Shade Effect on Antioxidant Activity of Dragon Fruit Genotypes in Aonla based Multistoried System

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Shade Effect on Antioxidant Activity of Dragon Fruit Genotypes in Aonla based Multistoried System

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The dragon gained popularity globally among farmers and consumers as a result of its antioxidant benefits. In the meantime, when compared to open field conditions, both genotypes of dragon fruit (white and red) are successfully grown in an aonla–based multistoried system without sacrificing fruit yield. On the other hand, the nutritional value of dragon fruit grown in shade has not yet been studied. However, the nutritional value of dragon fruit plays a significant role in its health benefits. The antioxidant content of dragon fruit genotypes grown under different shade levels (75% in multistoried and 78.6% in double storied) created by upper storied tree species has therefore been studied. Under a multistoried system the current study was carried out between July 2021– June 2022. Dragon fruit samples were collected and quality analysis was done at Agro–processing laboratory. Three replications of a two–factor randomized complete block design were used to examine the quality attributes of dragon fruit. Sample fruits of two dragon fruit genotypes were randomly collected from three treatments. The antioxidant activity of dragon fruit was not significantly impacted by the multistoried system although it produces larger and sweet red fleshed dragon fruit than open field condition. The antioxidant activities were measured by ABTS (2–2'–azinobis (3–ethyl–benzothiazoline–6–sulfonic acid) and DPPH were recorded the highest in multistoried system (T_1) 28.26 (87.13%) and 18.54 (91.51%) mg of ascorbic acid. Similar trend of variation was observed in total phenolic and flavonoid contents of dragon fruit pulp which were 28 mg GAE/100 mL and 48.94 mg QE/100 mL of juice, respectively. Between the genotypes of dragon fruit red flesh genotype contain higher antioxidants than white one. Total phenol, flavonoid content, ABTS and DPPH showed negative linear relationship with light intensity but showed positive liner relationship with antioxidant activity.

Key words: Antioxidant, Dragon fruit genotypes, Flavonoid, Multistoried, Phenol, Shade

INTRODUCTION

Dragon fruit (*Hylocereus* spp.), often called pitaya or pitahaya, is a vine type cactus that is originating to South America and is typically found growing in tropical climates, such as Southeast Asia. (Liaotrakoon, 2013; Patwary *et al*., 2013). Two genotypes of the *Hylocereus* species that are often and effectively introduced in Bangladesh are *Hylocereus undatus* (dragon fruit with white flesh) and *Hylocereus costaricensis* (dragon fruit with red flesh). Due to its vast range of adaptation, dragon fruit can flourish in a variety of climates and under challenging conditions such as high temperatures and low humidity. (Trivellini *et al*., 2020). Due to the nutritious benefits of this fruit, it is well–liked throughout the world. (Rifat *et al*., 2019). The fruit has a nice flavour, is crunchy, and is high in antioxidants. (Rao and Sasanka, 2015).

Fresh fruit and vegetable consumption are crucial for preventing the effects of free radicals (Tenore, G.C. *et al*., 2012) which are super reactive (Ruzlan, N. *et al*., 2010) and can cause harm to human cells and disturb homeostasis (Lobo, V. *et al*., 2010). Fruits and vegetables, are rich in antioxidant chemicals that can scavenge free radicals and stop peroxidation. (Tenore, G.C. *et al*., 2012 and Ruzlan, N. *et al*., 2010). Natural antioxidants are preferable and more desired as a defense against diseases caused by free radicals. (Ahmed, D. *et al*., 2015). Typically, flavonoids, a subclass of polyphenols, are the primary source of antioxidants. (Ruzlan, N. *et al*., 2010 and Pisoschi and Negulescu, 2011).

To determine the antioxidant capacity and characteristics of fresh fruits and vegetables, a variety of in–vitro antioxidant techniques can be used. (Dudonné, S.S.*et al*., 2009) such as ABTS (2,2'–azino–bis (3–ethylbenzthiazoline–6–sulphonic acid), DPPH, Total Phenol and electron transfer (ET)–based assays include the Total Flavonoid assays. An oxidant, when reduced, changes colour; the degree of the colour change is correlated with the antioxidant's concentration. An ET–based method evaluates an antioxidant's ability to reduce an oxidant (Dudonné, S.S. *et al*., 2009). The ABTS and DPPH techniques are widely used to evaluate the antioxidant activity of polyphenolics and colorants due to their ease of use, speedier reaction times, and compatibility with both aqueous and organic solvent systems (Wu, L–C. *et al*., 2006).

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The cultivation of this fruit is expanding quickly all over the world because of its sophisticated disease–prevention abilities and medicinal properties, as well as the abundance of vitamins and nutrients. The favourable tropical climate in Bangladesh has led to an increase in the production of dragon fruit. However, given Bangladesh's low per capita cultivable land and commitment to producing primary food crops to feed its rapidly growing population, there is no opportunity to expand the command area for dragon fruit. Bangladesh currently has 1119 people living there per square kilometre, with a population growth rate of 1.22 percent. (Population and Housing census 2022). In this case, finding a viable alternative agricultural method to produce several goods from the same plot of land is important. In this situation, the nation must create an agroforestry–or combined production system–that integrates crops and trees. By utilizing maximum Photosynthetically Active Radiation (PAR) and up taking the best nutrients from varied soil depths, multistoried systems provide maximum yield of a variety of fruits under different shade situations. Different components are organized in different tiers in this arrangement. The main issue is therefore the lower–storied crop's light constraint. Using upper–storied trees of a deciduous nature and maintaining the best pruning practices for the tree species are two ways to overcome this constraint. The country has more than 28.06 million homestead and many fruit tree orchards. The dragon fruit can easily grow as lower storied component of the homestead and tree orchard. Meanwhile both (red and white) dragon fruit genotypes are successfully grown in aonla based multistoried fruit production model without sacrificing the fruit yield comparing open field condition (Reza, 2021). However, there hasn't yet been any research done on the nutritional quality of dragon fruit growing under shade. Nonetheless, a major contributor to the health advantages of dragon fruit is its nutritional quality. The antioxidant content of dragon fruit genotypes grown in various shades produced by upper–storied tree species in multistoried production systems has therefore been studied.

MATERIALS AND METHODS

Study area

The Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) research farm of the Department of Agroforestry and Environment, Gazipur, is where the experiment was carried out in the multistory garden with aonla, carambola, and lemon as its foundation. The experiment ran from July 1, 2021, to June 30, 2022. This location was roughly 8.5 meters above sea level and lay between latitudes 24.09° N and longitudes 90.25° E (Roxy, 2017).

Design and arrangement of the experiment

The 21–year–old Aonla orchard, which was founded in 2000 and maintained an 8 m × 8 m distance, was the site of the dragon fruit experiment. In the line of Aonla, lemon and carambola were introduced alternately in 2008. In 2018, dragon fruits were sown as test crops in the tree alley. The planting was done using a two factorial randomized complete block design (RCBD) with three replications. Each treatment's dragon fruit plot measured 4 m by 6 m. Neighboring blocks were divided by aonla trees and other tree stories, and adjacent plots were separated by a distance of one meter. South of the Aonla orchard is an open field. The experiment consisted of two factors, which were Factor A: Agroforestry systems T_1: Aonla + Carambola + Lemon + Dragon fruit, T_2: Aonla + Dragon fruit and T_3: Dragon fruit (open field); factor B: Dragon fruit genotypes V_1: Red fleshed dragon fruit and V_2: White fleshed dragon fruit (Fig. 1)

Light measurement

Dragon fruit light incidence was measured for each replication of each treatment using a sunflex ceptometer (LP–80 AccuPAR). The purpose of the study was to calculate the amount of shading caused by the various tree species' stories, which were expressed as μ mol $m^{-2}s^{-1}$.

Dragon fruit length, diameter and weight

Fruit length and diameter were measured using slide calipers after harvest, and the mean values were recorded and expressed in centimeters (cm) based on treatment. The weight of the dragon fruit was determined using an electric balance, and the mean was then calculated and expressed in grams (g).

Antioxidant analysis

All the quality parameters of dragon fruit genotypes of different treatments with three replications were analyzed at the Agro–Processing laboratory of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). Total 36 fruits were used for quality analysis with three replications.

Total phenolic content (TPC)

Using Folin–Ciocalteu phenol reagents, the total phenol content of the dragon fruit pulp and crude extracts was calculated, and gallic acid was used for external calibration. The technique used in earlier studies to calculate the TPC is clear. (Uddin *et al*., 2018).

Total flavonoid assay (TFA)

With a few minor adjustments, the aluminum chloride colorimetric method–which Uddin *et al*., 2018 described–was used to determine the total flavonoid content of dragon fruits.

Evaluation of total antioxidant capacity (TAC)

The number of free radicals scavenged by a test solution is measured as total antioxidant capacity, or TAC, and is used to assess the antioxidant capacity of a wide range of samples (Pinchuk *et al*., 2012). TAC can be measured using either an indirect assay, which determines a sample's capacity to reduce a metal complex, or a direct assay, which is based on the ability to inhibit the oxidation of a substance. Total antioxidant activities of different crude extract of dragon fruit were observed

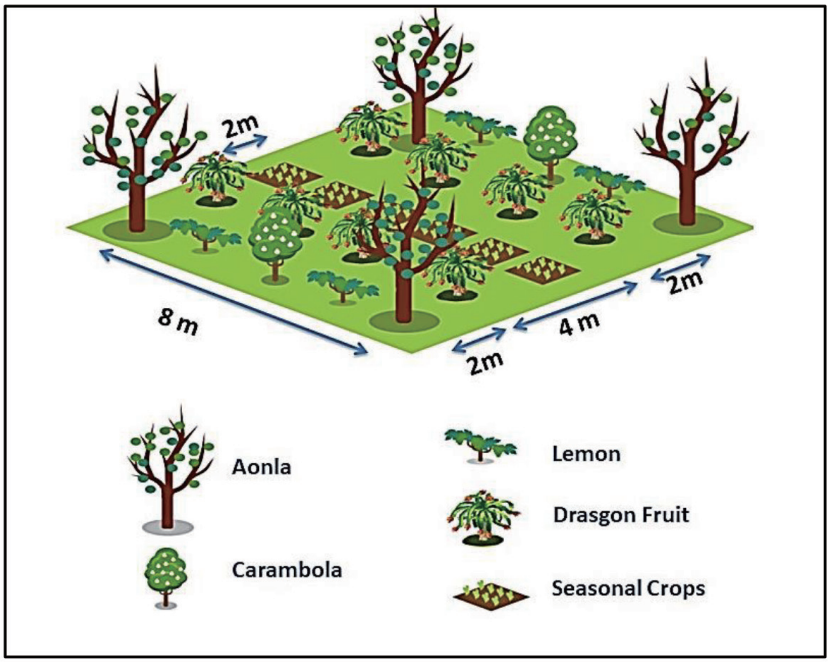

Fig. 1. Schematic diagram of Multistoried Fruit Production Model.

using the following method–

ABTS radical scavenging assay

With a little modification, the green ABTS complex formation method of Prieto *et al*., (1999) was used to assess the antioxidant activities of various extracts. The method has been reported to be used by many researchers such as Rafiquzzaman *et al*., (2016); Mann *et al*., (2016).

DPPH radical scavenging assay

The DPPH radical scavenging assay was used to assess the antioxidant properties of various extracts using a slightly modified version of Essam *et al*., 2014's methodology.

Data interpretations

MS–Excel and STATISTX 10 were the computer programs used to process, compute, and analyze all of the data. Tests that were required were run in order to compare the treatment means. At the 5% and 1% levels of significance, the mean differences were adjusted using the Least Significant Difference (LSD).

RESULTS AND DISCUSSION

Photosynthetically active radiation (PAR) distribution

The T_3 treatment (dragon fruit sole) had the highest mean maximum light intensity at 1503.36 μ mol $m^{-2}s^{-1}$. T_2 (aonla + dragon fruit) came in second with 1181.70 μ mol $m^{-2}s^{-1}$, and T_1 (multistoried system) had the lowest mean maximum light intensity at 1128.22 μ mol $m^{-2}s^{-1}$. 75 and 78.60% PAR were given to the T_1 and T_2 treatments, respectively. Due to variation of the canopy density of over storied tree species this light variation has been occurred upon dragon fruit. (Fig. 2).

Dragon fruit length, diameter and weight

The interaction effect of multistoried fruit production model and dragon fruit genotypes on fruit length, diameter and weight were significant (Table 1). The longest fruit was observed in T_1V_2 combination (white fleshed genotype in multistoried condition) that was 8.74 cm. The T_2V_2 combination produced moderate fruit length 8.42 cm which was statistically similar with T_3V_2 (8.21 cm). The smallest fruit was recorded in T_3V_1 combination which was also statistically similar with both T_1V_2 (7.57 cm) and T_2V_1 (7.51 cm) treatment combination. This study showed that white fleshed genotype produces long fruit compared to red fleshed genotype. Again, in case of fruit diameter multistoried system (T_1V_1) produced significantly the widest fruit (11.66 cm). The moderate fruit diameter was recorded in T_2V_1 (10.40 cm) which was statistically similar with T_3V_1 combination (9.83 cm). The narrowest fruit found in T_3V_1 combination (7.92 cm) which was statistically similar with T_1V_2 combination (8.59 cm) and T_2V_2 combination (8.20 cm). The red fleshed genotype produced wider fruit than that of white fleshed genotype. Red fleshed dragon fruit produced large fruit (261.67 g) in multistoried (T_1V_1). The moderate fruit weight was recorded in T_2V_1 (221.17 g) which was statistically similar with T_3V_1 treatment combination (208.33 g) again this T_3V_1 combination was statistically similar with T_1V_2 combination (182.42 g). Minimum fruit weight and edible portion (154.34 g) was obtained from T_3V_2, which was statistically similar to those of T_2V_2 (159.71 g). Multistoried system provided larger fruit compared to open field and other treatment this was may be due to the lower number of fruits per plant (4–6 fruit per plant in multistoried, 5–10 fruits per plant in double storied and 6–13 fruits

per plant in open field) which increases the fruit weight of dragon fruit.

Antioxidant activity of dragon fruit

Total phenolic content (TPC)

The total phenolic content (TPC) of the extract was calculated using the calibration curve of gallic acid, which was found to be y=0.0116x + 0.162 (R^2=0.9987), where x is the total amount of phenolic compounds in mg per 100 mL of juice and y is the absorbance value at a wavelength of 765 nm. This study revealed that, the maximum phenol was found in multistoried with red flesh (T_1V_1) dragon fruit (28 mg GAE/100 g), which was statistically identical with that of aonla based dragon fruit system (T_2V_1) (27.59 mg GAE/100 g) and open field condition (T_3V_1) (27.26 mg GAE/100 g) in red one. But the minimum total phenol was recorded in open field condition with white flesh genotype (T_3V_2) of dragon fruit (20.05 mg GAE/100 g) which were statistically similar with T_1V_2 and T_2V_2 (Table 2).

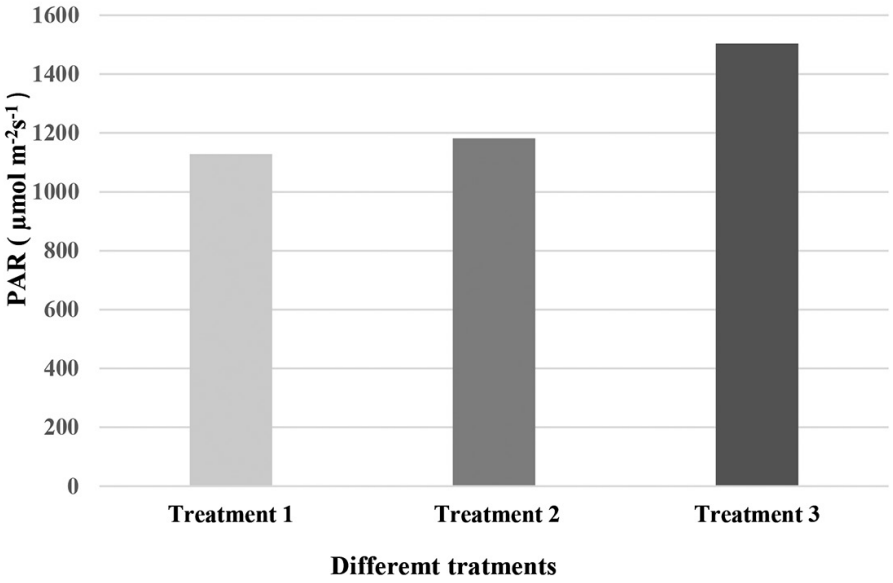

Fig. 2. Distribution of the average photosynthetically active radiation (PAR) across various treatments.

Table 1. Effects of genotypes and agroforestry systems on the length, diameter, and weight of dragon fruit at harvest in a multistoried system based on aonla

Treatment Combination	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)
T_1V_1	7.57c	11.66a	261.67a
T_1V_2	8.74a	8.59c	182.42cd
T_2V_1	7.51c	10.40b	221.17b
T_2V_2	8.42ab	8.20c	159.71d
T_3V_1	7.31c	9.83b	208.33bc
T_3V_2	8.21b	7.92c	154.34d
CV %	7.42	10.71	17.34

In a column, means followed by same letter (s) are not statistically different at 5% level of significance by DMRT. T_1: aonla + carambola + lemon + dragon fruit, T_2: aonla + dragon fruit, T_3: dragon fruit sole (open field), V_1: red fleshed dragon fruit, V_2: white fleshed dragon fruit.

Table 2. Antioxidant activity of dragon fruit genotypes in different treatment

Nutrient	Phenol	Flavonoid	ABTS	DPPH
Treatment Combination	(mg of gallic acid)	(mg of QE)	(mg of ascorbic acid)	(mg of ascorbic acid)
T_1V_1	28.00a	48.94a	28.26a (87.13%)	18.54a (91.51%)
T_1V_2	20.50b	42.83ab	28.20a (85.19%)	18.45b (80.46%)
T_2V_1	27.59a	48.32a	28.23a (87.03%)	18.52a (89.57%)
T_2V_2	20.43b	39.33b	28.19a (85.01%)	18.35c (69.18%)
T_3V_1	27.26a	48.06a	28.22a (87.03%)	18.49b (85.91%)
T_3V_2	20.05b	36.56b	28.00a (84.93%)	18.27d (60.32%)
CV	10.90	6.55	0.39	0.17

T_1: aonla + carambola + lemon + dragon fruit, T_2: aonla + dragon fruit, T_3: dragon fruit sole (open field), V_1: red fleshed dragon fruit, V_2: white fleshed dragon fruit.

This variation was observed may be due different shade level. Karimi *et al*., (2013) found that Under 630 mol m^{-2} s^{-1} light intensity, there was considerably (p 0.05) greater activity with increasing total phenolics and flavonoids in all plant organs. According to Somporn *et al*., (2012), plants cultivated in lychee shadow had the highest overall phenolic content and antioxidant activity. The main phenolic acid that was present in high concentrations (40–77.2% of the total phenolic acid) was chlorogenic acid. This acid increased with decreasing light intensity, with full sun being the lowest and lychee trees being the highest. This could be because the phenolic compositions of the fruit promote antioxidant activity. Choo, W.S., (2011) observed that the total phenolic content in dragon fruit pulp was 15.92 1.28 mg GAE/100 g and 24.22 0.95 mg GAE/100 g, respectively. These values were almost identical to the outcomes of the present investigation. Different sample preparation methods, environmental development variances, varying levels of shadow, and/or different fruit maturation stages could all contribute to the differential in total phenolic content (Ramli, N.S., 2014; Ahmed, D., 2015).

Total flavonoid content (TFC)

The majority of plants that produce edible fruit contain a group of polyphenolic substances called flavonoids. They make up the majority of the fruit's yellow, red, and blue hues. However, flavonoids are probably the most dynamic naturally occurring phytochemical because of their wide range of chemical and biological activities, such as their ability to scavenge free radicals and act as antioxidants (Kahkonen *et al*., 1999). The quercetin equivalent (mg of QE/100 mL) was used to express the flavonoid content (standard curve equation: $y = 0.0102x - 0.0637$, $R^2 = 0.9693$). From (Table 1), the maximum flavonoid content was found in multistoried condition with red flesh genotype of dragon fruit (48.94 mg of QE/ 100 mL), which was statistically identical with that of aonla based dragon fruit system(T_2V_1) and open field condition (T_3V_1) in red flesh genotype which are 48.32 mg of QE/ 100 mL and 48.06 mg of QE/ 100 mL. But the minimum phenol was recorded in open field condition with white flesh genotype of dragon fruit (36.56 mg of QE/ 100 mL which were statistically similar with T_2V_2.

The result was higher may be due to different shade condition where T_1 treatment got low light intensity. According to Ghasemzadeh *et al*., (2010), two varieties of Malaysian young ginger (*Zingiber officinale*) were subjected to four levels of glasshouse light intensities (310, 460, 630, and 790 μmol m^{-2} s^{-1}) in order to examine the impact of light intensity on the production, accumulation, and partitioning of total phenolics (TP), total flavonoids (TF), and antioxidant activities. The *Halia Bara* variety saw the highest levels of TF biosynthesis under low light intensity (310 μmol m^{-2} s^{-1}).

Total antioxidant capacity

Using the ABTS Radical Scavenging Assay, the overall antioxidant activity of the pulp from dragon fruits was assessed.

ABTS radical scavenging assay

Based on a decolorization procedure, the ABTS assay was created. When combined with antioxidants, dark blue ABTS+ changes to a light blue or colourless state that can be detected spectrophotometrically at 734 nm. (Pellegrini, 2003). As a positive control for the ABTS scavenging assay, ascorbic acid was also used to create a standard calibration curve. For ascorbic acid, the calibration equation was $y = 0.368x - 9.525$ ($R^2 = 0.9963$). The dragon fruit pulp's ability to scavenge free radicals was statistically comparable across all treatment combinations. The ranged from 87.24% (28.26 mg of ascorbic acid/100 ml) to 84.93% (28.00 mg of ascorbic acid/100 ml) (Table 2). This outcome is comparable to the Abd Manan, 2019 outcome. The slight discrepancy may have been caused by the various levels of shade since plants have antioxidant defence mechanisms to survive under shade, which boosts plant antioxidant levels. Reza *et al*., (2020) found a similar outcome in the leaves of soybean plants. Most plants that were shaded had higher antioxidant activities than those that were exposed to full sunshine, according to Somporn *et al*., (2012). The lychee shade–grown plants had the highest antioxidant activity (94.1%), while the full–sun grown plants had the lowest antioxidant activity (89.9%).

DPPH radical scavenging assay

An initial test to determine an extract's potential as an antioxidant is the DPPH assay. This assay has been widely employed to assess various substances' ability to scavenge free radicals. As a positive control for the DPPH assay, ascorbic acid was also used to create a standard calibration curve. For ascorbic acid, the calibration equation was $y = 2.3134x + 43.13$ ($R^2 = 0.9877$). The dragon fruit pulp's ability to scavenge free radicals was 18.54 mg (91.51%) in the T_1V_1 treatment combination, which was statistically comparable to the T_2V_1 treatment combination. T_3V_2 18.47 mg (83.91%) showed moderate DPPH, which was statistically comparable to the T_3V_2 treatment combination. T_2V_2 18.27 mg (60.32%) showed the lowest DPPH (Table 2).

Difference between two dragon fruit genotypes in respect to antioxidant

When compared to dragon fruit genotypes with white flesh, red flesh genotypes had higher phenol (27.61 mg) flavonoid (48.39 mg) and DPPH (18.54 mg) content. However, the red dragon fruit genotype's ABTS concentration (28.21 mg) was statistically comparable to that of the white one (Table 2). The red flesh genotype of dragon fruit had higher phenol, flavonoid, and ABTS contents than the white flesh genotype, which may be related to their genetic make–up (Table 3).

Relationship between light intensity (PAR μ mol $m^{-2}s^{-1}$) of agroforestry system and dragon fruit length, diameter and weight

Dragon fruit genotypes were found to have linear

associations with light (PAR mol $m^{-2}s^{-1}$) and length, diameter, weight of dragon fruit which were estimated as y = –0.0007x + 8.3127 (R^2 = 0.9919), y = –0.0038x + 15.452 (R^2 = 0.6758), y = –0.1065x + 356.73 (R^2 = 0.6023) for red fleshed dragon fruit (V_1) and y = –0.0011x + 9.9152 (R^2 = 0.7611), y =–0.0015x + 10.101 (R^2 = 0.7819), y = –0.0545x + 234.83 (R^2 = 0.5514), for white fleshed dragon fruit (V_2). The R^2 values of the equations for red fleshed and white fleshed dragon fruit were 0.9919, 0.6758, 0.6023 and 0.7611, 0.7819, 0.5514 respectively, which were high and significant (Fig. 3). The R^2 values indicated that 99.19, 67.58, 60.23 and 76.11, 78.19, 55.14 percent phenol, flavonoid, ABTS and DPPH content of red and white fleshed dragon fruit were attributed to light (PAR μ mol $m^{-2}s^{-1}$).

As per the relationship, red and white skinned dragon fruit's length, diameter and weight declined at a rate of 0.0007 mg, 0.0038 mg, 0.1065 mg and 0.0011 mg, 0.0015 mg, 0.0545 mg for each unit of changing light intensity (PAR mol $m^{-2}s^{-1}$).

Relationship between light intensity (PAR μ mol $m^{-2}s^{-1}$) of agroforestry system and phenol, flavonoid, ABTS, DPPH content of dragon fruit genotypes

Linear relationships between light (PAR μ mol $m^{-2}s^{-1}$) and phenol, flavonoid, ABTS, DPPH content of dragon fruit genotypes were estimated as y = –0.0016x + 29.704 (R^2 = 0.8078), y = –0.0018x + 50.739 (R^2 = 0.6592), y = –0.0001x + 28.371 (R^2 = 0.7647) and y = –0.0001x + 18.668 (R^2 = 0.9255) for red fleshed dragon fruit (V_1) and y =–0.0012x + 21.843(R^2 = 0.9998), y = –0.0139x + 57.222(R^2 = 0.8041), y = –0.0006x + 28.833 (R^2 = 0.9923) and y =–0.0004x + 18.864 (R^2 = 0.5832) for white fleshed dragon fruit (V_2). The R^2 values of the equations for red fleshed and white fleshed dragon fruit

Table 3. Difference between two dragon fruit genotypes on antioxidant activity

Nutrient	Phenol	Flavonoid	ABTS	DPPH
Treatment Combination	(mg of gallic acid)	(mg of QE)	(mg of ascorbic acid)	(mg of ascorbic acid)
V_1	27.61a	48.39a	28.21a (86.95%)	18.54a (88.66%)
V_2	20.32b	38.24b	28.14a (85.02%)	18.34b (66.98%)
CV	10.90	6.55	0.49	0.17

V_1: red fleshed dragon fruit, V_2: white fleshed dragon fruit.

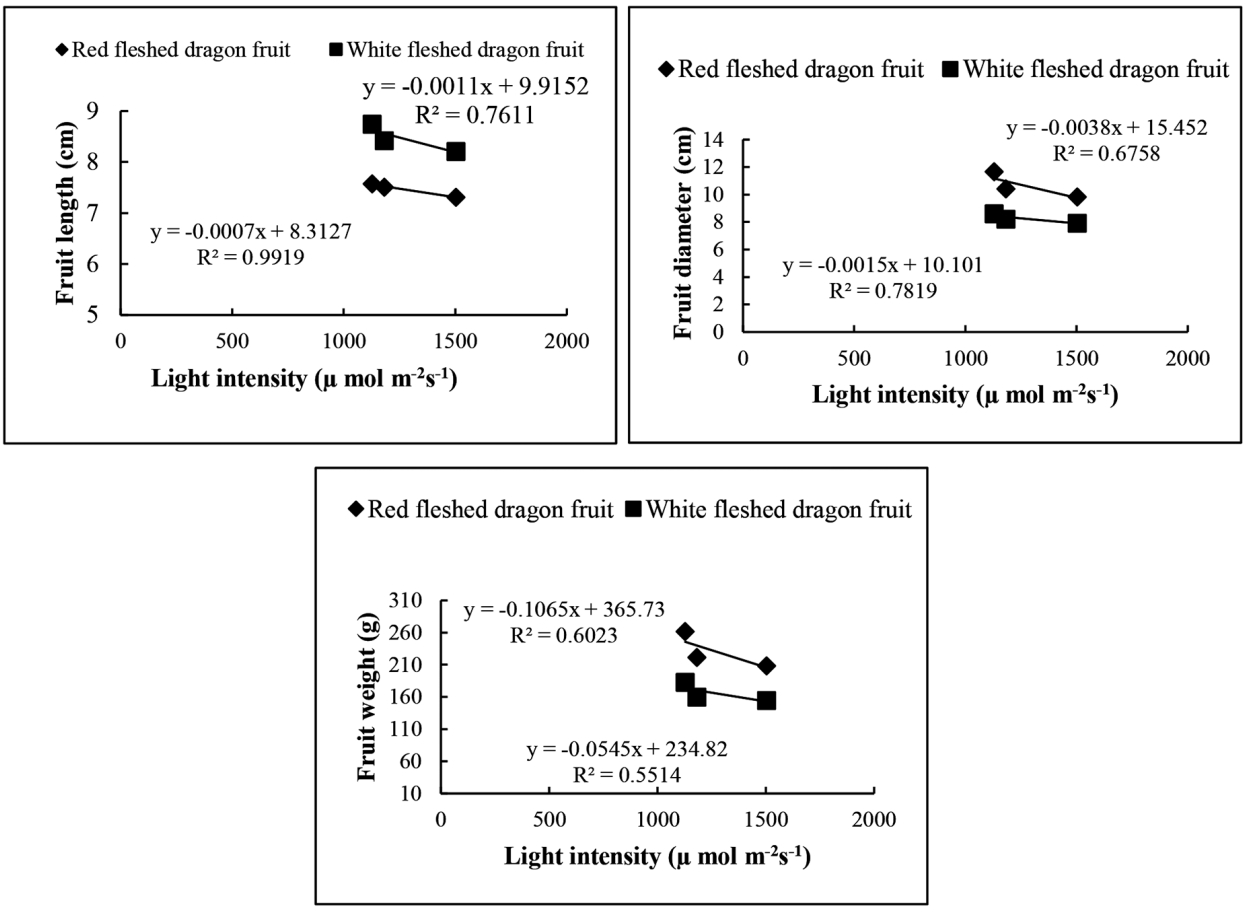

Fig. 3. Connection between dragon fruit genotypes' length, diameter, and weight and light intensity (PAR μmol $m^{-2}s^{-1}$), T_1: aonla + carambola + lemon+ dragon fruit, T_2: aonla + dragon fruit, T_3: dragon fruit sole (open field).

were 0.8078, 0.6592, 0.7647, 0.9255 and 0.9998, 0.8041, 0.9923, 0.5831 respectively, which were high and significant (Fig. 4). The R^2 values indicated that 80.78, 65.92, 76.47, 92.55 and 99.98, 80.41, 99.23, 58.31 percent phenol, flavonoid, ABTS and DPPH content of red and white fleshed dragon fruit were attributed to light (PAR μ mol $m^{-2}s^{-1}$). Total phenol content is rising in the T_1 treatment under low light conditions, which may be a result of the plant's ability to tolerate stress in the shade. Obaidullah *et al*., (2022) found in their experiment that phenol is a crucial plant ingredient, or secondary metabolite, that increases in concentration under stressful conditions. Phenol's hydroxyl groups provide it an anti–oxidative role in scavenging ROS. The quantity of ABTS was essentially the same across all treatment combinations; any modest variations were likely caused by varying shadow intensities. According to Obaidullah *et al*., (2022), plants' capacity to withstand stress is greatly influenced by their antioxidant defense system. Total antioxidant activity was found to be highest (97 μ g/g) in the control condition at 150 DATI and lowest (45.2 μg/g) in the high stress condition at 12 dS/m salinity level. As per the findings of Somporn *et al*., (2012), plants grown in shade exhibited significantly higher levels of DPPH scavenging than those grown in full sun. Moreover, the highest levels of DPPH scavenging were observed under lychee shade.

Total Phenolic Content, Total Flavonoid Content, and Antioxidant Assay Correlation

Fidrianny and Sahar, (2014) state that if $0.68 \leq r \leq 0.98$, then Pearson's correlation was positively high. Table 4 displays the correlations between the genotypes of dragon fruit pulp across all assays, demonstrating that the TPC and TFC of the red and white genotypes were positively high ($0.812 \leq r \leq 0.971$). The results indicate that phenolic compounds present in the pulp of dragon fruit (Ruzlan *et al*., 2010; Wu *et al*., 2006; Choo and Yong, 2011; Jan *et al*., 2013) and very potent antioxidants (Ahamed *et al*., 2015 and Dudonne *et al*., 2009) played a major role in contributing to the fruit's antioxidant capacity. These correlations are positive and high between TPC and DPPH of red and white fleshed dragon fruit genotype (r=0.816 and 0.968), as well as TPC and ABTS (r=0.952 and r= 0.982). Wu *et al*., (2006) found that because of the different kinds of polyphenols they contain, the phenolic content of extracts from pulp and peels was found to be linearly correlated with antioxidant capacity. The molecular structure's hydroxyl groups (–OH) or other hydrogen–donating groups (=NH, –SH) boost the antioxidant activity. Comparatively, Table 4's TFC and DPPH (r=0.884 and r=0.997) and TFC and ABTS (r=0.991 and r=0.730) correlations indicate that, in addition to flavonoids, a class of phenolic compounds, betalains pigment made up of yellow betaxanthins and red–violet betacyanin were the main source of the red fleshed dragon fruit's antioxidant capacity

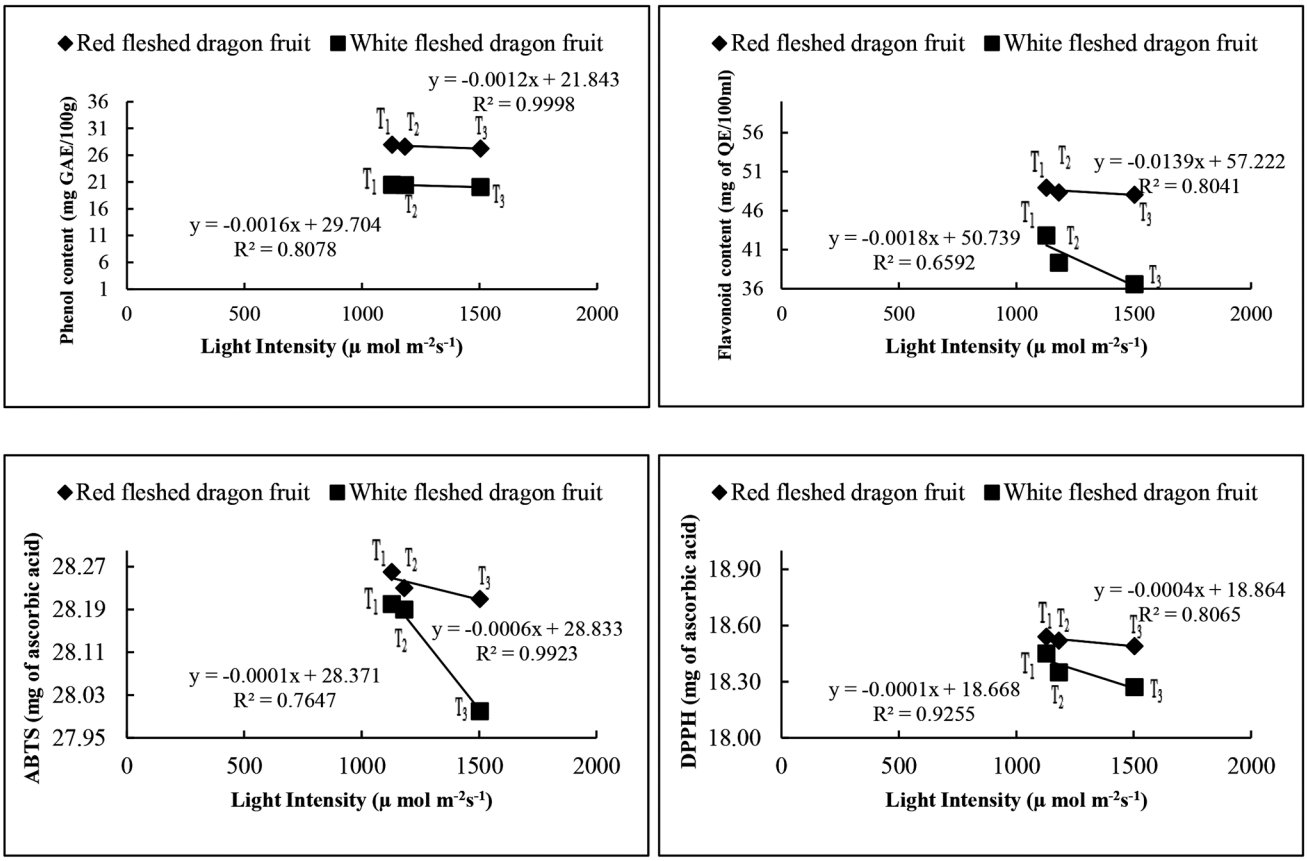

Fig. 4. Connection between light intensity (PAR μ mol $m^{-2}s^{-1}$) and phenol, flavonoid, ABTS, DPPH content of dragon fruit genotypes, T_1: aonla + carambola + lemon+ dragon fruit, T_2: aonla + dragon fruit, T3 : dragon fruit sole (open field).

Table 4. Pearson's correlation coefficients of antioxidants activities and capacities, total phenolic content and total flavonoid content of dragon fruit genotypes

Traits	DPPH		ABTS		TPC	
	V_1	V_2	V_1	V_2	V_1	V_2
ABTS	0.784	0.732				
TPC	0.968	0.816	0.952	0.989		
TFC	0.884	0.997	0.991	0.730	0.971	0.812

TPC= Total Phenolic Content, TFC = Total Flavonoid Content, DPPH = 2,2–Diphenyl–1–picrylhydrazyl assay, ABTS = 2–2'– azinobis (3–ethyl–benzothiazoline–6–sulfonic acid) assay, V_1= Res fleshed dragon fruit, V_2= White fleshed dragon fruit.

(Esquivel *et al*., 2007). High polyphenol content was found to enhance the capacity to prevent the harmful effects of free radicals (Ruzlan *et al*., 2010; Ahamed *et al*., 2015; Dudonne *et al*., 2009; Wu *et al*., 2006; Rebecca *et al*., 2010; Fidrianny and Sahar, 2014 and Brahim *et al*., 2018). Previous research has shown a strong relationship between the number of phenolic compounds present in plants and their antioxidant capacity (Dudonne *et al*., 2009 and Brahim *et al*., 2018).

CONCLUSIONS

Although the multistory fruit growing approach did not significantly alter nutritional quality, the analyzed nutritional quality metrics do vary marginally between different treatments. The Aonla + Lemon + Carambola + Dragon fruit–based treatment (T_1) with low light intensity was shown to have the highest antioxidant content. Dragon fruit with red flesh has been determined to be superior to dragon fruit with white flesh. However, total phenol, flavonoid and DPPH concentration demonstrated a positive linear connection with ABTS while a negative linear relationship with light intensity. The fruit is a highly desirable crop since it contains a substantial number of antioxidants.

AUTHOR CONTRIBUTIONS

Anika Reza contributed to the study conception, material and sample preparation, and analysis. The first draft of the manuscript was written by Anika Reza. Md. Md. Main Uddin Miah and Tofayel Ahamed designed and supervised the research work. Md. Ahiduzzaman and Sohana Parvin and Minhaz Ahmed helped in the methodology, data analysis and preparation of manuscript. Masaru Matsumoto critically reviewed the manuscript with valuable suggestions and comments. All authors read and approved the final manuscript.

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