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PROFITABILITY OF THREE VEGETABLES IN AONLA BASED MULTISTORIED AGROFORESTRY SYSTEM

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Abstract

Aonla based multistoried agroforestry with vegetables is a promising solution to mitigate the devastating effects of climate change by offering multidimensional benefits. However, Bangladeshi farmers are less aware and equipped. about the cultivation techniques and benefit of multistory agroforestry production systems. Therefore, the present study was aimed to assess the yield potentiality and profitability of aonla based multistoried vegetables production system during the period of November 21 to March 22. Three individual experiments each for tomato, eggplant and potato were laid out in a single factor Randomized Complete Block Design (RCBD) with three replications. Upper storied plant aonla received 100% Photosynthetically Active Radiation (PAR), but incident light was gradually decreased on middle storied (carambola, lemon, dragon fruit) and lower storied (vegetables) in multistoried conditions. The vegetables experienced 50, 78, 98, and 100% PAR in T_1 (Multistoried), T_2 (Aonla + Dragon fruit + Vegetables), T_3 (Dragon fruit + Vegetables) and T_4 (Sole cropping of vegetables) treatment, respectively. Considering the yield of tested vegetables in heaviest shade (T_1), suitability rank was eggplant > tomato > potato. The per plant yield reduction was also high in T_1 such as potato (40.47%) > tomato (34.29%) > eggplant (33.17%). A positive polynomial (for tomato) and linear (for eggplant and potato) relationship was found between yield and light (% PAR). BCR of dragon fruit + eggplant based system 5.02 was found quite profitable. When both BCR and LER were taken into account, the aonla + dragon fruit + eggplant agroforestry system was found the best production technique for production diversification, maximum land use efficiency, and better profitability.

Keywords: Yield, economics, tomato, eggplant, potato, multistoried agroforestry.

Introduction

Bangladesh is an agriculture-based country where most of the people are directly or indirectly involved in agriculture and it is the main driving force for their livelihood. Moreover, Bangladesh is a small deltaic country with 8.82 million hectares of arable land to feed more than 165 million people (BBS, 2021). But increasing non-agricultural uses of land for home, roads and highways, educational institutions, industries and other buildings makes the per capita arable land shrinking over the years gradually. Agricultural production is not increasing expectedly in the background of the overgrowing population. Around 80% of arable land is used for cereal crop cultivation, reducing the space available for other revenue

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crops. Furthermore, for ecological stability and sustainability, a country needs 25% of forest land of its total land area (Rashid, 2013). In Bangladesh agricultural land makes up 65% of its geographical surface and forest lands account for almost 17.58% (BBS, 2019). FAO/WHO (2017) recommended a minimum of 400 g of fruit and vegetables per person per day, whereas people eat only 36 and 167 g of fruit and vegetables per day, respectively (BBS, 2018). Therefore, alternative, nutrient-sensitive, and climate-smart agricultural practices should be pursued to overwhelm the above-mentioned constraints in crop production.

Rural life has always been heavily influenced by agroforestry, notably in Bangladesh. It is essential for preserving the productivity of the land base and for providing household food and energy security, income and employment, investment opportunities, and environmental protection (Miah *et al.,* 2018). Due to its contribution to the economy, society, and ecology, agroforestry can be seen as a potential option for addressing societal expectations and models of sustainable development (Bargali *et al.,* 2009; Jahan *et al.,* 2022). One of the promising solutions for diverse output, high revenue creation, and climate-smart agriculture is an aonla-based multistoried agroforestry system. The study of Deb (2020) revealed that multistoried agroforestry systems have the potential to preserve the plant and animal diversity in different climatic zones of the region and different plant species grown in these multistoried agroforestry systems are confounded by the livelihood requirements and traditional knowledge.

Aonla (*Emblica officinalis*) is a deciduous tree that is productive, hardy, and advantageous for farmers with poor soil which naturally grown in terrace ecosystem of Bangladesh. It has a lot of ascorbic acid and is abundant in minerals, polyphenols, and tannins (Maheshwari *et al.,* 2022). Additionally, rich in reducing sugars, ascorbic acid, and minerals like potassium, calcium, magnesium, and phosphorus, carambola (*Averrhoa carambola*) is a tropical fruit. (Hu *et al.,* 2021). *Citrus limon*, a fruit high in vitamin C, can thrive in a variety of soils, ecosystems, and cultural settings in more than 100 different nations. (Ghosh *et al.,* 2010). Dragon fruit (*Hylocereus* spp.), is rich in essential nutrients such as vitamins, minerals, complex carbohydrates, fiber, antioxidants and betacyanin, which serves as a red/purple pigment with antioxidant properties (Liaotrakoon, 2013).

Potato is one of the main food crops in Bangladesh after rice and wheat and Bangladesh is producing 9987 million MT potatoes in 2020-2021 (BBS, 2021). With a total production of 587 million MT in 2020–2021, eggplant is one of the second-most significant, affordable, and well-liked vegetable crops (BBS, 2021). Tomato a cultivated solanaceous perennial plant bearing a mildly acid, rich in vitamin A, C, calcium and phosphorus; used as fresh or cooked. In Bangladesh, the area of cultivation is about 13,066 ha with the production of about 448 million MT tomatoes in 2020-2021 (BBS, 2021). But still there are gaps prevailed in Bangladesh of these three important vegetables in terms of supply and demand.

Considering the above facts, it was aimed to find out a high productive multistoried agroforestry system, which can be a sustainable land use practice and high yielding multistoried model comprising medicinal plant (aonla), fruit trees (carambola, lemon, dragon fruit) and vegetables through maximum utilization of natural resources (light, water, nutrients) and vertical space for homestead and upland ecosystem of Bangladesh. Therefore, the study was undertaken to examine the yield and economics of tomato, eggplant and potato grown as lower storied crops in aonla based multistoried agroforestry system and also to explore the relationship between PAR of different systems and yield of each vegetables.

Materials and Methods

The aonla orchard was established in 2000 maintaining 8 m x 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 storied. Each carambola plant was planted just middle of two aonla trees and each lemon plant was planted just middle of aonla and carambola plant. Dragon fruit was established in the alley of the fruit trees. So, in the experiment aonla tree was treated as upper storied (1^{st} storied), lemon and carambola were treated as 2^{nd} storied, dragon fruit was treated as 3^{rd} storied and vegetables i.e. tomato, eggplant and potato were treated as lower storied (4^{th} storied) crops.

Design of the experiment

The experiment was laid out in a single factor Randomized Complete Block Design (RCBD) with three replications. Tomato, eggplant and potato were designed as separate experiment. The plot size for each treatment was 4 m x 6 m. Adjacent plots was separated by 1 m distance and neighboring blocks was separated by aonla trees and other tree stories. Aonla Orchard has an adjacent open field to its south where tomato, potato, eggplant and dragon fruits were grown as sole crop. Sole stand of aonla, carambola and lemon were present to the north of multistoried.

Factor A: Agroforestry Systems (4)

T_1 = Aonla + Carambola + Lemon + Dragon fruit + Tomato / Eggplant / Potato (4 storied AGF)

T_2 = Aonla + Dragon fruit + Tomato / Eggplant / Potato (3 storied AGF)

T_3 = Dragon fruit + Tomato / Eggplant / Potato (2 storied AGF)

T_4 = Open field (Tomato / Eggplant / Potato) (sole cropping)

Field Preparation, fertilizer application, and intercultural operation

The field was tilled with spade to achieve a suitable soil condition. Total cow dung (15 t ha^{-1} for each field), potassium in the form of muriate of potash (250 kg ha^{-1}), and P_2O_5 in the form of triple superphosphate (200 kg ha^{-1}), 50% of nitrogenous (N) fertilizer in the form of urea was applied (150 kg ha^{-1}) as a basal dose during the final preparation of the plot. The remaining N (150 kg ha^{-1}) fertilizer was applied at first week of transplanting and at fruiting in two equal doses (25% in each case). To ensure sufficient soil moisture, irrigation was done using a flexible hose pipe when necessary. Weeding were done regularly to reduce competition between weeds and crops for resources when it was necessary.

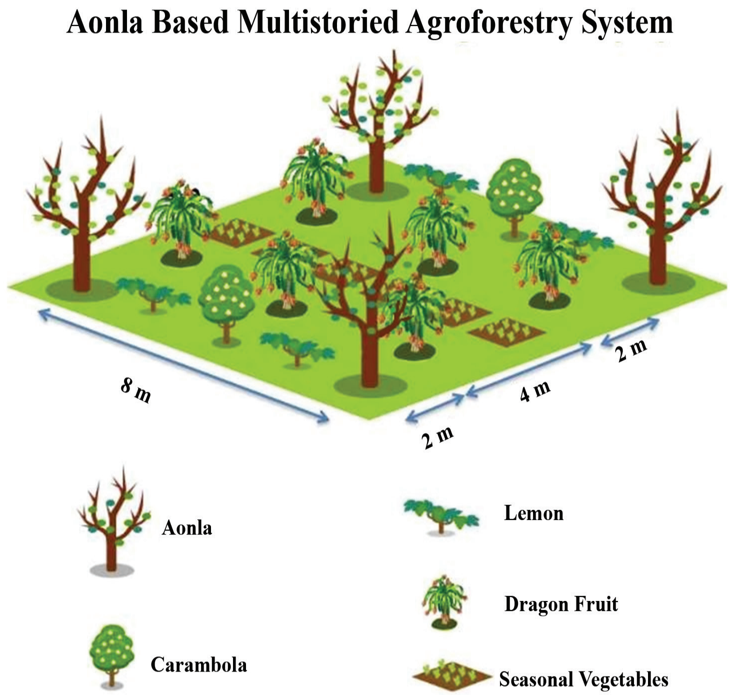

Fig. 01. Schematic diagram of aonla based multistoried technology.

For viral vector control, Actellic®50EC was applied every 25 days interval. Very few seedlings in the plot were damaged after planting and these seedlings were replaced with new seedlings. The replacement was done with healthy seedlings in the afternoon with a bowl of soil. It was important to note that under the agroforestry system, other management practices such as irrigation, fertilizer application were not applied to aonla, carambola and lemon trees, apart from pruning, that's why no production cost was considered for calculating BCR.

Harvesting and data collection

Harvesting of tomato and eggplant were done from 7th February to 21th February and 15th February to 15th march 2022, respectively. On the other hand, potato was harvested on 1st March 2022. Data were recorded on different parameters like number of fruit per plant and individual fruit weight from the sample plants during the experiment. Plants in the outer rows and at the end of the middle rows were excluded from the random selection to avoid a border effect. Five plants of tomato, eggplant and potato were randomly selected from a replication for the collection of data. Photosynthetically active radiation (PAR) was measured on each vegetables row using LP-80 Accu PAR Ceptometer to determine the extent of shading by the tree species. Such measurement was done at 9.30 am. 12.30 pm and 3.30 pm each day at a one-week interval during the whole vegetable growing period.

BCR and LER calculation

Benefit-cost ratio (BCR) and land equivalent ratio (LER) were determined according to the following equations in an aonla-based agroforestry system.

Benefit cost ratio (BCR) = Gross return / Total cost of production.

Land equivalent ratio = Ci / Cs + Ti / Ts, where, Ci is crop yield under agroforestry, Cs is crop yield under sole cropping, Ti is fruit yield under agroforestry, and Ts is fruit yield under sole cropping (Das, 2020)

Statistical analysis

All data were processed, calculated, and analyzed using computer software such as MS Excel and STATISTIX 10. The mean-variance was adjusted by the LSD test at the 5% significance level.

Results and Discussion

Availability of Photosynthetically Active Radiation (PAR) in different agroforestry systems

Availability of light is the most important limiting factor for the under-storied crop in every multistoried agroforestry system. The extent of light interception by the tree canopy and the competition for light are also limiting factors for the success of component crops in a multistoried agroforestry system. Different systems received different light levels due to various sizes and shapes of overstory canopy. The light incidence in aonla-based multistoried agroforestry system was measured at 9.30 am. 12.30 pm and 3.30 pm each day at a one-week interval. The measurement was taken at 14 DAT and continued up to 67 DAT. The light incidence in different combinations of aonla-based multistoried agroforestry systems has been presented in Table 1. Among different aonla-based multistoried agroforestry systems, the highest photosynthetically active radiation (PAR) was recorded in open filed condition (T_4) (989.15 µmol m^{-2} s^{-1} at 9.30 am, 1345.93 µmol m^{-2} s^{-1} at 12.30 pm, 750.43 µmol m^{-2} s^{-1} at 3.30 pm). The lowest PAR for understored crop was recorded in aonla + carambola + lemon + dragon fruit-based system (T_1) (370.77 µmol m^{-2} s^{-1} at 9.30 am, 860.5 µmol m^{-2} s^{-1} at 12.30 pm and 300.34 µmol m^{-2} s^{-1} at 3.30 pm). The recorded PAR in aonla + dragon fruit-based system (T_2) and dragon fruit-based system (T_3) was varied between PAR in aonla

Table 1. Availability of Photosynthetically Active Radiation (PAR) in different combinations of multistoried agroforestry systems

	PAR Average			Daily Average light (µmol m^{-2} s^{-1})	% PAR compare to open field
	Time				
Treatments	9:30 AM	12:30 AM	3:30 AM		
T_1: Aonla + Carambola+ Lemon+ Dragon fruit+ Vegetables	370.77	860.50	300.34	508.87	50%
T_2: Aonla + Dragon fruit+ Vegetables	783.65	1130.57	515.56	809.92	78%
T_3: Dragon fruit + Vegetables	977.67	1316.79	722.77	1005.74	98%
T_4: Vegetables in open field (Control)	989.15	1345.93	750.43	1028.19	100%

+ carambola + lemon + dragon fruit fruit-based system (T_1) and open filed condition (T_4). Thus, ultimately mean PAR of a day was also the highest (1028.19 µmol m^{-2} s^{-1}) (100%) in open field condition (T_4) followed by dragon fruit based system (T_3) (1005.74 µmol m^{-2} s^{-1}) (98 %), aonla + dragon fruit-based system (T_2) (809.92 µmol m^{-2} s^{-1}) (78%) and aonla + carambola + lemon + dragon fruit-based system (T_1) (508.87 µmol m^{-2} s^{-1}) (50%). Upper storied plant aonla received 100 % PAR, but incident light was gradually decreased on carambola, lemon, dragon fruit, and vegetables in multistoried conditions. Vegetables growing in open fields and aonla (upper storied component) received 100% PAR. Light intensity decreases with the increase of canopy coverage. The availability of light in aonla-based multistoried agroforestry system was lower than open field possibly due to its dense canopy coverage. Different systems received different levels of light due to the different sizes and shapes of the overstory canopy (Ferdous, 2021).

Yield and yield attributes of tomato

Individual fruit weight, number of fruits per plant of tomato are the important yield contributing character. Both the parameter found significant due to these different aonla-based agroforestry systems (Table 2). Significantly the highest individual fruit weight (51.25g), number of fruits per plant (56.20) and yield per plant (2.88 Kg) were recorded in dragon fruit-based system (T_3). This might be due to the extra nutrient management of dragon fruit. Notably, the Aonla + Carambola + Lemon + Dragon fruit-based agroforestry system (T_1) had the lowest individual fruit weight (47.88g), number of fruits per plant (38.20) and per plant yield (1.82 Kg). T_4 treatment had the highest yield (44.33 t ha^{-1}), whereas T_3 treatment (28.80 t ha^{-1}) and T_2 treatment (15.25 t ha^{-1}) had intermediate yields. The T_1 treatment had the lowest yield (9.10 t ha^{-1}). The T_4 treatment had a better yield due to a larger plant population. There was a

Table 2. Individual fruit weight, number of fruits per plant, per plant yield, fruit yield (t ha^{-1}) and per plant yield variation of tomato in different agroforestry systems

Treatments	Individual fruit weight (g)	No. of fruit plant^{-1}	Yield plant-1 (Kg)	Fruit yield (t ha^{-1})	Per plant yield variation over sole cropping (%)
T_1: Aonla + Carambola+ Lemon + Dragon fruit + tomato (pp5000/ha)	47.88d	38.20c	1.82c	9.10	-34.29
T_2: Aonla + Dragon fruit + tomato (pp5500/ha)	49.06c	55.30b	2.71b	15.25	-2.16
T_3: Dragon fruit + tomato (pp10000/ha)	51.25a	56.20a	2.88a	28.80	+3.97
T_4: Tomato in open field (pp16000/ha)	50.56b	54.80b	2.77b	44.33	---
CV (%)	1.97	3.88	3.51		

In a column, means followed by the same letter (s) are not statistically different at a 5% level of significance by LSD. CV = Coefficient of Variance.

distinct yield variance between agroforestry systems. Aonla + Carambola + Lemon + Dragon Fruit (T_1) based system (-34.29%) and T_2 system (-2.16%) were discovered to have a negative per plant yield variation compared to sole cropping. The agroforestry system (T_3) based on dragon fruit showed positive per plant yield variation (+3.97%). Hanif *et al.* (2010) in okra and Rahman *et al.* (2010) in tomato also obtained similar results.

Yield and yield attributes of eggplant

Each fruit size and the quantity of fruits per eggplant plant are crucial yield-contributing characteristics of eggplant (Table 3). Significantly, the eggplant sole cropping (T_4) had the highest number of fruits per plant (35.66) and fruit yield per plant (2.96 Kg), which was statistically comparable with T_3 treatment and the values were 34.66 and 2.87 Kg, respectively. Notably, the Aonla + Carambola + Lemon + Dragon fruit-based agroforestry system (T_1) had the fewest fruits per plant (23.00) and per plant yield (1.97 Kg) but individual fruit weight was found the highest (86.00 g). T_4 treatment had the highest yield (47.36 t ha^{-1}), while T_3 treatment (28.07 t ha^{-1}) and T_2 treatment (15.05 t ha^{-1}) had moderate yield. The T_1 treatment had the lowest yield (9.89 t ha^{-1}). Due to higher plant population yield was higher in T_4 treatment. Marked yield variation was observed in different agroforestry systems**.** The highest negative per plant yield variation was found in aonla + carambola + lemon + dragon fruit (T_1) based system (-33.17 %), T_2 system (-7.77 %) and T_3 system (-3.04 %) compare to open field condition (T_4). Rahman *et al.* (2018) also found the highest number of fruit (9.50) and per plant yield (0.855 Kg) in open field compared to agroforestry system.

Yield and yield attributes of potato

Every fruit size and the number of fruits per potato plant are significant yield-contributing characteristics. (Table 4). Significantly, the

Table 3. Fruit weight, number of fruits per plant, per plant yield (kg), fruit yield (t ha^{-1}) and per plant yield variation of eggplant in different agroforestry systems

Treatments	Weight of fruit(g)	No. of fruit plant^{-1}	Yield plant^{-1} (Kg)	Yield (t ha^{-1})	Per plant yield variation over sole cropping (%)
T_1: Aonla + Carambola+ Lemon + Dragon fruit + eggplant (pp5000/ha)	86.00a	23.00d	1.97d	9.89	-33.17
T_2:Aonla+Dragonfruit+ eggplant(pp5500/ha)	85.53a	32.00c	2.73c	15.05	-7.77
T_3: Dragon fruit + eggplant(pp10000/ha)	83.00b	34.66b	2.87b	28.70	-3.04
T_4: Eggplant in open field ((pp16000/ha))	83.16b	35.66a	2.96a	47.36	---
CV (%)	0.96	1.02	1.02		

In a column, means followed by the same letter (s) are not statistically different at a 5% level of significance by LSD. CV = Coefficient of Variance.

highest tuber number (9.1), tuber weight (46.3g) and per plant yield (420 g) were observed in potato sole cropping (T4) which was statistically similar with T_3 treatment (Dragon fruit + Potato) and the values were 8.99, 46.1g and 410 Kg plant^{-1}, respectively.

Higher yield were obtained in the T_4 treatment (42.00 t ha^{-1}), while yields in the T_3 treatment (15.1 t ha^{-1}) and T_2 treatment (9.11 t ha^{-1}) were determined to be modest. The T_1 treatment's decreased yield (5.06 t ha^{-1}) was noted. This substantial variation was brought about by shadow and system-wide heterogeneity in plant populations. Yield variation was attributed by various shade levels of different treatment. Negative yield variation was found in aonla + carambola + lemon + dragon fruit (T_1) based system (-40.47 %), then dragon fruit-based agroforestry system (T_2) (-19.40 %) and T_3 system (-2.38 %). Similar outcome for potato was found by Sultana (2014).

Relationship between light intensity (% PAR) of agroforestry system and yield of tomato, eggplant and potato

Relationship between PAR (%) and yield of tomato, eggplant and potato in aonla based agroforestry system were estimated and separately presented (Fig. 2). In case of eggplant and potato, positive linear relationship was found. On the other hand, a quadratic polynomial relationship was found between yield of tomato and light (% PAR) which was represented as $Y = -0.0006x^2 + 0.1031x - 1.9497$ ($R^2 = 0.9934$), where are R^2 value was high and significant. The R^2 value indicated that 99.34% of the contribution to the yield of tomato could be explained by percent PAR. This equation also stated that yield of tomato was maximum at 98 percent

Table 4. Total number of tuber plant^{-1}, weight of per tuber, yield per plant (g) yield of potato (t ha^{-1}) and per plant yield variation of potato in different agroforestry systems

Treatments	Tuber Number plant^{-1}	Weight (g tuber^{-1})	Yield (g plant^{-1})	Yield (t ha^{-1})	Per plant yield variation over sole cropping (%)
T_1: Aonla + Carambola+ Lemon + Dragon fruit + Potato (pp19500/ha)	7.02c	37.01c	250c	5.06	-40.47
T_2:Aonla+Dragonfruit+ Potato (pp26500/ha)	8.18b	42.03b	340b	9.11	-19.40
T_3: Dragon fruit + Potato (pp36500/ha)	8.99a	46.10a	410a	15.10	-2.38
T_4: Potato in open field (pp100000/ha)	9.10a	46.30a	420a	42.00	--
CV (%)	4.61	10.5	15.48		

In a column, means followed by the same letter (s) are not statistically different at a 5% level of significance by LSD. CV = Coefficient of Variance.

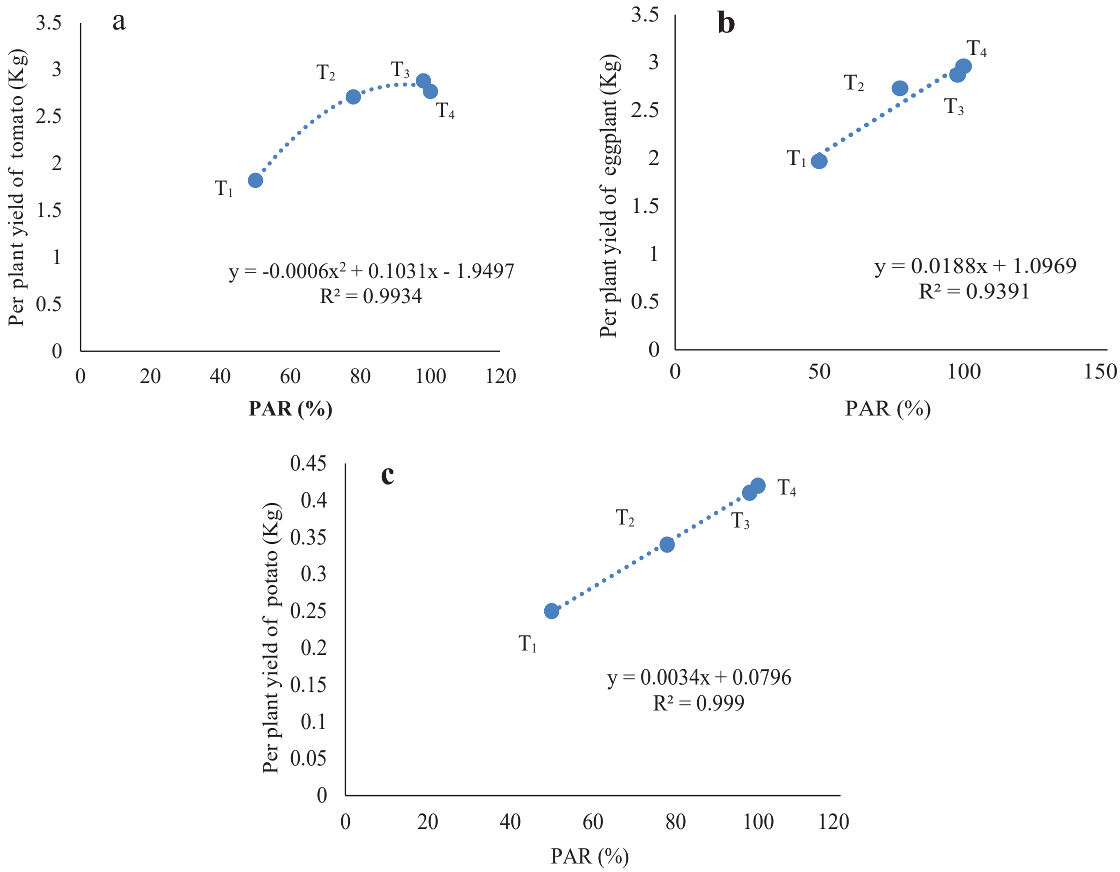

Fig. 2. Relationship between PAR (%) of agroforestry system and yield of tomato (a), eggplant (b) and potato (c) in aonla based multistoried agroforestry systems.

PAR level and beyond this PAR tomato yield decreased at the rate of 0.0006 Kg plant^{-1} for per unit changing of percent PAR. Similar result was found by Miah (2001) for tomato.

For eggplant and potato, the linear relationships between receiving PAR (%) and yield were noted and estimated as Y = 0.0188 X + 1.0969 and Y = 0.0034X + 0.0796, respectively. The findings of the equation revealed that increasing PAR (%) increases the yield of eggplant and potato irrespectively. The R^2 values (0.9391 and 0.999) were positive and significant, which indicated that the contribution of 93.91% and 99.9% of eggplant and potato yield could be attributed by % PAR of agroforestry system. The relationship also stated that yield of eggplant and potato were increased at the rate of 0.0188 and 0.0034 Kg plant^{-1}, respectively for per unit changing of light intensity (PAR %). Reza *et al.* (2022) found a similar outcome for dragon fruit and similar relationships were obtained in cauliflower, and cabbage by a study of Pingki (2022).

Land use efficiency and economic performance of model LER

There are several tools for measuring land use efficiency of mixed cropping or inter cropping or agroforestry. Such as HI, LER and TPF etc. For measuring land use efficiency of agroforestry, LER is commonly used (Reza *et al.,* 2022). In this experiment LER was also measured (Table 5) for knowing the profitability of land use. Sole cropping yield of tomato, eggplant, potato, dragon fruit, carambola and aonla were 44330, 47360, 42000, 6030, 3580 and 4300 Kg ha^{-1} and lemon yield was 21250 pieces ha^{-1}. The highest LER (3.33) was recorded in aonla + carambola + lemon + dragon fruit + eggplant (T_1) followed by aonla + carambola + lemon + dragon fruit + tomato and potato-based system. The lowest LER (1.36) was recorded in dragon fruit + potato (T_3). The result proved that multistoried production system (aonla + carambola + lemon + dragon fruit+ brinjal was the most efficient land use system. Multistoried production system (T_1) showed the highest values of LER as because there were more (five) component crops in the same piece of land. The greatest LER (3.48) was recorded by Pingki (2022) for tomato in aonla based multistoried system. Rahman et. al. (2018) also discovered the land equivalent ratio (LER) 2.17 for the jackfruit + eggplant based agroforestry system.

Table 5. Yield, economics and land use efficiency of different multistoried production system comparing sole cropping

Treatments		Yield (Kg ha^{-1})	Total cost (BDT)	Gross income (BDT)	Net return (BDT)	BCR	LER
	Tomato	44330	456012	886600	430588	1.94	
T_4	Eggplant	47360	455315	1184000	728685	2.60	
	Potato	42000	516000	840000	324000	1.62	
	Dragon fruit + Tomato	6120 +28800	387607	1800000	1412393	4.64	1.66
T_3	Dragon fruit + Eggplant	6120 + 28700	387189	1944000	1556811	5.02	1.62
	Dragon fruit + Potato	6120 + 15100	423600	1526000	1102400	3.60	1.37
	Aonla + Dragon fruit + Tomato	7383.48 + 3564.4 + 15250	387607	1276301.8	888694.8	3.29	2.64
T_2	Aonla + Dragon fruit + Eggplant	7383.48 + 3564.4 + 15050	387189	1347551.8	960362.8	3.48	2.61
	Aonla + Dragon fruit + Potato	7383.48 + 3564.4 + 9110	423600	1153501.8	729901.8	2.72	2.51
T_1	Aonla + Carambola + Lemon + Dragon fruit + Tomato	8112 + 2238.6 + 5615 + 2251.2 + 9100	387607	1000244	612637	2.58	3.33
	Aonla + Carambola + Lemon + Dragon fruit + Eggplant	8112 + 2238.6 + 5615 + 2251.2 + 9890	387189	1065494	678305	2.75	3.34
	Aonla + Carambola + Lemon + Dragon fruit + Potato	8112 + 2238.6 + 5615 + 2251.2 + 5060	423600	919444	495844	2.17	3.25

Unit price (Tk Kg^{-1}): Tomato (20), Eggplant (25), Potato (20), Aonla (35), Carambola (20), Dragon fruit (200) and Lemon (7Tk per piece)

BCR

BCR is the one of the most important economic indexes, to measure the profitability of the system. The maximum BCR was observed in T_3 (Dragon fruit-based agroforestry system). The highest BCR 5.02 was recorded for dragon fruit + eggplant system followed by dragon fruit + tomato (4.64) (Table 5). The moderate BCR was recorded for T_2 (Aonla + dragon fruit + tomato / eggplant / potato) and the value range from 2.72 to 3.48. The minimum BCR was found in sole cropping (T_4) of tomato (1.94), eggplant (2.60) and potato (1.62). The BCR value indicated that dragon fruit + eggplant based system (T_3) was the most profitable practice followed by dragon fruit + tomato and then dragon fruit + potato. Due to maximum plant population of dragon fruit per hector and their high market price, BCR became higher in T_3 treatment than T_2 (Aonla + dragon fruit + tomato / eggplant / potato) treatment as there are only 50 percent plant population of dragon fruits were associated in aonla tree. Rahman *et. al.* (2018) calculated BCR for jackfruit + eggplant agroforestry system and sole eggplant system which were 4.56 and 3.13, respectively indicating very close to our findings.

Conclusion

In a resource-constrained country like Bangladesh, aonla-based multistoried agroforestry systems can play a vital role in producing diversify yield throughout the year. Despite the single cropping system of seasonal crops, agroforestry provides higher yield. Different vegetables can be associated with aonla based multistoried system but all are not economically profitable. Due to multiple crop combination LER was always higher in multistoried system but profitability will depend on the yield and income of lower storied crops as the upper storied component yield remain almost similar. Considering both BCR and LER, aonla + dragon fruit + eggplant agroforestry system was found the superior production practice for diversify production, maximum land use efficiency and higher income generation. Although considering only BCR, dragon fruit + eggplant based system was found highly profitable.

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