RESEARCH ARTICLE

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# Suitability of Broccoli in Aonla based Multistoried Fruit Production Model

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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. Disappointedly, Bangladeshi farmers are less equipped about the cultivation techniques, economics, and yields of multistory agroforestry production systems. Consequently, the goal of the current study was to evaluate the profitability and yield potentiality of aonla-based multistoried broccoli production system during the period of November 22 to March 23. Three separate multistory agroforestry systems were covered by the three treatments, while an open field served as the control treatment. to keep track of the system's expansion and economic success; soil analysis, photosynthetically active radiation, plant height, number of leaves, head length, head width, head weight, total yield, BCR, and LER were calculated following different established methods. While compared to sole cropping, the agroforestry approach drastically reduced the production of broccoli by 89%. Soil organic matter, nitrogen, phosphorous, potassium, and sulfur were higher in agroforestry system than that of control plot. In fact, the agroforestry system had some negative effects on the rate of crop growth in understored conditions. Despite, net return and BCR from aonla-based multistoried agroforestry system were 4-11 lakh and 2.24-3.98, which was 69-87 and 41- 67 %, respectively higher than sole cropping systems. The LER of aonla based multistoried agroforestry system was 3.20. The major conclusions show that aonla orchards can be converted to agroforestry systems to increase productivity, generate money, and protect the environment, however due to poor performance, broccoli cannot be grown in multistory systems.**

**Keywords:** Aonla, Broccoli, Multistoried Agroforestry, Suitability.

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## I. Introduction

Bangladesh, is a home of 165 million people at present and has a population density of 1,265 people per km$^2$, is located at the meeting point of two opposing environments in the Bay of Bengal to the south and the Himalayas to the north [1]. With over 2.2% of the world's population, it is the tenth most populated nation. Urban areas are home to 65 million people, or 39.4% of the overall population [2]. Lots of people depend on agriculture, which underpins the entire economy, for their livelihoods. Agriculture is a major source of income and is strongly related to the security of food and nutrients [3]. A fall in agricultural output would occur in tandem with a reduction in the amount of arable land under the current scenario of rising human population and unpredictability of the climate. It is shrinking at an alarming rate of 0.005 ha/head/year [4].

Surprisingly, the country has impressively grown food grain output during the previous 20 years, approaching self-sufficiency at the national level, by producing around 28 million metric tons of grains, principally rice and wheat [1], [5] as well as a decrease in the number of people living in poverty.

Despite significant progress in lowering poverty and raising agricultural output, 25% of the population is still regarded as food insecure [6]. Although Bangladesh's agricultural sector has achieved enormous strides because of technology advancement, non-technological elements like high temperatures and inconsistent rainfall are hampering the sector's ability to produce food. Conversely, grain output expanded dramatically, and there is a tremendous disparity between the amount that is produced and what is needed for vegetables and fruits [7]. According to [8] recommendations, people should consume at least 400 g of fruits and vegetables daily, yet the average person only consumes 36 and 167 g of each, respectively [1]. Low vegetable consumption puts an excessive amount of pressure on grains and leads to malnutrition, which raises a variety of health concerns. As there is no scope of horizontal expansion of individual fruit and vegetables production as a result, it is necessary to find alternative production methods that boost output while being sustainable by integrating fruits and vegetables.

Nowadays, agroforestry is recognized as a sustainable land use that combines trees and vegetables to improve farmers' capacity to adapt to climate change due to its numerous advantages, such as diverse product lines, additional sources of revenue, and environmental services [9], [10]. It benefits farmers' socioeconomic standing as well as soil fertility, water quality, biodiversity preservation, aesthetic appeal, erosion control, and carbon sequestration to lessen global warming [7], [11]. Due to differences in terrain, soil, water, and climatic benefits, Bangladesh has been practicing agroforestry in varied patterns across ecosystems since ancient times [12].

Multistoried agroforestry systems provide production of diverse fruits and vegetables under various shade situations by maximizing different levels of Photosynthetically Active Radiation (PAR). Different components are organized in several layers in this system. The lower-storied crop's light limitation is therefore the most crucial factor. Therefore, choosing a lower storied crop for a multistoried system is a crucial and challenging challenge. As a result, many initiatives to identify acceptable crops for the lower stories are going on [13]. Vegetables are screening in a multistory agroforestry system including broccoli.

Broccoli (*Brassica oleracea* L. var. *italica*), which belongs to the genus Brassica in the family Cruciferae regarded as a significant vegetable crop grown worldwide. In recent years, Japan has assumed a respectable position in the production of this crop. Broccoli, which has its origins in western Europe, is a highly popular vegetable in the United States of America. In India, the crop is also regarded as a commercial crop. According to [14] In Bangladesh, broccoli is one of the non-traditional and recently developed Cole crops

A high-yielding multistory agroforestry system with vegetables, fruit trees (carambola, lemon, dragon), medicinal plants (aonla), and vegetables was sought after for Bangladesh's homesteads and uplands in light of the aforementioned facts. This system was also intended to maximize the use of natural resources (light, water, nutrients, and vertical space). Therefore, the study was undertaken to achieve the following objectives; i) to study the yield and yield contributing characteristics of broccoli in different agroforestry systems, and ii) to evaluate the economic performance of broccoli in aonla based agroforestry system.

## II. Methods and Materials

### A. Study Site, Weather Conditions, and Soils

The research was conducted at the experimental field of the Department of Agroforestry and Environment at the Bangabandhu Sheikh Mujibur Rahman Agricultural University in Bangladesh (24° 02′ 10.3″ N; 90° 23′ 57.4″ E) from November 22 to March 23 (Fig 1). The silty clay loam texture of the soil on this site (Table I) represents the Agro-ecological zone of the Madhupur Tract (AEZ-28) [15].


Fig. 1. Location of the study area in Bangladesh.

TABLE I: Soil Organic Carbon, $P^H$, Nitrogen, Phosphorus, Potassium, and Sulfur Content under Different Treatments (0-15 cm Depth)

| Treatment | Soil organic carbon | Soil $P^H$ | Total N content (%) | Available P content (ppm) | K content (meq/100g soil) | Available S content (ppm) |
|---|---|---|---|---|---|---|
| $T_1$ | 1.21 | 4.96 | 0.13 | 11.69 | 0.26 | 32.09 |
| $T_2$ | 1.05 | 5.02 | 0.12 | 9.29 | 0.22 | 27.19 |
| $T_3$ | 0.92 | 5.11 | 0.09 | 7.12 | 0.19 | 26.45 |
| $T_4$ | 0.63 | 5.16 | 0.06 | 5.57 | 0.16 | 23.31 |

$T_1$: Aonla + Carambola+ Lemon + Dragon fruit + Broccoli, $T_2$: Aonla + Dragon fruit + Broccoli, $T_3$: Dragon fruit + Broccoli, $T_4$: Broccoli in open field (sole).

### B. Experimental Design and Treatment Composition

An existing twenty-three-year-old aonla orchard maintained an 8 m × 8 m distance was transformed into a multistoried agroforestry system. Aonla was treated as an element of the overstory. In 2008, two aonla trees were surrounded by carambola and lemon trees were established between two aonla trees which created a middle-storied structure. In the alley of tree lines, two dragon fruit genotypes (Red and white-fleshed dragon fruit) were grown in September 2018. In addition to the dragon fruit plant, broccoli was also planted in the middle of the dragon fruit. Broccoli was spaced 60 cm between rows and 60 cm between plants, respectively (Fig. 2). Utilizing a randomized complete block design, three replications of broccoli were examined in various combinations. These treatments were as follows:

**$T_1$**: Aonla + carambola + lemon + dragon fruit + broccoli;
**$T_2$:** Aonla + dragon fruit + broccoli ;
**$T_3$**: dragon fruit + broccoli ;
**$T_4$**: Broccoli in the open field (Control).

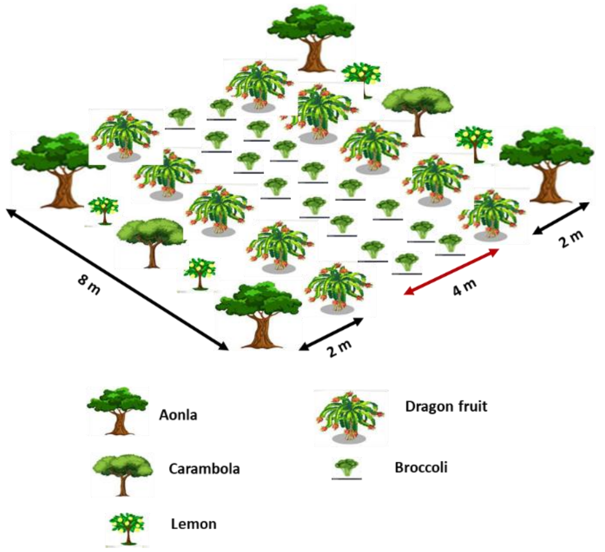


Fig. 2. Schematic diagram of aonla based multistoried agroforestry system.

### *C. Field Preparation, Fertilizer Application, and Intercultural Operation*

The experimental field was tilled with a spade to achieve a suitable soil condition. In the final soil preparation, soil was fertilized with 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 $ha^{-1}$). Nitrogenous (N) fertilizer in the form of urea was applied at a dose of 300 kg $ha^{-1}$, of which 50% was applied as a basal dose during the final preparation of the plot. Two equal applications of the remaining N, P, and K fertilizer—25% in each—were added before planting and once the crop began to bear fruit. When irrigation was required, it was carried out using a flexible hose line to guarantee adequate soil moisture. To lessen competition for resources between weeds and crops, they are routinely weeded. Every 25 days, Dursban 20 EC was applied for insect control. Very few seedlings in the plot were damaged after planting and these seedlings were replaced with new seedlings. The replacement was done with same-aged healthy seedlings in the afternoon with a bowl of soil. It is significant to note that, aside from pruning, aonla, carambola, and lemon trees were not subjected to other management measures under the agroforestry system, such as irrigation and fertilizer application.

### *D. Harvesting and Data Collection*

Harvesting of broccoli started from 14th February 2023 to 1st March 2023. Data were recorded on the following parameters from the sample plants during the experiment. To prevent a border effect, plants on the outside rows and at the ends of the middle rows were not included in the random selection. For the purpose of gathering data, five broccoli plants from a replication were chosen at random. Leaf length, leaf breadth, leaf number plant-1, SPAD (Soil Plant Analysis Development) value of leaves, plant height, head length, head breadth, individual head weight, and yield were measured. The SPAD 502 plus Chlorophyll meter (Konica Minolta Sensing, Inc., Japan) was used to determine the amount of chlorophyll in the leaf from the chosen plant. Photosynthetically active radiation (PAR) was measured on each crop row as functions of multi-strata and distances from the tree base using LP-80 Accu PAR Ceptometer to determine the extent of shading by the tree species. This measurement was carried out three times daily, separated by a week, at 9.30 am, 12.30 pm, and 3.30 pm. At 14 DAPS, the measurement started, and it continued until 67 DAPS.

### *E. Economic and Land Use Evaluation*

The benefit-cost ratio (BCR) and land equivalent ratio (LER) in an aonla-based agroforestry system were calculated using the equations used by [16].

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 [17].

### *F. Statistical Research*

Using computer programs like MS Excel and STATISTIX 10, all data were processed, computed, and examined. The LSD test was used to modify the mean-variance at the 5% level of significance. The analyzed data were used to construct the table and graph.

## III. RESULTS AND DISCUSSION

The results of the field experiment are presented in this chapter under certain headings in a systematic manner in accordance with the objectives.

### *A. Photosynthetically Active Radiation (PAR) Availability in Various Agroforestry Systems*

In every multistory agroforestry system, the lack of light is the main limiting factor for the understoried crop. In a multistoried agroforestry system, component crops' success is also constrained by the degree of light absorption by the tree canopy and the competition for light. Due to the variable widths and shapes of the overstory canopy, various systems got varying amounts of light. An aonla-based multistory agroforestry system had its light incidence monitored daily at 9.30 am, 12.30 pm, and 3.30 pm for a period of one week. At 14 DAPS, the measurement started, and it continued until 67 DAPS. The light incidence in different aonla-based multistoried agroforestry systems has been presented in Table II. Among different agroforestry systems, the highest photosynthetically active radiation (PAR) was recorded in open filed condition ($T_4$) (997.5 µ mol $m^{-2}$ $s^{-1}$ at 9.30 am, 1179.61µmol $m^{-2}$ $s^{-1}$ at 12.30 pm, 731.94 µ mol $m^{-2}$ $s^{-1}$ at 3.30 pm). The lowest PAR was recorded in aonla + carambola + lemon + dragon fruit-based system ($T_1$) (351.46 µ mol $m^{-2}$ $s^{-1}$ at 9.30 am, 425 µ mol $m^{-2}$ $s^{-1}$ at 12.30 pm and 282.44 µ mol $m^{-2}$ $s^{-1}$ 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 + 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 (969.68 µ mol $m^{-2}$ $s^{-1}$) (100%) in open field condition ($T_4$) followed by dragon fruit based system ($T_3$) (879.24 µ mol $m^{-2}$ $s^{-1}$) (90 %), aonla + dragon fruit-based system ($T_2$) (617.64 µ mol $m^{-2}$ $s^{-1}$) (63%) and aonla + carambola + lemon + dragon fruit-based system ($T_1$) (352.97 µ mol $m^{-2}$ $s^{-1}$)

(36%). 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. The amount of canopy cover causes a reduction in light intensity. Due to its extensive canopy cover, the multistory agroforestry system built on an aonla tree was less light-available than an open field. Similar result was found by [18] in cauliflower in aonla based multistoried agroforestry system [19] discovered that the amount of photosynthetically active radiation, which regulates photosynthesis, the production of dry matter, and agricultural productivity, was often lower in taller species.

TABLE II: AVAILABILITY OF PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR) IN DIFFERENT AONLA BASED AGROFORESTRY SYSTEMS

| Treatments | Time | | | Average light (µ mol $m^{-2}$ $s^{-1}$) | Percent of the open field light |
|---|---|---|---|---|---|
| | 9:30 AM | 12:30 AM | 3:30 AM | | |
| $T_1$ | 351.46 | 425.09 | 282.44 | 352.97 | 36% |
| $T_2$ | 679.66 | 772.83 | 400.44 | 617.64 | 63% |
| $T_3$ | 954.33 | 1091.66 | 591.72 | 879.24 | 90% |
| $T_4$ | 997.50 | 1179.61 | 731.94 | 969.68 | 100% |

$T_1$: Aonla + Carambola+ Lemon + Dragon fruit + Broccoli, $T_2$: Aonla + Dragon fruit + Broccoli, $T_3$: Dragon fruit + Broccoli, $T_4$: Broccoli in open field (sole).

## B. Plant Height

Various agroforestry techniques had a considerable average impact on plant height, as seen in Fig. 3.

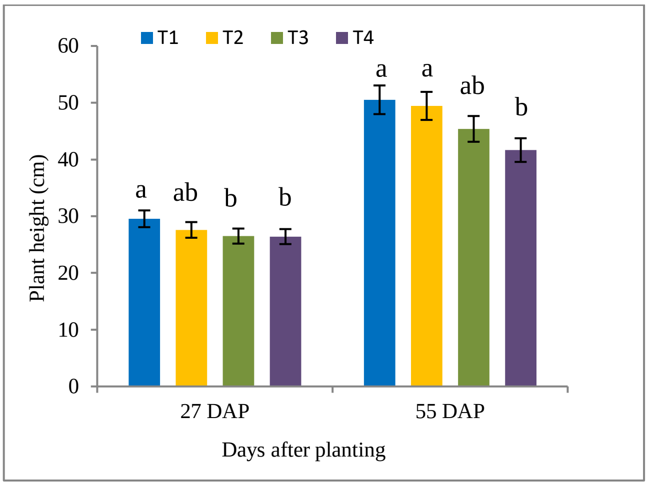


Fig 3. Plant height of broccoli at 27 DAP and 55 DAPS in different aonla-based multistoried agroforestry systems. $T_1$: Aonla + Carambola+ Lemon + Dragon fruit + Broccoli, $T_2$: Aonla + Dragon fruit + Broccoli, $T_3$: Dragon fruit + Broccoli, $T_4$: Broccoli in open field (sole).

At 27 DAPS, the tallest plant (29.54 cm) was found in the agroforestry system $T_1$ based on aonla + dragon fruit, followed by $T_2$ based on aonla + dragon fruit (27.58 cm), and $T_3$ based on dragon fruit (26.5 cm). Significantly, the open field condition ($T_4$) with 100% light availability was where the shortest plant (26.41 cm) was found. At 55 DAT, a nearly identical pattern of variation in plant height was discovered. The tallest plant (50.52 cm) was found in an agroforestry system based on aonla, carambola, lemon, and dragon fruit ($T_1$), while the smallest plant (41.65 cm) was located in an open field ($T_4$). The lowest sunlight was present in the aonla + dragon fruit (T1) based system (36% light), followed by the aonla + dragon fruit ($T_2$) (63%) and dragon fruit ($T_3$) (90%), and full sunlight was present in the open field condition ($T_4$) (100%). However, the plant grew the longest in T1 because the higher shade leaves provide a larger area for absorbing more light for photosynthesis in a place where light levels are low. Shoot growth is accelerated in low-light environments. Additionally, when a plant is in the shade, it releases the hormone auxin, which causes it to display apical dominance and raise the plant's height so that it can capture more light [20]. Similar result was observed by [21] in cotton, [22] in okra, [13] in dragon fruit, and [18] in cauliflower.

## C. Number of Leaves

At 27 DAP and 55 DAPS, several aonla-based agroforestry systems had a substantial impact on the total number of leaves plant$^{-1}$, an essential morphological characteristic of broccoli.

Different vegetables responded differently under different aonla-based agroforestry systems as well as open field conditions. In 27 DAP and 55 DAP the highest number of leaves plant$^{-1}$ was found in dragon fruit-based agroforestry system ($T_3$) and the values were 7.46, 13.60 and the minimum number of leaves plant$^{-1}$ was found in aonla + carambola + lemon + dragon fruit ($T_1$) based agroforestry system and the values were 6.66 and 11.26 (Fig 4). A moderate number of leaves plant$^{-1}$ was found in open field condition ($T_4$) and aonla + dragon fruit-based system ($T_2$) at 27 DAP and 55 DAPS. The maximum number of leaves in dragon fruit-based agroforestry system ($T_3$) is due to experiencing almost full sunlight (90 %) and very good soil nutrient levels and low competition for resources. Similar result was observed by [23] in eggplant, [24] in radish and [18] in cauliflower.

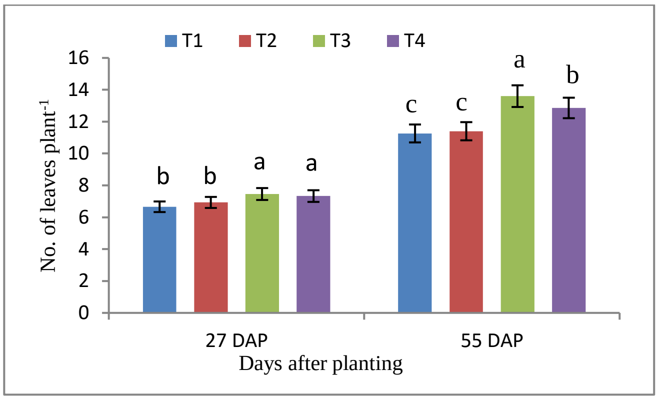


Fig. 4. Number of leaves plant$^{-1}$ of broccoli at 27 DAP and 55 DAPS in different aonla-based multistoried agroforestry systems. $T_1$: Aonla + Carambola+ Lemon + Dragon fruit + Broccoli, $T_2$: Aonla + Dragon fruit + Broccoli, $T_3$: Dragon fruit + Broccoli, $T_4$: Broccoli in open field (sole).

## D. Leaf Length and Leaf Breadth

Leaf length and leaf breadth are important morphological characteristics of broccoli. No significant variation was observed for leaf length but variation observed in leaf breadth plant-1 on different days after transplanting in different aonla-based agroforestry systems (Table III). The highest leaf length was observed in aonla + carambola + lemon + dragon fruit ($T_1$) based system was (38.30 cm) and it was statistically similar with aonla + dragon fruit-based system ($T_2$), dragon fruit-based agroforestry system ($T_3$), and open field condition ($T_4$).

Leaf breadth was also significantly varied due to different aonla-based agroforestry systems. The highest leaf breadth plant-1 was observed in aonla + carambola + lemon + dragon fruit-based system ($T_1$) (16.42 cm). The moderate leaf breadth plant-1 was found in aonla + dragon fruit($T_2$) based system (15.92 cm) that did not vary from dragon fruit-based agroforestry system ($T_3$) (15.73 cm). The lowest leaf breadth plant-1 (12.64 cm) was found in open field conditions ($T_4$) which was statistically different from other systems. In a shaded environment plant leaves try to harvest more light for photosynthesis by expanding their surface area, therefore length and width are likewise increased in $T_1$. As a result, the promotion of leaf cell division and growth under darkened conditions increased [25].

TABLE III: LEAF LENGTH AND BREADTH OF BROCCOLI IN DIFFERENT AONLA BASED AGROFORESTRY SYSTEMS

| Treatment | Leaf length (cm) | Leaf breadth (cm) |
|---|---|---|
| $T_1$ | 38.30a | 16.42a |
| $T_2$ | 36.21a | 15.92a |
| $T_3$ | 36.14a | 15.73a |
| $T_4$ | 32.66a | 12.64b |
| CV (%) | 9.71 | 6.42 |

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. $T_1$: Aonla + Carambola+ Lemon + Dragon fruit + Broccoli, $T_2$: Aonla + Dragon fruit + Broccoli, $T_3$: Dragon fruit + Broccoli, $T_4$: Broccoli in open field (sole).

### *E. Soil Plant Analysis Development (SPAD) Value*

SPAD values of the leaves of broccoli were significantly influenced when they were grown under different aonla-based agroforestry systems (Table IV). At 42 DAT, the highest SPAD value (117.25) was found in open field condition ($T_4$) and the lowest SPAD value (56.36) was found in Aonla + Carambola + Lemon + Dragon fruit-based agroforestry system ($T_1$). An almost similar trend of variation was found in 55 DAT where the highest SPAD value (112.21) was found in open field condition ($T_4$) and the lowest SPAD value (55.04) was found in Aonla + Carambola + Lemon + Dragon fruit-based agroforestry system ($T_1$). In shade conditions, plant synthesis more chlorophyll to harvest more sunlight [18].

TABLE IV: SPAD VALUE OF BROCCOLI LEAVES IN DIFFERENT AONLA BASED AGROFORESTRY SYSTEMS AT 42 AND 55 DAT

| Treatments | 42 DAT | 55 DAT | Mean |
|---|---|---|---|
| $T_1$ | 56.37d | 55.04d | 55.705 |
| $T_2$ | 64.25c | 60.27c | 62.26 |
| $T_3$ | 88.41b | 80.37b | 84.39 |
| $T_4$ | 117.25a | 112.21a | 114.73 |
| CV | 4.12 | 6.60 | |

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. $T_1$: Aonla + Carambola+ Lemon + Dragon fruit + Broccoli, $T_2$: Aonla + Dragon fruit + Broccoli, $T_3$: Dragon fruit + Broccoli, $T_4$: Broccoli in open field (sole).

### *F. Yield Contributing Parameters of Broccoli*

Head length and Head breadth are important yield contributing characters and it was found significant due to different agroforestry systems (Table V). The highest head length (13.76 cm) was obtained in dragon fruit-based agroforestry system ($T_3$) which was superior to other systems. The moderate head length was found in aonla + dragon fruit-based system ($T_2$) (12.04 cm) which was statistically similar to that of the open field condition ($T_4$) (11.90 cm) and Aonla + Carambola + Lemon + Dragon fruit-based system ($T_1$) and the value was 11.43. Head length was the highest in dragon fruit-based agroforestry system ($T_3$) because it could accumulate more nutrients compared to other agroforestry systems.

Head breadth was also significantly varied due to different agroforestry systems. The highest Head breadth (13.40 cm) was observed in Dragon fruit-based agroforestry system ($T_3$) which was statistically varied from other systems. The moderate head length was found in aonla + dragon fruit-based system ($T_2$) (12.20 cm) which was statistically similar with open field condition ($T_4$) (12.19 cm) and Aonla + Carambola + Lemon + Dragon fruit-based agroforestry system ($T_1$) and the value was 11.30. Head length was the highest in Dragon fruit-based agroforestry system ($T_3$) because it could accumulate more nutrients compared to other agroforestry systems. Head breadth was highest in dragon fruit-based agroforestry system ($T_3$) because the light intensity was higher in $T_3$ (90%) and competition for water and nutrients was less in $T_3$. The reduced head length and diameter under agroforestry practices, however, might be caused by significantly more shade and a slower mobilization of reserve that assimilates to the reproductive organs [3] on a tomato cultivar in a multistory agroforestry system and [23] in a jackfruit-eggplant based agroforestry system both showed similar findings. Fruits planted in open fields received more nutrients and light than those produced under tree species, resulting in larger fruit heads with greater diameter.

Marked variation was exhibited with respect of head yield (t $ha^{-1}$) due to the main effect of different agroforestry system (Table V). The maximum marketable head yield of broccoli (12.43 t $ha^{-1}$) was found in open field condition ($T_4$) and the lowest marketable curd yield of broccoli (1.38 t $ha^{-1}$) was recorded in Aonla + Carambola + Lemon + Dragon fruit-based system ($T_1$). The moderate head yield was recorded in Dragon fruit-based system ($T_3$) then in aonla + dragon fruit-based system ($T_2$) the values were 3.39 t $ha^{-1}$ and 1.39 t ha-$^{1}$. The result revealed that broccoli can be grown in shade and partial shade conditions but yield loss is high compared to open field.

TABLE V: PERFORMANCE OF BROCCOLI IN AGROFORESTRY SYSTEM AND SOLE

| Treatments | Plant population ($ha^{-1}$) | Head length (cm) | Head breadth (cm) | Individual weight (g) | Yield (Kg $ha^{-1}$) | Yield (t $ha^{-1}$) | Per plant yield variation over sole cropping (%) |
|---|---|---|---|---|---|---|---|
| $T_1$ | 6250 | 11.43b | 11.30b | 222.0b | 1387.5 | 1.38 | - 89 |
| $T_2$ | 6250 | 12.04b | 12.20b | 223.7b | 1398.1 | 1.39 | -89 |
| $T_3$ | 10000 | 13.76a | 13.40a | 338.9a | 3389.0 | 3.39 | -73 |
| $T_4$ | 27777 | 11.90b | 12.19b | 291.0ab | 12435.8 | 12.43 | ------ |
| CV (%) | | 3.24 | 5.67 | 20.43 | | | |

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. $T_1$: Aonla + Carambola+ Lemon + Dragon fruit + Broccoli, $T_2$: Aonla + Dragon fruit + Broccoli, $T_3$: Dragon fruit + Broccoli, $T_4$: Broccoli in open field (sole).

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Low photosynthetic capability of plants, which hinders the reproductive growth of plants, was presumably the cause of the lower number of broccolis under considerably more protracted and intense shadowed conditions. The features of the stomata and mesophyll cells of shaded plants were related to the decreased photosynthetic potential of those plants. According to [26] light availability was higher in open fields compared to agroforestry systems, which effect on head weight. The outcomes of our study are corroborated by [27] on tomato cultivars under ghora neem (*Azadirachta indica*) and sissoo (*Dalbergia sissoo*) based agroforestry systems and [23] in jackfruit-eggplant based agroforestry system. Diffuse light promotes the establishment of vegetative structures in agroforestry systems, whereas intense light favors the growth of flowers, fruits, and seeds. On the other hand, [28] observed comparable results and suggested that leaf litter inputs from agroforestry trees may provide appropriate nutrients and organic matter to support crop growth, possibly boosting plant height of broccoli.

### G. Evaluation of Production System

#### 1) Benefit Cost Ratio (BCR)

The production systems are economically evaluated by different tools (Table VI). Such as gross income (GI), and benefit-cost ratio (BCR). Considering gross income, the highest income (1593450 Tk ha$^{-1}$) was recorded in Dragon fruit-based agroforestry system ($T_3$) and the lowest income (621794 Tk ha$^{-1}$) in open field conditions (Broccoli sole crop). On the other hand, the highest benefit-cost ratio (BCR) (3.98) was found in the Dragon fruit-based system ($T_3$) and the lowest benefit-cost ratio (BCR) (1.33) was found in the open field condition (Broccoli sole crop). The result revealed that dragon fruit-based system ($T_3$) was good enough in all the production systems in terms of BCR. Trees in farming regions increase crop yield by adding mulch and nutrients, shading exposed soils, preventing erosion, capturing airborne dirt, and bringing animals and birds who leave behind manure and urine. In addition, there are surplus resources of aonla, carambola, lemon, and dragon fruit, such as firewood, construction materials, and seeds. The natural resources produced by aonla, carambola, lemon, dragon fruit, and restored ecosystems sustainably boost rural families' consumption and lower the cost of farm inputs like fertilizers and animal feed. Compared to conventional land use schemes, each of these characteristics increased farm income. The outcomes of this research are supported by [29] in jackfruit-pineapple agroforestry production systems, [30] at fruit-tomato based agroforestry systems, and [22] in jackfruit-eggplant based agroforestry systems.

#### 2) Land equivalent ratio (LER)

Agroforestry, mixed cropping, and intercropping can all be measured using a variety of methodologies. including HI, LER, etc. LER is frequently used to assess the effectiveness of agroforestry's utilization of land. For the purpose of determining the profitable land use, LER was also measured in the current study. The Aonla + Carambola + Lemon + Dragon fruit-based agroforestry system ($T_1$) had the greatest LER (3.20), while the Dragon fruit-based system ($T_3$) had the lowest LER (1.27). The aonla + dragon fruit-based system ($T_2$) recorded the moderate LER (2.33). The findings revealed that the most effective strategy for using land was a multistory production system ($T_1$) that included aonla, carambola, lemon, dragon fruit, and broccoli. In the multistory system ($T_1$ and $T_2$), the LER for broccoli (sole crop) was greater than two. It indicates that twice as much space will be required to produce the same component yield from sole cultivation. Bangladesh is one of the countries with the highest population densities in the world, hence this concept is crucial for Bangladesh.

## IV. Conclusion

In a resource-constrained and populous country like Bangladesh, multistoried agroforestry systems can play a vital role in producing multiple yield components and increasing job opportunities to the unemployed people of Bangladesh throughout the year. Despite the single cropping system of seasonal crops providing higher yield than their respective agroforestry (Comparing the agroforestry system to sole cropping, production of broccoli dropped drastically by 89%.), but total system production was higher in dragon fruit-based agroforestry system. Aonla-based multistoried fruit production model had net returns and BCRs of 4–11 lakh and 2.24–3.98 that were, respectively, 69–87 and 41–67% greater than sole cropping systems. The LER of aonla based multistoried fruit production model was 3.20, which was about triple than double storied system. But the result did not to allow broccoli in multistoried system as its performance was poor.

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TABLE VI: Total income, cost, BCR and LER of broccoli in agroforestry system and sole cropping

| Treatments | Gross Income (Tk ha$^{-1}$) | The total cost of production (Tk ha$^{-1}$) | Net Return (Tk ha$^{-1}$) | Income increased over sole cropping (%) | BCR | BCR increased over sole cropping (%) | LER |
|---|---|---|---|---|---|---|---|
| Broccoli sole ($T_4$) | 621794 | 466012 | 155782 | ---- | 1.33 | ---- | |
| Aonla + Carambola + Lemon + Dragon fruit + Broccoli ($T_1$) | 896382 | 399607 | 496774.8 | +69 | 2.24 | +41 | 3.20 |
| Aonla + Dragon fruit + Broccoli ($T_2$) | 1061201.8 | 399607 | 661594.6 | +77 | 2.65 | +50 | 2.33 |
| Dragon fruit + Broccoli ($T_3$) | 1593450 | 399607 | 1193842.8 | +87 | 3.98 | +67 | 1.27 |

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