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Production of dragon fruit under partial shade of aonla tree: a climate resilient agro- technology

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ABSTRACT

Aonla based multistoried production system is a climate resilient agro-technology to mitigate the devastating effects of climate change by offering multidimensional benefits. The goal of the present trail was to evaluate the performance and profitability of dragon fruit under shade of aonla tree. Three production systems were used as three treatments i.e. T_1 (multi-storied), T_2 (double storied) and T_3 (open field) with two dragon fruit genotypes such as V_1: Red fleshed dragon fruit and V_2: White fleshed dragon fruit. Data on temperature, photosynthetically active radiation, yield and benefit cost ratio (BCR) were evaluated. The temperature was reduced by 1.77 ℃ and 1.27 ℃ in T_1 and T_2 treatment, respectively. The maximum photosynthetically active radiation was the highest in T_3 treatment (1503.36µ mol $m^{-2}s^{-1}$) followed by T_2 (1181.70 µ mol $m^{-2}s^{-1}$) and the lowest in T_1 (1128.22 µmol $m^{-2}s^{-1}$). The highest fruit yield per plant (9.01 kg $plant^{-1}$) and BCR (5.04) were recorded in T_2 treatment with red fleshed dragon fruit. The result revealed that red fleshed genotype of dragon fruit was found as suitable and profitable for partial shade of multi-storied production system.

Key words: climate resilient, dragon fruit, shade, aonla, BCR

INTRODUCTION

Bangladesh is a deltaic small country of 1, 47,570 km^2 with a large population (168,770,968) having 8.77 million hectares of cultivable land (BBS, 2022). It has the lowest per capita arable land due to its high population density. Predominantly Bangladesh is an agro-based country and this sector employs 40.6% of the total labor force and contributes 11.50 % of the country's GDP (BBS, 2022). The prediction indicates that the built-up area will increase by 15.06%, whereas 9.77% of agricultural land will be converted to other land uses through urban expansion by 2029 (Kafy, 2021). Moreover, about 80% of arable land is used for cereal crop production, which consequently reduces the area of other cash crops. Under these scenarios, the existing land-use systems with separate allocation to agriculture and forest are insufficient to meet the demands for food, fuel, fodder, timber, and other minor products in the 21st century. The per capita consumption of fruits of Bangladesh is very low which is only 35.78 g/head/day against the standard requirements of 100 g/head/day (BBS, 2022). On the other hand, agriculture is always vulnerable to unfavorable weather events and climate conditions. Impact of climate change on agriculture is one of the major deciding factors influencing the future food security of mankind on earth. Although advance agricultural research has been trying to earn the food security for the people but nutritional security is not yet addressed.

Under the above conditions, climate smart integrated fruit gardening will be preferable cropping system for ecological balance and also for achieving nutritional security through

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diversified production at changing climate. According to Bernstein (2008) global temperature will increase 1.5 to 4℃ by the next 50 years. In this connection tropical fruit species like dragon fruit can be incorporated in different tree orchards which will easily be sustained at increasing temperature.

Multi-storied production system offers production of various fruits under different shade conditions by maximum utilization of different photosynthetically active radiation (PAR) levels. In this system different components are arranged in different layers. So, the light limitation of lower storied crop is most important consideration. Hence, lower storied crops selection for multistoried system is important and difficult task. Therefore, different initiative of screening of suitable crops for lower storied component is going on and dragon fruit genotypes are found suitable in aonla based system (Reza *et al*., 2022).

Aonla (*Phyllanthus emblica*) is one of the most important deciduous plants for agroforestry practices and also naturally grown in the terrace eco-system in Bangladesh. The fruit is highly nutritious and the richest source of vitamin C.

Dragon fruit is a vine cactus species belonging to the family Cactaceae (Patwary *et al*., 2013). The plant is attractive due to its exotic appearance (Liaotrakoon, 2013). Dragon fruits are gaining popularity for their nutritional and medicinal properties (Sonawane, 2017). This fruit is considered as an important economic fruit species worldwide due to its nutritional values (Rifat *et al*., 2019). The cultivar, season, climate, cultural practices, water availability, transport, handling and storage may affect the bioactive compounds of dragon fruit (Franke *et al*., 2004; Wall, 2006). Dragon fruit has great potential as a new crop for Mediterranean growers due to the requirement of little water and well adaption to the high temperatures (Trivellini *et al*., 2020). *Hylocereus costaricensis*, a red fleshed pitaya and *H. undatus*, a white fleshed pitaya is the two major species growing in Bangladesh. The biggest advantage of this crop is that once planted, it will grow for about 20 years, and 1 hectare could accommodate about 800 dragon fruit plant. It produces fruit in the second year after planting and attain in full production within five years. The flower is so beautiful that it is nicknamed as “Noble Women” or “Queen of the Night”. Potentiality of this fruit as lower storied crop in the multistoried agroforestry system is good which is observed by Reza *et al.* (2022). But very few research works have been done on this fruit in Bangladesh.

Considering the above facts, it was aimed to find out a high productive multi-storied production system, as a climate smart approach with dragon fruit for homestead areas in Bangladesh.

MATERIALS AND METHODS

Location

The experiment was conducted at the existing aonla based multi-storied garden in the Research Farm under the Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur-1706, Bangladesh from 1 July 2019 to 30 June 2023.

Climate, Weather and Soil

The experimental area has subtropical climate characterized by three distinct seasons, the monsoon or rainy season, the winter or dry season and the pre-monsoon or hot season. The soil of the experimental field was originally shallow red brown terrace which is silty clay loam in texture being acidic in nature (Brammer, 2022; Riyadh *et al*., 2018; Ferdous *et al*., 2022).

Experimental Design and Layout

The experiment was conducted in 23 years old aonla orchard established in 2000 maintaining 8 m × 8 m distance, which was used for the experiment. Lemon and carambola were planted in 2008 in between the aonla tree line which formed middle story. Each carambola plant was planted just middle of two aonla trees and each lemon plant was planted just middle of aonla and carambola plant. For further maximization of land use, two modern dragon fruit genotypes were planted in the alley as test crop. So, in the experiment, aonla tree was treated as upper storied lemon and carambola were treated as middle storied, dragon fruit was treated as lower storied crops. The experiment was laid out in a two factorial randomized complete block design (RCBD) with three replications. The experiment was consisted of the two factors as

Factor A: Agroforestry systems-

T_1: Aonla + Carambola + Lemon + Dragon fruit (Multi-storied)

T_2: Aonla + Dragon fruit (Double storied)

T_3: Dragon fruit (open field);

Factor B: Dragon fruit genotypes (Five years old)-

V_1: Red fleshed dragon fruit

V_2: White fleshed dragon fruit.

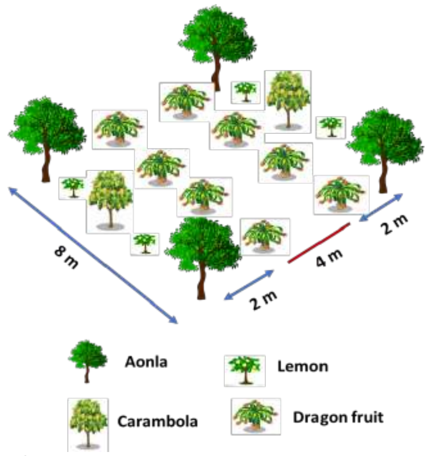

Figure 1. Schematic diagram of aonla based multi-storied technology

Data Collection

Climate parameter

Above ground maximum and minimum temperature of each treatment was recorded by Six's maximum and minimum thermometer. Light was measured by sunflex ceptometer (LP-80 AccuPAR) on each replication and it was done to determine the extent of shading by the aonla tree and expressed as $\mu molm^{-2}s^{-1}$.

Yield and yield contributing parameters

The total number of fruits plant^{-1}, fruit length, breath, weight, edible portion and total fruit yield plant^{-1} were taken gradually from each plot and averaged yield was converted to kgplant^{-1} then expressed in tha^{-1}.

Benefit Cost Ratio

Benefit cost ratio is the ratio of gross return with total cost of production. It was calculated by using the following formula (Alam, 2018). Benefit Cost Ratio = Gross return (Tk./ha)/Total cost of production (Tk/ha).

Data Analyses

All data were processed, calculated, and analyzed by using computer software MS-Excel and MSTAT- C. Necessary tests were performed to compare the treatment means. The mean differences were adjusted by Least Significant Difference (LSD) and Duncan's Multiple Range Test (DMRT) at 5 % level of significance.

RESULTS AND DISCUSSION

Temperature of the study location

The average maximum temperature was found in T_3 (32.33 ℃) followed by T_2 (31.06 ℃) and T_1 (30.56 ℃) in Fig2. The highest minimum temperature was recorded in T_3 (21.28 ℃) and the lowest minimum temperature was found in both T_2 and $T_1$and the value was 21.08℃. In T_1 and T_2temperature lowered by 1.77 ℃ and 1.27 ℃, respectively compared to the open field condition (T_3) due to the presence of double storied tree species. Similar result was obtained by Reza *et al.* 2022 in dragon fruit based multi-storied production system.

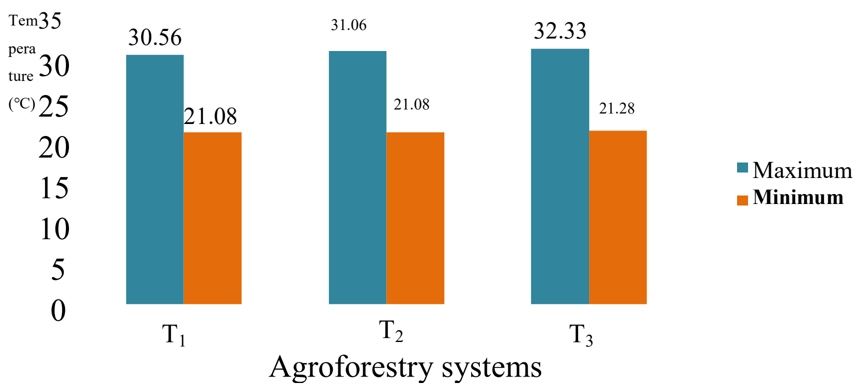

Figure 2. Prevailing average maximum and minimum temperature at different treatments during the study period.T_1: (aonla + carambola + lemon + dragon fruit), T_2: (aonla + dragon fruit), T_3: dragon fruit sole (open field)

Distribution of Photosynthetically Active Radiation (PAR)

The mean maximum light intensity was the highest in T_3 treatment (1503.36μ mol $m^{-2}s^{-1}$) followed by in T_2 (1181.70 μ mol $m^{-2}s^{-1}$) and the lowest in T_1 (1128.22 μmol $m^{-2}s^{-1}$). In T_1 and T_2 treatments, the light intensity were lowered by 375.15 μmol$m^{-2}s^{-1}$ (75 %) and 321.66 μmol$m^{-2}s^{-1}$ (78.60 %), respectively (Fig 3). Due to deciduous nature of aonla trees under-storied crops and trees received about 75 % to 80 % of the incident light. Different systems received different levels of light due to the different sizes and shapes of the over-story canopy (Reza *et al.*, 2022)

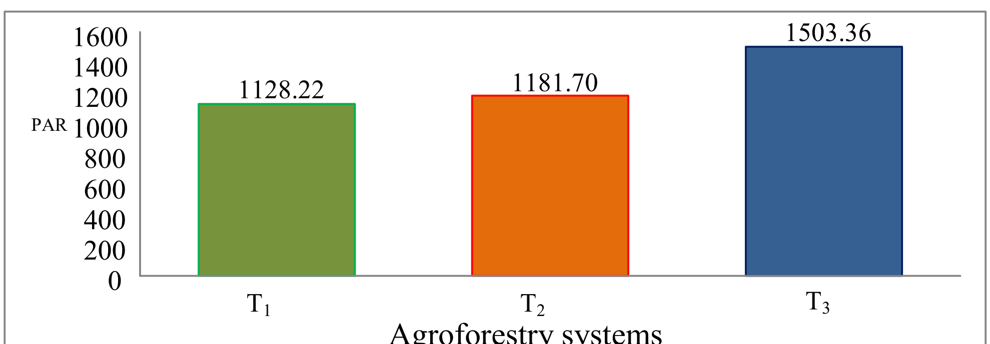

Figure 3. *Average Photosynthetically Active Radiation (PAR) distribution in different treatments.T_1: (aonla + carambola + lemon + dragon fruit), T_2: (aonla + dragon fruit), T_3: dragon fruit sole (open field)*

Number of dragon fruit/plant

Number of fruits per plant is the vital yield contributing character of dragon fruit, which was influenced significantly by the treatment combinations. The maximum number of fruits (41) was harvested from red fleshed genotype in open field (T_3V_1) which was statistically similar to that of same genotype under aonla (T_2V_1). Significantly the minimum number of fruits per plant (14) was recorded in T_1V_2 combination which is statistically similar to T_1V_1 combination. Other combinations produced the moderate number of fruits per plant and values were 30 and 31 for T_2V_2 and T_3V_2, respectively (Fig 4). The number of fruits per plant can be influenced by low sunlight. Insufficient sunlight can limit the rate of photosynthesis, leading to reduced energy available for the development of flowers and fruits. It can lead to poor flower development and consequently, a lower number of fruits. In our field different systems received different levels of light due to the different sizes and shapes of the over story canopy, where multi-storied system received lower sunlight as a result number of fruits might be lower in this system.

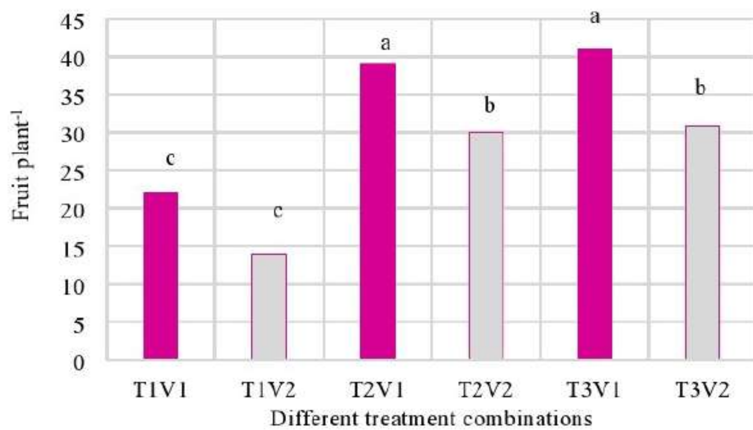

Figure 4. Number of dragon fruit per plant in different treatment combination. T_1: (aonla + carambola + lemon + dragon fruit), T_2: (aonla + dragon fruit), T_3: dragon fruit sole (open field), V_1: red fleshed dragon fruit, V_2: white fleshed dragon fruit

Fruit length and breath

The interaction effect of the aonla based systems and dragon fruit genotypes on fruit length and fruit diameter were significant (Table 1). The maximum dragon fruit length was observed in T_1V_1 combination (14.5 cm). The T_2V_2 combination produced moderate fruit length (12.20 cm) which was statistically similar to that of T_1V_2 and T_3V_2. On the other hand, the minimum fruit length was recorded in T_3V_1 (8.40 cm). Again, in case of fruit diameter the widest fruit (8.00 cm) was found in T_1V_2. The moderate fruit diameter was recorded in T_2V_2 (7.70 cm) which was statistically similar with T_1V_1 combination. The narrowest fruit found in T_3V_1 (6.20 cm) which was statistically similar with T_3V_2. This study showed that white fleshed genotype produced long and wide fruit as compared to red fleshed genotype. Nangare *et al.* (2020) also observed that dragon fruit is a fleshy berry, oblong to ovoid, up to 6-12 cm long and 4-9 cm thick, which is quite similar with this finding.

Table 1. Interaction effect of different production systems and genotypes (dragon fruit) on fruit length, fruit diameter, fruit weight, edible portion and yield of dragon fruit

Treatment Combination	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Edible portion of fruit (%)	Fruit yield (gm $Plant^{-1}$)	Fruit yield (t ha^{-1})
T_1V_1	11.70b	7.50b	232.00c	70.03c	4793.18	4.80
T_1V_2	14.5a	8.00a	295.00a	75.95a	3873.94	3.88
T_2V_1	10.00bc	7.00bc	231.00c	70.00c	8451.38	8.46
T_2V_2	12.20b	7.70b	279.34b	71.23b	7860.44	7.86
T_3V_1	8.40c	6.20c	154.00d	63.27d	10102.40	10.10
T_3V_2	10.7b	6.60c	216.00cd	66.01cd	10720.00	10.72
CV %	7.42	10.71	17.34	22.81	-	-
P- value	<0.05	<0.05	<0.05	<0.05	-	-

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.

Fruit weight and edible portion

The interaction effect of the aonla based production systems and dragon fruit genotypes had significant effect on fruit weight and edible portion (Table 1). The maximum fruit weight and edible portion (295.00 g and 75.95 %) were observed in T_1V_2. That's mean white fleshed genotype (V_2) produced large fruit in multi-storied. The minimum fruit weight and edible portion (154.00 g and 63.27 %) were obtained from T_3V_1, which was statistically similar to those of T_3V_2 (216.00 g and 66.01 %). Among the treatments, T_1 provided larger fruit compared to open field (T_3) and double storied treatment (T_2) this was due to the lower number of fruits per plant which increased the fruit weight and edible portion of fruit. Average fruit weight (350-400 g, although may weigh up to 900 g) was observed by Nangare *et al.* (2020).

Yield of dragon fruit

The red fleshed dragon fruit genotype (V_1) produced higher yield than that of white fleshed genotype (V_2) in - (T_1) and double storied (T_2) system but the highest yield (10.72 t ha^{-1}) was obtained from T_3V_2 (white fleshed genotype in open field) because of higher fruit weight of white dragon fruit. Almost similar yield was obtained from $T_2V_1$and T_2V_2 (red and white fleshed genotype in double storied) such as 8.46 and 7.86 t ha^{-1}. The lowest yield (3.88 t ha^{-1}) was recorded in T_1V_2.The result revealed that V_1 (red fleshed genotype) was found suitable for partial shade condition like aonla tree and successfully grown without scarifying the significant yield loss compare to that of open field (Table 1). Open field produce higher yield because of high number of plant population.

Yield of other fruits

There are three production system in this experiment, namely multi-storied system (T_1) which is composed of aonla, carambola, lemon and dragon fruit; double storied system (T_2) which is composed of aonla and dragon fruit and sole cropping (T_3) composed of completely dragon fruit (Table 2). The yields of aonla (8112 kg ha^{-1}) and carambola (2238.6 kg ha^{-1}) were recorded in T_1, along with 5615 pieces ha^{-1} of lemon and 4793.18 kg ha^{-1} red fleshed and 3873.94 kg ha^{-1} white fleshed dragon fruit, respectively. T_2 yields for aonla were 7383.48 kg ha^{-1}, while dragon fruit yields for the red and white fleshed genotypes were 8451.38 and 7860.44 kg ha^{-1}, respectively. Dragon fruit genotypes with red and white fleshed had yields of 10102.4 and 10720 kg ha^{-1} in T_3.

Table 2. Yield of other fruits in multi-storied system

Fruits / Treatments	Aonla ($kg\ ha^{-1}$)	Carambola ($kg\ ha^{-1}$)	Lemon ($piece\ ha^{-1}$)	Dragon fruit ($kg\ ha^{-1}$)	
				V_1	V_2
T_1	8112	2238.6	5615	4793.18	3873.94
T_2	7383.48	-	-	8451.38	7860.44
T_3	-	-	-	10102.4	10720

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.

Benefit Cost Ratio (BCR)

BCR is the one of the most important economic indices, to measure the profitability of the system. The maximum BCR was observed in T_2 (aonla + dragon fruit based double storied system).The highest BCR 5.04 was recorded for aonla + red fleshed dragon fruit followed by aonla + white fleshed dragon fruit (4.74) (Table 3). The minimum BCR 2.96 was found in T_1V_1 (white fleshed dragon fruit in multi-storied). The BCR value indicated that aonla + dragon fruit-based system (T_2) was the most profitable practice due to high market price and fruit yield per plant, BCR became higher in T_2 treatment than T_3 (openfield) and T_1 (aonla + carambola + lemon + dragon fruit) treatment. Rahman *et. al.* (2018) calculated BCR for jackfruit + eggplant agroforestry system (double storied system) and sole eggplant system and found higher BCR in double storied than sole cropping which were 4.56 and 3.13, respectively.

Table 3. Yield and economic analysis of different multi-storied production system comparing sole cropping

Treatments	Yield ($Kg\ ha^{-1}$)	Total cost (BDT)	Gross income (BDT)	Net return (BDT)	BCR	Rank
T_3V_1	10102.4	526797.48	2022400	1495602.52	3.83	4th
T_3V_2	10720	526797.48	2144000	1617202.52	4.06	3rd
T_2V_1	7383.48 + 8451.38	386180.26	1948697.8	1562517.54	5.04	1st
T_2V_2	7383.48 + 7860.44	386180.26	1830509.8	1444330	4.74	2nd
T_1V_1	8112 + 2238.6 + 5615 + 4793.18	386180.26	1326633	940452.7	3.43	5th
T_1V_2	8112 + 2238.6 + 5615 + 3873.94	386180.26	1142785	756604.7	2.96	6th

Unit price ($Tk\ Kg^{-1}$): Aonla ($35Tk\ Kg^{-1}$), Carambola ($20Tk\ Kg^{-1}$), Dragon fruit ($200Tk\ Kg^{-1}$) and Lemon ($7Tkpiece^{-1}$), 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.

CONCLUSION

Dragon fruit is recently commercially cultivated in Bangladesh and highly demandable fruit for its attractive fruit color, nutraceutical value, excellent export potential and highly remunerative in nature as produces yield from 14- 16 months after planting of stem cutting and yield up to 20 years. In T_1 and T_2 treatments temperature lowered by 1.77 ℃ and 1.27 ℃, respectively and due to deciduous nature of aonla trees under-storied crops. Trees received about 75 % to 80 % of the incident light that's why may be the length, breath and weight of dragon fruit was found maximum in double and multi-storied system. The highest fruit yield per plant (9.01 kg $plant^{-1}$) and BCR (5.04) were recorded in T_2 treatment with red flesh dragon fruit. The result revealed that red fleshed genotype of dragon fruit was found suitable and profitable for partial shade and successfully grown without scarifying the significant yield loss compare to that of open field.

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