nm, Gallic acid calibration curve generated, and results were expressed as mg/g gallic acid equivalents (GAE).

2.6 Statistical analysis

Data were compiled and recorded in triplicates. Results were reported as means ± standard deviation of the means. Additionally, differences in mean of sun and shade leaves were compared using T-test. Statistical analysis was done using the SPSS statistical software (IBM corp).

3. Results and Discussion

3.2 Influence of light on the plant photosynthesis

Varying light intensity influences the assimilation rate of *M. indica*. Sun exposed leaves contribute to the highest photosynthesis of the plant. The maximum photosynthesis, LCP as well as the LSP were higher in sun leaves compared to shade leaves. In addition, the photosynthetic light response curve was higher in sun leaves compared to shade leaves (Fig. 1).

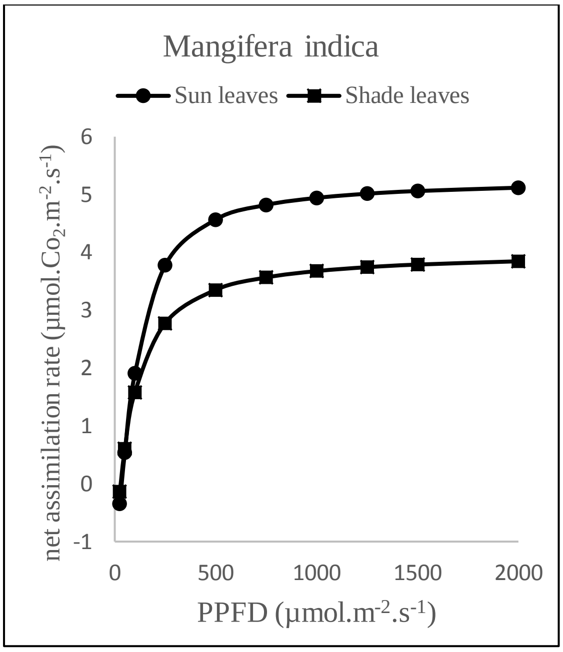

Fig. 1 Photosynthetic light response curve of *M. indica*.

The maximum photosynthesis recorded in sun leaves is due to higher number of chloroplast usually present in sun leaves [20]. Even though the quantum yield of sun and shade leaves were not significantly different ($P > 0.05$), the photosynthetic capacity of sun leaves is higher than that of shaded leaves. This is possible because the capacity is determined by the LSP and LCP of the leaves (Table 1).

Table 1 Photosynthetic light response parameters of *M. indica*.

	A_{max}	LCP	LSP	A_{qy}
S	6.62±0.12 ^{a}	34.30±2.1 ^{a}	976.73±42.13 ^{a}	0.042±0.009 ^{a}
SH	5.15±0.09 ^{b}	19.12±1.1 ^{b}	537.16±31.62 ^{b}	0.045±0.011 ^{a}

Where A_{max} is maximum photosynthesis in µmol.CO2 m^{-2} s^{-1}, LCP is light compensation point in µmol photons m^{-2} s^{-1}, LSP is light saturation point in µmol photons m^{-2} s^{-1}, A_{qy} is apparent quantum yield in mol CO_2 mol^{-1} photons, S is sun exposed leaves, and SH is shaded leaves. Different small letters indicate significant differences between sun and shade leaves ($P < 0.05$).

Leaves with lower LCP can use lower light intensity more than leaves with higher compensation point. The light intensity needed by a leaf to reach its maximum photosynthesis is referred to as the LSP. Above the LSP of a leaf, light will no longer be the limiting factor for photosynthesis, but rather, other factors like carboxylation rate will be the determining factors. Below the LSP, light will be the limiting factor for photosynthesis [20]. In a study, a plastic roof was use to provide shading to mango leading to a reduction in the photosynthetic photon flux density (PPFD) by about 700 µmol m^{-2} s^{-1}. This leads to an increase in the A_{net} of the plant [21]. The maximum photosynthesis of *M. indica* obtained in this study is 6.62±0.12 for sun leaves. In another study, the photosynthesis of *M. indica* ranges between 4 to 11 µmol m^{-2} s^{-1} [22]. Light was reported to affect the photosynthesis of *Arabidopsis thaliana* [23], while far red light positively influence the photosynthesis *Lactuca sativa* [24].

In *Camptotheca acuminuta* [25], red light can increase the plants biomass, leaf area, specific leaf area, Chl a and b, as well as carotenoid contents. Besides, A_{net}, stomatal conductance, and transpiration rate also increases under red light treatment. Moreover, chloroplast width, granular number and thickness, as well as number of grana lamellae were higher under red light compared to white, blue and yellow LED light [25]. Furthermore, the photosynthetic light response curve of grape vines grown under different LED light was highest under blue light [26].

3.2 Influence of light on the plant photosynthesis pigments

The photosynthetic pigments of sun and shade leaves of *M. indica* is represented in Fig. 2. From the results obtained, it is obvious that shade leaves were having high number of Chl a and Chl b compared to sun leaves. Shade leaves are thinner than sun leaves, giving them an opportunity to maximize capturing light photons. Shade leaves were greener than sun leaves because they have higher ratio of total chlorophyll to carotenoid content. Moreover, because shade leaves have higher Chl b content, their chlorophyll a to b ratio is lower than that of sun leaves. Nevertheless, sun leaves had higher Chl a to b ratio because they adapt to light more than shade leaves. In addition, sun exposed leaves had higher carotenoid content compared to shaded leaves due to the photo protective role of carotenoid. Carotenoid content of mango differs during the fruit development stage [27].

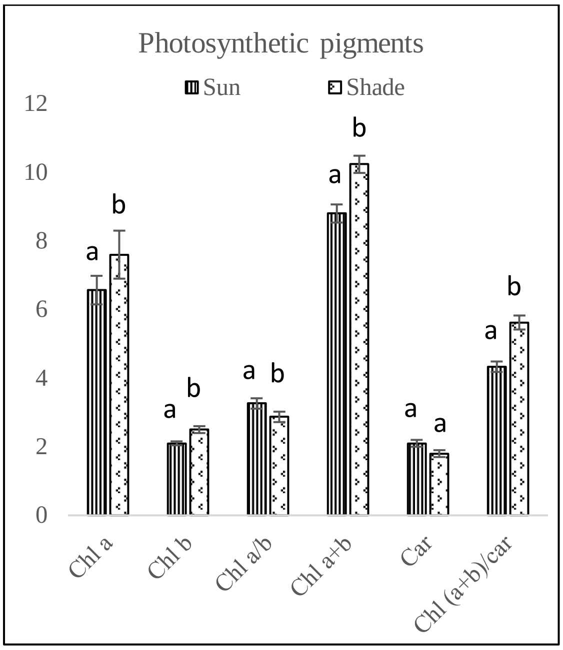

Fig. 2 Photosynthetic pigments of *M. indica*

Subbaiah et al. [28] reported that the Chl a content of mango was about 2.13mg/g, while the Chl b content was about 0.64 mg/g. The carotenoid and chlorophyll content of mango were highest under high light intensity and lowest when the light intensity was reduced with yellow and black fruit bag [29]. Even the β carotene present in mango differs according to the light available. Ripped mango fruit contain the highest β carotene [30]. In *Brassica Campestris*, shade treatment can increase the Chl b content [31]. Moreover, the Chl content of *Nannochloropsis* species was highest under red light and lowest under white light [32].

3.2 Influence of light on the plant total phenolic and flavonoid contents

Phenolic and flavonoids contents present in *M. indica* were higher in sun exposed leaves compared to shaded leaves. In Fig. 3, it is seen that the differences between the phenolic and flavonoid contents of sun exposed and shaded leaves is statistically significant ($P < 0.05$). Due to the fact that phenolics can accumulate in leaf epidermis as a result of adverse environmental conditions [33], *M. indica* sun exposed leaves accumulate higher amount of phenolics. Light can affect the flavonoid concentration of plants, for example [34] reviewed the effect of light on the accumulation of flavonoids in Ginkgo biloba.

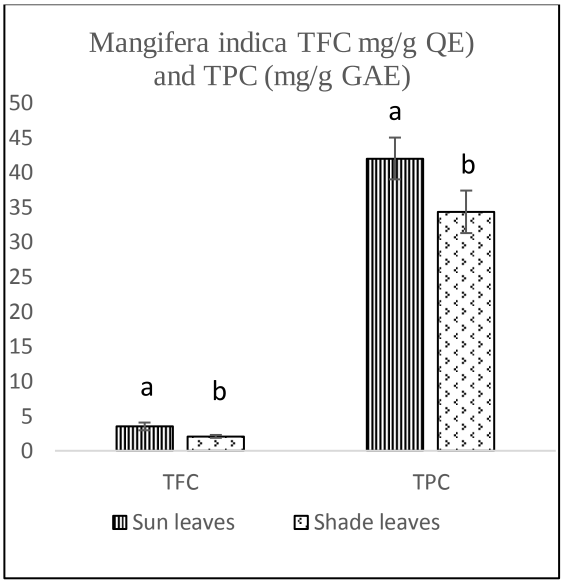

Fig. 3 Total phenolic and flavonoid contents of *M. indica*
Different small letters indicate significant differences among sun and shade leaves ($p < 0.05$).

In a recent study by De-Ancos et al. [35], the authors reported that the total phenolic content of mango was about 43 g/kg. Agatonovic-Kustrin et al. [36] on the other hand extracted about 26.92 mg/g GAE of phenolic contents in mango peel. In another study, the phenolic contents extracted from mango was about 57.86 µg/mg [37]. Moreover, total phenolic content of mango extracted by Dorta et al. [38] ranges between 47 to 79 g/100g DW while the total flavonoid contents ranges from 3 to 33 g/100g. In addition, total phenolic contents extracted from mango was about 960.4 mg/kg GAE [39].

Blue light can influence the accumulation of phenolic content of *Lachenalia* species [19], while red light can influence the phenolic content of *Brassica oleracea* [14]. UV light affect the phenolics and pigment content of broccoli sprouts [40], carrots [41], *Vigna radiate* sprouts [42], *Gracilaria chilensis* [43], *Capsicum chinense* [44], and *Solanum lycopersicum* [45]. High light intensity affects the phenolic and flavonoid content of *Salvia plebeia* [46], *Brassica* species [47] and *L. sativa* [48]. Even mulberry treated with pulsed light ultrasound have higher phenolic content than mulberry treated with other ultrasound treatments [49].

4.0 Conclusion

To this point, it is obvious that the photosynthesis, pigment and phenolic content of *M. indica* depends on the available light. Furthermore, sun leaves contribute to the highest photosynthesis of the studied plant. Besides, the photosynthetic pigments of the plant varies, with higher concentration of Chl in shaded leaves and higher concentration of carotenoid in sun exposed leaves. In addition, the phenolic content of the studied plant are higher in sun exposed leaves compared to shaded leaves.

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