



Performance of Dragon Fruit Genotypes Grown in a Multistoried Production System

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ABSTRACT

Background: The aonla-based multistoried production model is a climate-smart and profitable agro-technology that optimizes land use and mitigates climate change effects. Farmers in Bangladesh are grow dragon fruit as a single crop but only dragon fruit cultivation is not suitable for an over populated country like Bangladesh. 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. But the biochemical composition of dragon fruit grown in shaded condition yet not been studied before.

Methods: This study investigated the impact of shaded conditions on fruit yield and biochemical composition. Using a two-factor randomized complete block design with three replications, six treatment combinations were evaluated for quality attributes.

Result: Results indicated that multistoried cultivation did not significantly alter the biochemical composition of dragon fruits. The red-fleshed genotype under sole cropping exhibited the highest values in key parameters, including calories (62.43 Kcal), vitamin C (24.8 mg), sugars (11.92%), fiber (0.58 g), protein (1.16 g), pH (4.64), total soluble solids (25%), carbohydrates (12.49 g) and ash (1.76%). The white genotype performed well under multistoried and double-storied conditions. Mineral analysis revealed a consistent ranking of K > Mg > Na > Ca across treatments, with white genotypes containing higher K, Mg and Ca, while Na was higher in red genotypes. These findings confirm that the aonla-based multistoried model supports dragon fruit cultivation without compromising nutritional quality, promoting sustainable agriculture in land-limited and climate-sensitive regions.

Key words: Aonla-based production, Biochemical composition, Climate-smart agriculture, Dragon fruit genotypes, Multistoried agroforestry.

INTRODUCTION

Dragon fruit is gradually making its way into the fields by winning the hearts of farmers through its immense popularity. Dragon fruit (*Hylocereus* spp.), also referred to as pitaya or pitahaya, is a kind of vine cactus that is native to South America and is typically found growing in tropical climates, such as Southeast Asia (Athira and Mini, 2024; Liaotrakoon *et al.*, 2013; Patwary *et al.*, 2013). This high value fruit is well accepted worldwide due to its nutritional importance. Two genotypes of the *Hylocereus* species, namely *Hylocereus costaricensis* (red fleshed dragon fruit) and *Hylocereus undatus* (white fleshed dragon fruit), are introduced in Bangladesh (Rifat *et al.*, 2019). Dragon fruit has a wide adaptation range hence it can easily be grown in different corners of the world. The attractive color and taste of dragon fruit pulp rich in water-soluble fiber, vitamin C and antioxidants including Betalains, hydroxycinnamates and flavonoids, make it very attractive (Moshfeghi *et al.*, 2013). It helps in weight loss, enhances digestion, lowers blood LDL cholesterol and strengthens the immune system, in order to lower the risk of heart disease, flavonoids and hydroxycinnamates work on blood vessels and brain cells, respectively. Moreover, it protects against germs and fungus and supports the body's general function (Verma *et al.*, 2017). The fruit species of *Hylocereus* are rich in phytochemicals, antioxidants, calcium, phosphorus, magnesium, fiber and vitamins (Pavithra and Mini, 2023; Mahdi *et al.*, 2018; Sushmitha *et al.*, 2018). The

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production of this fruit is expanding quickly all over the world because of its health benefits, as well as the wealth of vitamins and nutrients (Mazid *et al.*, 2025). The favorable tropical climate in Bangladesh has led to an increase in the production of dragon fruit. In 2014, Bangladesh produced

only 66 tons of dragon fruit on 18 hectares of land, according to the Horticulture Wing of the Department of Agricultural Extension (DAE). In fiscal 2020-21, farmers grew pitaya on 695 hectares of land to bag 8,660 tons of the fruit, which is more than double the total yield of 3,463 tons the previous year. Seeing their success, more farmers in other regions are now trying to grow the fruit.

Dragon fruit cultivation has gained significant attention among farmers in Bangladesh due to its potential as a novel and profitable crop. However, the country's limited arable land and high population density (Population and Housing Census, 2022) pose challenges to dedicating land solely to dragon fruit cultivation. In this context, adopting integrated farming systems such as the aonla-based multistoried production model is crucial (Reza *et al.*, 2022). This climate-smart agro-technology not only optimizes land use but also mitigates the adverse effects of climate change by providing diverse benefits. While both red and white dragon fruit genotypes have been successfully cultivated in this multistoried system without compromising fruit yield compared to open-field conditions, the impact of shaded environments on the biochemical composition of dragon fruit has not been previously explored. Understanding how shade levels affect the nutritional quality of dragon fruit grown in multistoried systems is essential for promoting this sustainable cultivation method. This study aims to fill this knowledge gap by assessing the biochemical composition and quality attributes of dragon fruit genotypes under varying shade levels, thereby contributing to the development of sustainable and efficient production practices in Bangladesh.

MATERIALS AND METHODS

Location and experimental design

This location of the experiment was between the longitudes of 90.25° E and 24.09° N and it was 8.5 meters above sea level (Reza *et al.*, 2024). The sample fruits were collected between July 2021 and June 2023 from existing multistory fruit production model (Fig 1), which is based on aonla, carambola, lemon and dragon fruit research plot of the Department of Agroforestry and Environment, Gazipur Agricultural University, Gazipur-1706. Three replications of a two-factor randomized complete block design were used to examine the quality attributes of dragon fruit at the Agro-processing laboratory. An experiment as conducted using two factors viz., Factor A: Fruit production model T_1 : Aonla + Carambola + Lemon + Dragon fruit (multistoried), T_2 : Aonla + Dragon fruit (double storied) and T_3 : Dragon fruit (sole cropping); Factor B: Dragon fruit genotypes, V_1 : Red fleshed dragon fruit and V_2 : White fleshed dragon fruit. A total 36 number of samples were used throughout the experiment.

Physical attributes measurement

The incidence of sunlight on dragon fruit was measured using a sunflex ceptometer (LP-80 AccuPAR) to determine the shading levels created by various tree species,

expressed as $\text{mol m}^{-2}\text{s}^{-1}$. After harvest, the fruit weight, length and breadth were recorded.

Proximate content analysis

Proximate parameters analyzed in the study included moisture content, total soluble solids (TSS), total sugar, reducing sugar, non-reducing sugar, fat, fibre, protein, ash and carbohydrate. The moisture was determined using the gravimetric method described in (Ranganna, 2015). TSS was measured using a digital refractometer (HI 96801, HANNA Instruments). Total sugar, reducing sugar and non-reducing sugar content were estimated using Fehling's titration method, with a standard sugar solution for calibration (Ranganna, 2015). Fat content was estimated using a Soxhlet apparatus, where fat was extracted with petroleum ether at 70-80°C for 8 hours (Ranganna, 2015). Fiber content was measured as crude fiber by sequentially treating the sample with dilute sulfuric acid and sodium hydroxide solutions. Protein content was calculated by estimating nitrogen using the Kjeldahl method (Ranganna, 2015). Ash was estimated by burning samples at 550°C in a muffle furnace until constant weight was achieved. Total carbohydrate content of the samples was calculated by difference, that is, by subtracting the measured protein, fat, ash and moisture content (Pearson, 1976).

Determination of pH and vitamin C

The pH of the dragon fruit samples was determined by using a pH meter (Model: LE pH Electrode LE438-IP67, Mettler Toledo, Hong Kong). The ascorbic acid content was determined using the 2,6-dichlorophenol-indophenol visual titration method as described by (Ranganna, 2015).

Determination of minerals

Sodium (Na), magnesium (Mg), calcium (Ca) and Potassium (K) were determined using Atomic Absorption Spectrometer (Model- PinAAcle 900H) at specific wavelengths for each mineral according to Sanchez-Castillo *et al.*, 1998.

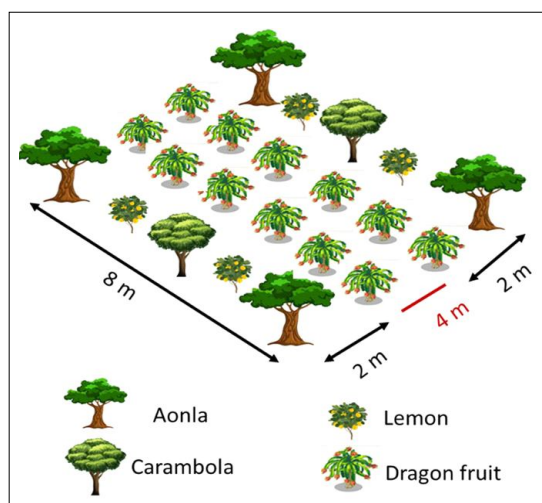


Fig 1: Schematic diagram of multistoried fruit production model.

Measuring the energy content

Total calories of samples were estimated using an oxygen bomb calorimeter (Model: 1341, Parr Instrument Company, USA).

Data analyses

MS-Excel, STATISTX 10 and R software (version 4.3.2) were used to process, calculate and analyze the data. To compare the treatment means, the necessary tests were run. Least Significant Difference (LSD) was used to adjust the mean differences at 5% and 1% level of significance.

RESULTS AND DISCUSSION

Photosynthetically active radiation (PAR) distribution

The T_3 treatment (dragon fruit sole) had the highest mean maximum light intensity ($1503.36 \mu\text{mol m}^{-2} \text{s}^{-1}$), followed by the T_2 treatment (aonla + dragon fruit) at $1181.70 \mu\text{mol m}^{-2} \text{s}^{-1}$ and the T_1 treatment (multistoried system) at $1128.22 \mu\text{mol m}^{-2} \text{s}^{-1}$. The PAR received by the T_1 and T_2 was 75 and 78.60%, respectively. Due to variation of the canopy density over storied tree species light variation has occurred on dragon fruit (Fig 2).

Fruit length, diameter and weight

The interaction of the multistoried fruit production model and dragon fruit genotypes significantly affected fruit length, diameter and weight (Fig 3). The longest fruit (8.74 cm) was observed in the T_1V_2 combination (white-fleshed genotype in multistoried), while the smallest (7.92 cm) was in T_3V_1 . The multistoried system (T_1V_1) produced the widest fruit (11.66 cm), while the narrowest was in T_3V_1 (7.92 cm). Red-fleshed genotypes produced larger, wider fruit (261.67 g in T_1V_1). The multistoried system yielded larger fruit (154.34 g in T_3V_2) due to fewer fruits per plant, increasing individual fruit weight (Reza *et al.*, 2022).

Moisture level

The moisture contents of dragon fruit in different treatments and genotypes were given in Table 1. The white fleshed genotype had the maximum moisture content (86.36%) in the T_3V_2 treatment, moderate moisture content was found in T_2V_2 treatment and in T_1V_2 treatment. The lowest moisture content was found in the red fleshed genotype of dragon fruit in T_3V_1 (84.10 %) and in T_2V_1 (84.16 %) treatments, respectively. According to (Nomura *et al.*, 2005 and Sonawane, 2017) the moisture percentage of dragon fruit was 83-89%, which was roughly close to the dragon fruit used in the study.

pH

pH is the measurement of acidity or alkalinity of a product. pH of dragon fruit samples was not significantly varied and the value ranged from 4.63 to 4.66 (Table 1). According to Sonawane, (2017) and Nomura *et al.*, (2005) dragon fruit pH range was 4 to 6 which supports the present findings.

Brix content

The highest TSS (25.28%) was recorded in the T_3V_1 treatment, followed by T_1V_1 and T_2V_1 . The lowest TSS

(23.06%) was found in T_3V_2 , which was statistically similar to T_1V_2 (23.11%) and T_2V_2 (23.10%). These results suggest that red dragon fruit, with higher TSS content, is sweeter than white-pulped varieties. Mallik *et al.* (2018) reported that TSS in dragon fruit ranges from 23.10% to 27.17%, with fruit setting times significantly influencing TSS content.

Energy content

Energy measurement is crucial for dietary balance. T_2V_1 had the highest energy content (62.70 Kcal/100 g), followed by T_3V_1 (62.50 Kcal/100 g), while T_2V_2 had the lowest (40.40 Kcal/100 g) (Table 1). Red-fleshed dragon fruit had higher energy content than the white-fleshed variety. Patel and Ishnava, (2019), Nurul and Asmah, (2014) and Wichienchot *et al.* (2010) reported 60 Kcal/100 g in fresh dragon fruit.

Sugar content

The highest total and reducing sugar were in T_1V_1 , followed by T_2V_1 and T_3V_1 , while T_1V_2 had the lowest (Table 1). T_2V_1 had the highest non-reducing sugar and $T1V2$ the lowest. Shaded conditions in multistoried models may enhance sweetness. Red dragon fruit, with higher TSS, had more sugar than the white variety (Liaotrakoon *et al.*, 2013). Nurul and Asmah, (2014) noted that the growing environment significantly affects dragon fruit's nutritional and phytochemical composition.

Fat content

Both the dragon fruit genotypes contain 0.395 g/100 g fat in all the three treatments (Table 1). According to Sonawane, (2017) the fat level of dragon fruit was 0.4 g/100 g which was roughly similar to the dragon fruit that was studied.

Carbohydrate content

Energy measurement is crucial for dietary balance. T_2V_1 had the highest energy content (62.70 Kcal/100 g), followed by T_3V_1 (62.50 Kcal/100 g), while T_2V_2 had the lowest (40.40 Kcal/100 g) (Table 1). Red-fleshed dragon fruit had higher energy content than the white-fleshed variety. Patel and Ishnava, (2019); Nurul and Asmah, (2014) and Wichienchot *et al.* (2010) reported 60 Kcal/100 g in fresh dragon fruit.

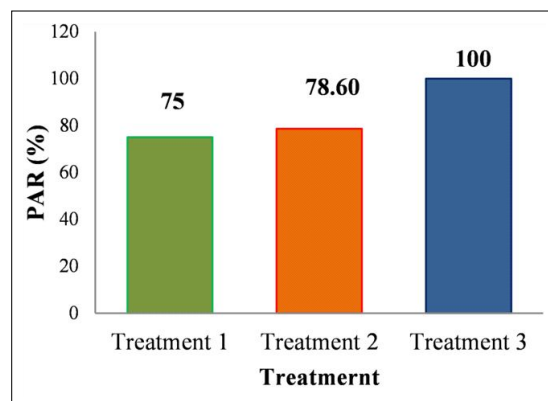


Fig 2: Typical distribution of PAR (Photosynthetically Active Radiation) under various conditions.

Fiber content

Dragon fruit's highest fiber content was in T_3V_1 (0.68 g/100 g), moderate in T_2V_1 (0.55 g) and lowest in T_3V_2 (Table 1). Red-

fleshed dragon fruit had more fiber, likely due to genetics. Liaotrakoon *et al.* (2013) reported fiber content ranging from 0.5-0.7 g/100 g, supporting this study.

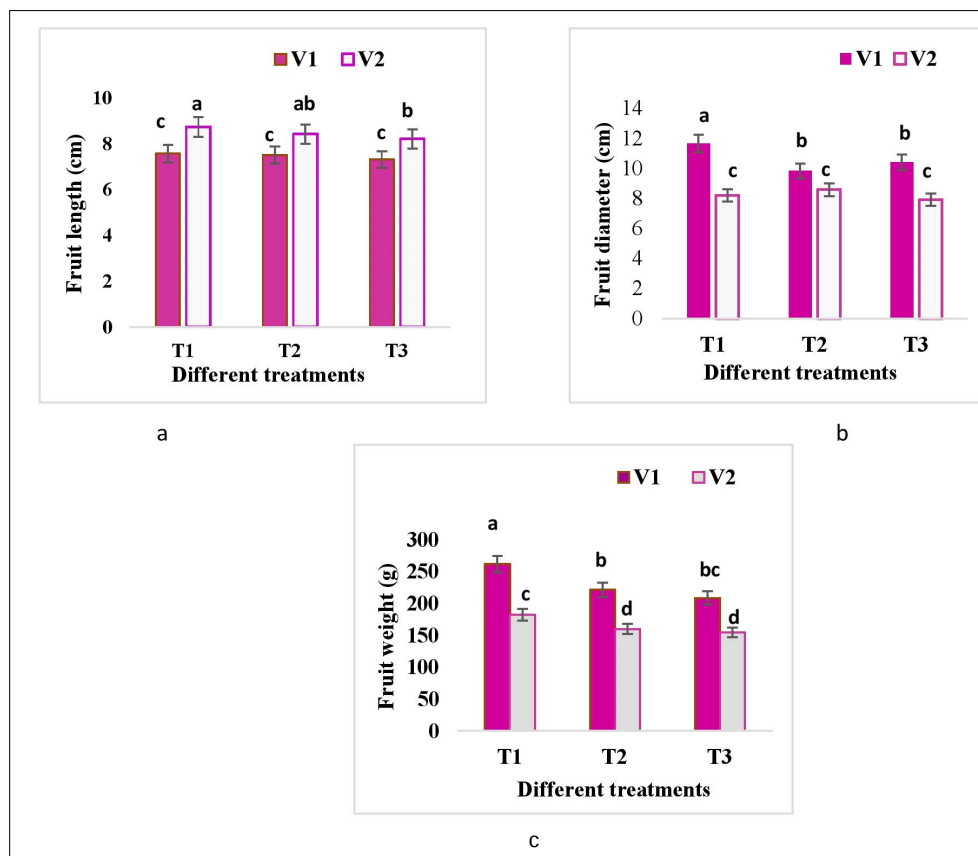


Fig 3: Dragon fruit (a) length, (b) breath and (c) weight at harvest in a multistoried fruit production model. (T_1 : Aonla + carambola + lemon + dragon fruit, T_2 : Aonla + dragon fruit, T_3 : Dragon fruit sole).

Table 1: Biochemical composition of dragon fruit genotypes under various treatment regimes (100 g of fresh dragon fruit pulp).

Treatment Nutrients	T_1V_1	T_1V_2	T_2V_1	T_2V_2	T_3V_1	T_3V_2	CV
Moisture (%)	84.83b	85.30b	84.16c	85.36b	84.10c	86.36a	0.49
pH	4.63	4.64	4.63	4.66	4.66	4.63	1.33
TSS (%)	25.21ab	23.11c	25.1b	23.10c	25.28a	23.06c	0.47
Energy (Kcal)	62.10c	50.10d	62.70a	40.40e	62.50b	49.7d	0.13
Total sugar (%)	12.4a	6.20d	11.7b	6.21d	11.68b	6.49c	0.64
Reducing sugar (%)	11.49a	5.60d	10.41b	5.58d	10.41b	5.72c	0.70
Non-reducing sugar (%)	0.93b	0.60d	1.27a	0.68d	1.26a	0.71c	0.29
Carbohydrate (g)	12.33c	10.80d	12.5b	10.57e	12.64a	10.85d	0.38
Fat (g)	0.39a	0.39a	0.39a	0.39a	0.39a	0.39a	0.39a
Fiber (g)	0.52c	0.31d	0.55b	0.31d	0.68a	0.31d	1.70
Protein (g)	1.16ab	1.11b	1.17a	1.13ab	1.16ab	1.12b	2.42
Ash (%)	1.80a	1.60c	1.79a	1.60c	1.80a	1.60c	2.88
Vitamin C (mg)	24.70b	22.79c	24.83ab	22.80c	25.12a	22.80c	0.84

T_1 : Aonla + carambola + lemon + dragon fruit (multistoried), T_2 : Aonla + dragon fruit (double story), T_3 : Dragon fruit sole (open field), V_1 : Red fleshed dragon fruit, V_2 : White fleshed dragon fruit.

Note: Different letters in a column indicate significant difference.

Protein content

Protein content of dragon fruit varied from 1.17 to 1.11 g among all the treatment combinations and there was no significant difference found. (Table 1). According Sonawane, (2017) protein content of dragon fruit was 0.50 to 1.10 g/100 g fresh sample which supports the result.

Ash level

T3V1 has noticeably the greatest ash content (1.80 g/100 g) and the lowest ash content was found in T₃V₂ (1.60 g/100 g) treatment combination (Table 1). Red fleshed dragon fruit genotype produced comparatively higher amount of ash than white one irrespective of treatments. This variation in ash content might be due to the genetic make-up of dragon fruit genotypes. According to Kishore, (2016) ash content of dragon fruit varies from 1.50 g to 2.00 g which was approximately similar to that of the result.

Vitamin C content

Treatment combinations significantly affected vitamin C content in dragon fruit. T₃V₁ had the highest (25.12 mg/100 g), while T₁V₂ had the lowest (22.79 mg) (Table 1). Full sun exposure increased vitamin C levels. Sumaryani and Dharmadewi, (2018) reported 29.00 mg in red-fleshed and 22.30 mg in white-fleshed dragon fruit. Sonawane, (2017) found 20.50 mg, while Kishore, (2016) reported 25.00 mg, aligning with the present study.

Mineral composition

Minerals are essential for health, classified as macro and trace elements. The T₁V₁ treatment yielded the highest mineral content in dragon fruit, with K (5.80 mg) being the highest, followed by Mg and Na, while Ca was lowest (0.76 mg). All treatments showed a similar trend (K > Mg > Na > Ca), likely influenced by genotype and shading (Table 2).

Table 2: Mineral composition of dragon fruit in different agroforestry treatment combination (100 g of fresh dragon fruit pulp).

Treatment	Minerals (mg/g)			
	Sodium (Na)	Calcium (Ca)	Magnesium (Mg)	Potassium (K)
T ₁ V ₁	1.33b	0.76c	2.43b	5.80a
T ₁ V ₂	1.34c	1.01c	3.92b	7.50a
T ₂ V ₁	1.75c	0.61d	3.23b	6.12a
T ₂ V ₂	1.46c	1.02c	4.20b	7.66a
T ₃ V ₁	1.96c	0.61d	3.50bc	5.6a
T ₃ V ₂	0.34c	0.87c	3.94b	7.47a
CV	0.73	1.06	1.48	1.54

T₁: Aonla + carambola + lemon + dragon fruit (multistoried), T₂: Aonla + dragon fruit (double storied), T₃: Dragon fruit sole (open field), V₁: Red fleshed dragon fruit, V₂: White fleshed dragon fruit.

Note: Different letters in a column indicate significant difference.

Table 3: Nutritional comparison between two dragon fruit genotypes.

Nutrients	Genotype		p-value
	Red fleshed genotype	White fleshed genotype	
Moisture (%)	84.36a	57.24b	<0.05
pH	4.64	4.62	NS
TSS (%)	25.00a	23.00b	<0.05
Energy content (Kcal)	62.43a	48.70b	<0.05
Total sugar (%)	11.92a	6.50b	<0.05
Reducing sugar (%)	10.77a	5.88b	<0.05
Non-reducing sugar (%)	1.15a	0.70b	<0.05
Carbohydrate (g)	12.49a	10.50b	<0.05
Fat	0.39	0.39	NS
Fiber content (g)	0.58a	0.32b	<0.05
Protein (g)	1.16a	0.75b	<0.05
Ash (%)	1.76a	1.06b	<0.05
Vitamin C (mg)	24.8a	22.8b	<0.05
Sodium (mg/g)	1.58a	0.69b	<0.05
Calcium (mg/g)	0.63b	0.66a	<0.05
Magnesium (mg/g)	2.50b	3.20a	<0.05
Potassium (mg/g)	4.59b	6.31a	<0.05

Note: Different letters between column in the same row indicate significant difference.

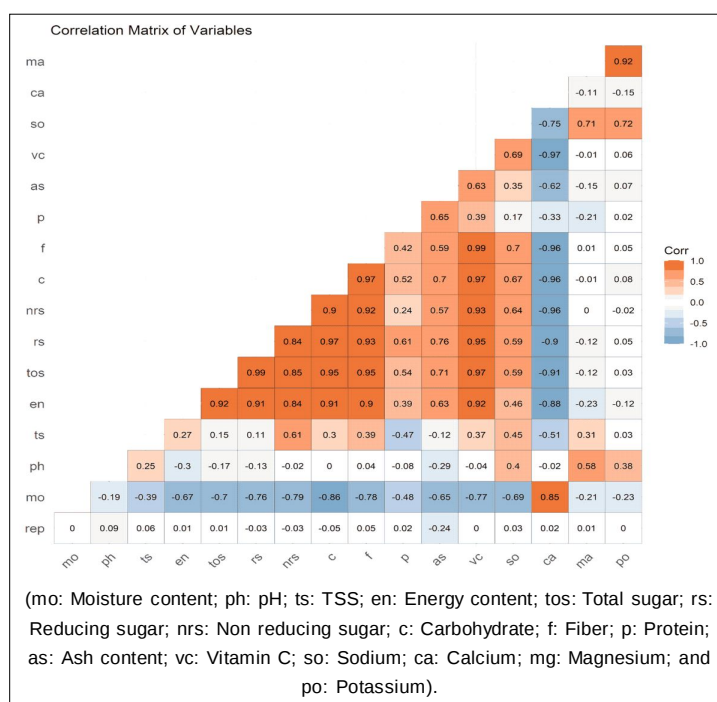


Fig 4: Correlation matrix of nutritional qualities of dragon fruit.

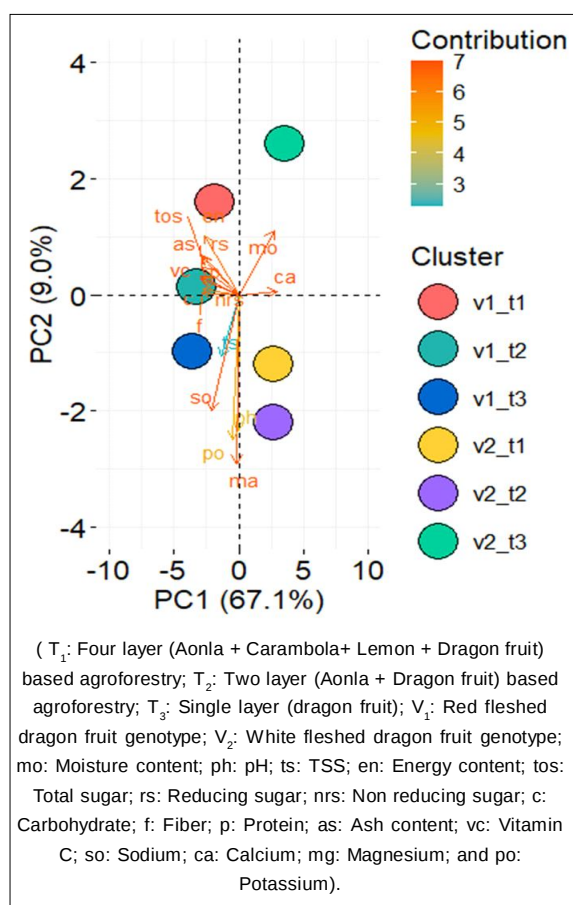


Fig 5: Biplot principal component analysis of dragon fruit genotypes in different shade level and their effect in nutritional quality.

Liaotrakoon *et al.* (2013) noted that genotype and flowering time affect fruit growth, size and nutritional quality.

Nutritional comparison of dragon fruit genotypes

Two dragon fruit genotypes showed significant nutritional differences under various treatments (Table 3). The red-fleshed genotype had higher moisture, TSS, energy, sugars, fiber and vitamin C than the white-fleshed type. Mineral content also varied significantly (Table 3), with red-fleshed dragon fruit containing more Na (1.58 mg/g), while the white-fleshed type had slightly higher Ca (0.66 mg/g), K (6.31 mg/g) and Mg (3.20 mg/g), likely due to genetic factors. Liaotrakoon *et al.* (2013) noted species, origin and harvest time influence nutritional quality, while Nurul and Asmah, (2014) highlighted environmental effects. The correlation heat map (Fig 4) reveals strong positive and negative relationships, including a significant negative correlation between fiber and sodium ($r = -0.96$) and a strong positive correlation between total sugar and energy content ($r = 0.99$).

Biplot principal component analysis

The first two principal components (PC1: 67.1%, PC2: 9.0%) explain 76.1% of the total variance (Fig 5). The PCA biplot reveals six distinct clusters representing dragon fruit genotypes and treatments. Genotypes V₁ and V₂ are clearly separated, indicating significant differences. Treatments 2 and 3 enhance ash content and vitamin C, while treatment 1 boosts total and reducing sugars in V₁. In V₂, treatment 3 improves mineral traits like calcium and magnesium, aiding treatment optimization.

CONCLUSION

Dragon fruit is a fruit of full sun light, but this fruit can be cultivated in 75-78.6% shade condition in multistoried fruit

production model. Cultivation in shade does not spoil the nutritional quality of this fruit although multistoried fruit production model with maximum shade produces large (261.67 g) and sweet (TSS, 25%) dragon fruit than open field condition where plants get full sunlight. Double storied system where 78.60% shade produces almost same quality fruits like open field condition. The studied nutritional quality parameters vary between red fleshed and white fleshed genotypes of dragon fruit and red fleshed genotype of dragon fruit found superior than white fleshed genotype in content nutrients but minerals like Ca, Mg and K are slightly higher in white flesh genotype of dragon fruit than red one.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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