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Performance of Radish in Aonla based Multistoried Agroforestry System

Jannatul Ferdous, Tofayel Ahamed, Md. Main Uddin Miah, and Md. Mizanur Rahman

ABSTRACT

An experiment was conducted in a 19-years old aonla orchard from October 2019 to January 2020 at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) research farm to determine the performance of different radish varieties in aonla based multistoried agroforestry systems. The study consisted of two factors viz. four agroforestry systems (aonla + carambola, aonla + lemon, aonla only, and open field) and four radish varieties (BU mula-1, BARI Mula-1, BARI Mula-2 and Rocky 45) laid out in a two factorial randomized complete block design with three replications. Findings exhibited that light availability in the open field was 727.02 µmol m-2s-1 which was significantly higher over the aonla based multistoried agroforestry systems. Light received by the aonla + lemon, aonla, and aonla + carambola systems were 74.13, 65.57, and 52.77% of the open field, respectively. The highest (276.47 g) leaf fresh weight produced by Rocky 45 was noticed in aonla + carambola system and the lowest leaf weight produced by BU mula-1 was found in an open field. The highest root fresh weight (592 g) was produced by Rocky 45 in the open field, and the lowest root fresh weight (102.60 g) was produced by BU mula-1 in aonla + carambola based system. The highest root yield (39.47 t/ha) of Rocky 45 was produced in an open field and a higher leaf yield (18.43 t/ha) was reported in BU mula-1 among four radish varieties. Among four radish varieties, Rocky 45 performed better yield in open field conditions and aonla based agroforestry system.

Keywords: Agrofotestry system, Aonla, Multistoried, Radish, Variety.

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I. INTRODUCTION

Bangladesh is one of the largest deltaic (1,47,570 sq. km), the most densely populated (162.7million) countries in the world. Rapid population growth rate (1.37%) is exerting immense pressure on usable land ultimately reducing per capita available land at an alarming rate [1]. Bangladesh has an agrarian economy, most of her inhabitants (40.60%) directly or indirectly depend on agricultural activities for their livelihood. The contribution of the agriculture sector to GDP is about 14.23% [2]. To feed this increasing population agricultural land should be intensified. Under this situation, it is necessary to explore a system that can help to overcome the shortcomings of high investment in traditional agriculture. Now it is urgent agriculture productions need to be increased by using modern or appropriate techniques [3]. Agroforestry may be an alternate practice for surmounting low productivity in case of low input-low output and small-scale farming systems. It aims at improving productivity by effective utilization of above and belowground spaces, which are not utilized in single tier systems [4]. Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management unit as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economical interactions between the different components [5]. Fruit-tree-based agroforestry involves the intentional, simultaneous association of annual or perennial crops with perennial fruit-producing trees on the same farm unit. Because of the relatively short juvenile (pre-production) phase of fruit trees, the high market value of their products, and the contribution of fruits to household dietary needs, fruit-tree-based agroforestry enjoys high popularity among resource-limited producers worldwide [6]. Various new and traditional agroforestry systems are practiced throughout our country. Aonla based agroforestry system is found in a terrace of Bangladesh.

Aonla (*Emblica officinalis*) is a deciduous tree species belonging to Euphorbiaceae family, native to India. The fruit of *E. officinalis* is considered a ‘wonder fruit for health’ because of its unique qualities. The fruit of aonla is the richest source of vitamin C and also pectin. The species is capable of yielding fruits under adverse conditions on marginal land. It has many medicinal properties and also anticancer properties [7]. Carambola as a dwarf species is found to grow under some large trees in the homesteads of the country. It is also a rich source of reducing sugars, ascorbic acid, and minerals like K, Ca, Mg and P [8]. Lemon belongs to Rutaceae family and is considered the third most important citrus species after orange and mandarin [9]. Lemon is normally grown as a lower storied species in the dense homestead vegetation of Bangladesh. It is also a vitamin C rich fruit that is adaptable to a wide range of soils, and environments [10]. So, these two species have enough potential to grow as a middle storied component of multistoried agroforestry systems. Growing crops layer by layer is called multilayered/ multistoried cropping system. It is an important cropping system in the homestead of Bangladesh as well as in the world [11]. According to [12], vegetable production has increased five times in the past 40 years. The land under vegetable cultivation in the country has increased at the rate of 5.0 percent in the last decade. Bangladesh has scored 3rd in the global vegetable production, next to China and India. The farmers are getting a huge profit from vegetable production which changes their living. Nonetheless, in Bangladesh, a large number of vegetables are grown in the homestead including open areas as sole crops but are seldom found in association with trees as agroforestry system. Considering the benefits of this system, it is better to explore an economically and ecologically benefited multistoried agroforestry system comprising medicinal plants (aonla), fruit trees (carambola, lemon), and winter vegetables i.e., radish which can utilize maximum natural resources like light, water, nutrients, and space) for homestead or small land utilization. Radish (*Raphanus sativus* L.) is a member of the Brassicaceae family. They are cool-season, fast-maturing, easy to grow annual or biennial herbaceous plants grown for their roots [13]. Radish is rich in antioxidants and minerals like calcium, potassium, ascorbic acid, folic acid, vitamin B_6, riboflavin, magnesium, and copper. The leafy part contains almost six times the vitamin C content of its root and is also a good source of calcium and iron. It is very low in fats [13].

Considering the above facts and exploring a suitable multistoried tree-vegetable combination, the present study primarily aimed to improve the existing systems to a more productive one that may contribute better to uplift the socio-economic condition of the poor farmers. In this view, the study addressed to evaluate the performance of different radish varieties and select suitable variety(ies) in aonla based multistoried agroforestry system.

II. Methods and Materials

A. *Location and Time of Experiment*

The study was conducted in the existing 19 years old aonla orchard established in 2000 at BSMRAU research farm at the department of Agroforestry and Environment department, Gazipur from 01st October 2019 to 30th January 2020. The experimental site is located in the agro-ecological zone of AEZ-28 (Madhupur Tract) at 24° 9′ N latitude and 90° 26′ E longitude with an elevation of 8.5 meters from sea level.

B. *Soil Characteristics*

The soil of the experimental field was terrace soil and belongs to the locally termed Salna series of shallow red-brown terrace soil [14], [15] of Madhupur Tract (AEZ 28). At the experimental site, the soil is silty clay loam in texture being acidic in nature. As a result, the soil develops poor fertility status and impeded internal drainage. The initial soil status of different treatments was as follows:

TABLE I: Initial Soil Status of Different Treatments

Soil characters	T_1	T_2	T_3	T_4
Soil pH	5.50	5.06	5.26	5.20
Soil OM (%)	2.31	2.21	2.44	2.31
Nitrogen (%)	0.12	0.11	0.065	0.061
Phosphorus (ppm)	6.18	11.62	9.05	4.56
Potassium (meq/100 g soil)	0.18	0.17	0.17	0.16
Sulfur (ppm)	27.24	15.49	19.23	13.62

C. *Experimental Design and Treatment*

The experiment was laid out in a factorial Randomized Complete Block Design with three replications. Factor A: Four radish varieties i.e., V_1 = BU mula 1, V_2 = BARI Mula-1 (TASAKISAN), V_3 = BARI Mula-2 (PINKY), V_4 = Rocky 45. Factor B: Four agroforestry systems i.e., T_1 = Aonla and carambola trees, T_2 = Aonla and lemon trees, T_3 = Aonla trees only, T_4 = Open field. Thus, four varieties of radish interacted with four agroforestry systems making 16 treatment combinations.

D. *Plot Size and Land Preparation*

The unit plot size was 7 m × 1 m measured by measuring tape and accommodating about 70 plants in each plot having row to row and plant to plant spacing of 50 cm and 30 cm, respectively. Each unit plot was separated by 50 cm. The land used for the experiment was well prepared with a tractor followed by harrowing and laddering up to a good tilth. During land preparation, clods were broken, and weeds and stables of the previous crops were collected and removed from the field. The plots were prepared and leveled smoothly according to the design and layout.

E. *Crop Establishment*

Seeds were sown in line with the assigned plots as well as in the control plots on 24th November 2019. Seed rate was 9-12 kg/ha. Thinning and weeding were done whenever necessary. Cow dung (8-10 t/ha), TSP (115-138 kg P/ha) and half of Urea (138 – 161 kg N/ha) and MoP (108-118 kg K/ha) were applied during the final land preparation and the rest of the Urea and MoP were applied in two equal installments at 20 and 40 days after sowing. Various intercultural operations such as weeding, irrigation, pest and disease control, etc. were accomplished for better growth and development of the radish seedlings. Thinning was done by maintaining 30 cm plant to plant distance for 15 Days after Sowing. Light irrigation was applied to avoid stagnation, but it was repeated after every 7 days up to 15 days before harvesting. Radish crops were harvested when roots were about 1 inch in diameter at the soil surface. Twenty plants were randomly selected and harvested from each plot for green yield. Harvesting was done 60 days after sowing.

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F. Sampling and Data Collection

Five plants of each variety were randomly selected from each replication for the collection of data. Leaf fresh weight, root fresh weight, leaf dry weight, root dry weight, leaf yield, and root yield were determined every 30 days intervals at 30 and 60 days from the sample plant during vegetable harvesting. Fresh yield was determined from selected plants in a plot that was converted to total yield in ton/ha and dry yield per plant (sun-dried for 5 days and then oven-dried for 72 hours at 65 °C) was determined from selected plants in a plot.

G. Data Analysis

All data were processed, calculated, and analyzed by using computer software such as MS-Excel and STATISTX 10. The data on various growth and yield contributing characteristics of the four tested radish varieties were statistically analyzed to observe the significant variation of the results due to different agroforestry systems. The analysis of variance for each of the studied characters was done by F (variance ratio) test following Randomized Complete Block Design (RCBD). The mean variance was adjusted by LSD test at a 5% level of significance. Table and graph were made from analyzed data.

III. Results and Discussion

In this chapter, the findings of the field experiment have been exhibited systematically according to the objectives under particular headings.

A. 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 multistoried agroforestry systems. Different components received different light levels due to the various size and shapes of the 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 20 DAS and continued up to 60 DAS. The mean light incidence in the radish growing season at different aonla based multistoried agroforestry systems have been presented in Fig 1.

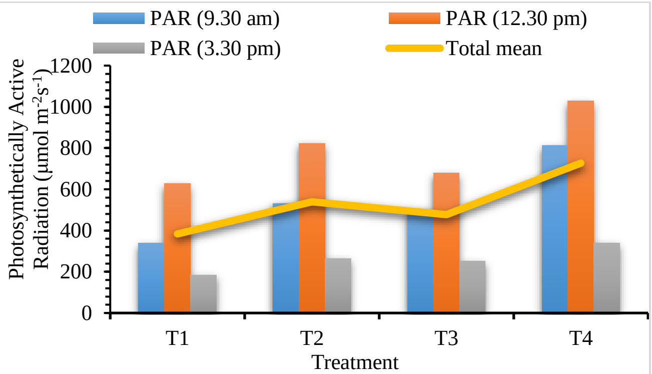

Fig. 1. Mean availability of PAR measured three times a day within the radish growing season in different Aonla based multistoried agroforestry system.

Among different aonla based multistoried agroforestry systems, the highest photosynthetically active radiation (PAR) was recorded in open filed condition (T_4) (813.19 µmol m^{-2} s^{-1} at 9.30 am, 1027.92 µmol m^{-2} s^{-1} at 12.30 pm, 339.94 µmol m^{-2} s^{-1} at 3.30 pm) within the radish growing season. The lowest PAR was recorded in aonla + carambola based system (T_1) (339.29 µmol m^{-2} s^{-1} at 9.30 am, 627.03 µmol m^{-2} s^{-1} at 12.30 pm, and 184.7 µmol m^{-2} s^{-1} at 3.30 pm) within the radish growing season. The recorded PAR in aonla + lemon based system (T_2) and aonla based system (T_3) was varying between PAR in aonla + carambola based system (T_1) and open field condition (T_4). Thus, ultimately seasonal mean PAR of a day was also the highest (727.02 µmol m^{-2} s^{-1}) in open field condition (T_4) followed by aonla + lemon based system (T_2) (538.97 µmol m^{-2} s^{-1}), aonla based system (T_3) (476.68 µmol m^{-2} s^{-1}) and aonla + carambola based system (T_1) (383.67 µmol m^{-2} s^{-1}). 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. Although there was higher canopy coverage in T_1 than T_2, T_3; T_2 showed higher light intensity than T_3. It might be due to the position of T_2 (aonla + lemon based system) and T_3 (aonla based system) plot in the experimental site. T_2 (aonla + lemon based system) plot was placed on the east side which was the starting point of the experimental field. But T_3 was placed in the middle point which was the south side of the field. So, T_3 plot gets a lower amount of light due to partial shading of the adjacent field comparatively than T_2. [16] observed that [17] was observed that shading by taller species usually reduced the photosynthetically active radiation that regulates photosynthesis, dry matter production, and yield of a crop.

B. Leaf Fresh Weight and Root Fresh Weight

a) Effect of agroforestry system

The mean effect of different agroforestry systems on leaf and root fresh weight was significant which is presented in Fig. 2.

At 30 DAS, the highest leaf fresh weight (85.92 g) was observed in open field (T_4) which was significantly different from other treatments. In contrast, the lowest leaf fresh weight (44.44 g) was found in aonla + carambola based system (T_1). At 60 DAS, the highest leaf fresh weight (223.17 g) was noticed in open field (T_4) that did not vary with the value observed in aonla based system (T_3). In contrast, the lowest leaf fresh weight was found in aonla + carambola based system (T_1). Root fresh weight was found the highest in open field (T_4) at both sampling date. However, the lowest root fresh weight was noticed in T_2 (7.38 g) at 30 DAS. At 60 DAS, the lowest leaf fresh weight was recorded in T_1 and it did not vary significantly with the value recorded in T_3. Similar result was reported by [18], [19] in radish. The lower leaf fresh weight at reduced light conditions may be due to lower production of photosynthates under low light condition [20]. It observed that plants cultivated in low light levels have more apical dominance than plants produced in high light levels, resulting in taller plants in partial shade [21].

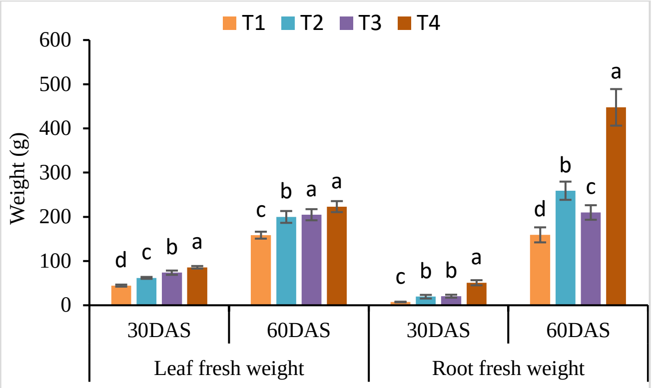

Fig. 2. Mean effect of different agroforestry systems on leaf fresh weight and root fresh weight of radish at 30 DAS and 60 DAS.

b) Responses of radish varieties

Varietal performance of radish in leaf and root fresh weight is presented in Table Ⅰ.

Results showed that leaf fresh weight did not vary among four varieties at 30 DAS. On the other hand, at 60 DAS, the highest leaf fresh weight was noticed in BU mula-1 (233.02 g) which did not vary with the recorded value in BARI Mula-2. In contrast, the lowest leaf fresh weight was found in Rocky 45 (152.42 g). At 30 DAS, the highest root fresh weight (41.29 g) was noticed in Rocky 45 and the lowest root fresh weight was found in BU mula-1. At 60 DAS, Rocky 45 gained the highest amount of root fresh weight (356.08 g). Root fresh weight did not vary between BARI Mula-1and BARI mula-2 at both sampling dates. On the other hand, root fresh weight was found the lowest in BU mula-1 (176.28 g). Leaf and root fresh weight were significantly different among different varieties due to their genetic characteristics.

c) Interaction effect

Interaction effect of the agroforestry system and varieties on the leaf fresh weight and root fresh weight of radish was significant (Table Ⅱ). Result showed that at 30 DAS, the highest leaf fresh weight was produced by Rocky 45 (95.36 g) in aonla + carambola based system (T_1V_4) and it did not vary with the value observed in T_2V_4, T_4V_3, T_4V_4. However, the lowest value was recorded in T_3V_1 but it did not vary with the value recorded in T_1V_1, T_1V_2, T_2V_1, T_3V_1, T_4V_1. At 60 DAS, the highest leaf fresh weight (276.47 g) was produced by Rocky 45 in aonla + carambola based system (T_1V_4) which was statistically similar to the value recorded in T_4V_1, T_4V_2, T_2V_1. On the other hand, the lowest value was recorded in T_4V_1 which did not vary significantly from the value recorded in T_4V_1, T_4V_2. At 30 DAS, the highest root fresh weight (78.05 g) was produced by Rocky 45 in an open field (T_4V_4). In contrast, the lowest root fresh weight was recorded in BU Mula-1 at aonla + carambola based system (T_1V_1) but it did not vary with the value recorded in T_1V_1, T_1V_2, T_1V_3, T_1V_4, T_2V_1, T_3V_1. At 60 DAS, Rocky 45 produced the highest root fresh weight (592 g) in open field (T_4V_4) but it did not vary with the value recorded in T_2V_4. In contrast, the lowest root fresh weight was found in T_1V_1 but it did not vary with the value recorded in T_2V_1. Rest of the interaction effects on root weight were statistically different.

In open field conditions, high light intensity resulted in more photosynthesis which consequently increased dry matter percentages and caused increased root weight compared to agroforestry systems. [17], [22] observed fresh yield of Kangkong and Okra under shade condition content more water compared to open field condition and they opined the possible cause of this higher water content was due to less transpiration under shade condition. Light availability was higher in the open field compared to the agroforestry system, which effect root weight. The outcomes of our study are corroborated by [23] on tomato cultivars under ghoraneem (*Azadirachta indica*) and sissoo (*Dalbergia sissoo*) based agroforestry systems.

C. Leaf dry Weight and Root Dry Weight

a) Effect of agroforestry system

Leaf dry weight and root dry weight are important yield contributing characteristics that were found to be influenced by different agroforestry systems and open field conditions. These effects are presented in Fig 3.

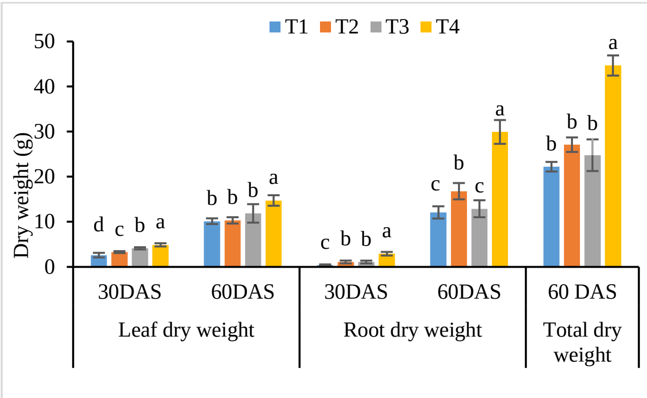

Fig. 3. Mean effect of different agroforestry systems on leaf dry weight and root dry weight and total dry weight of radish at 30 DAS and 60 DAS.

At 30 DAS, the maximum leaf dry weight was found in an open field (4.89 g) significantly followed by aonla based system (T_3), aonla + lemon based system (T_2) and then aonla + carambola based system (T_1). At 60 DAS, significantly the highest leaf dry weight was found in an open field (14.74 g) while leaf dry weight observed in T_3, T_2, T_1 did not vary. At 30 DAS, root dry weight was significantly the highest in open field conditions (2.92 g) while root dry weight was observed in T_2 and T_3 did not vary significantly. In contrast, the lowest root dry weight was found in T_1 (0.42 g) at 30 DAS. At 60 DAS, significantly the highest root dry weight was found in open field conditions (29.94 g). Root dry weight did not vary between T_1 and T_3. At harvesting time, the maximum total dry matter was found in open field conditions (44.67 g). In aonla + carambola based system (T_1), the total dry matter was found minimum that did not vary with the noticed value in aonla + lemon based system and aonla based system.

b) Responses of varieties

Determination of root dry weight is an important factor that was significantly different among four varieties under this study (Table Ⅲ). Leaf dry weight did not vary among varieties at 30 DAS. At 60 DAS, BU mula-1 produced significantly the highest leaf dry weight (15.94 g) but leaf dry weight did not vary among BARI Mula-1, BARI Mula-2 and Rocky 45.

TABLE II: MEAN EFFECT OF RADISH VARIETIES ON LEAF AND ROOT FRESH WEIGHT IN AONLA BASED MULTISTORIED AGROFORESTRY SYSTEM AT 30 AND 60 DAS

Variety	Leaf fresh weight (g)		Root fresh weight (g)	
	30DAS	60DAS	30DAS	60DAS
BU Mula 1	64.99 ± 6.80a	233.02 ± 11.92a	11.27 ± 2.26c	176.28 ± 16.01c
BARI mula-1	68.07 ± 5.16a	185.47 ± 15.83b	21.40 ± 5.43b	280.72 ± 20.13b
BARI mula-2	62.37 ± 4.01a	215.47 ± 13.06a	24.28 ± 4.94b	262.92 ± 39.20b
Rocky 45	70.58 ± 5.84a	152.42 ± 11.11c	41.30 ± 7.42a	356.08 ± 27.64a
$LSD_{(0.05)}$	8.43	18.79	3.04	30.812
CV(%)	15.20	11.46	14.86	13.74

Different alphabetical letters showed a statistically significant level ($P < 0.05$) among the varieties, following a least significant difference (LSD) test.

TABLE III: INTERACTION EFFECT OF AGROFORESTRY SYSTEM AND VARIETY ON LEAF FRESH WEIGHT AND ROOT FRESH WEIGHT OF RADISH AT 30 DAS AND 60 DAS

Treatment interaction	Leaf fresh weight (g)		Root fresh weight (g)	
	30DAS	60DAS	30DAS	60DAS
T_1V_1	43.45 ± 3.32g	173.80 ± 9.73def	5.41 ± 0.44i	102.60 ± 6.73h
T_1V_2	53.17± 3.38efg	223.20 ± 18.31bc	6.58 ± 1.20hi	174.07 ± 10.02fg
T_1V_3	67.99± 7.41de	258.60 ± 5.64ab	7.51 ± 1.72hi	185.27 ± 16.94ef
T_1V_4	95.36± 2.15a	276.47 ± 7.04a	10.00 ± 1.25ghi	243.20 ± 5.65de
T_2V_1	46.79± 4.67fg	151.53 ± 13.06efg	6.71 ± 0.71hi	113.40 ± 0.59gh
T_2V_2	61.16± 1.27def	189.67 ± 15.84cd	12.51 ± 2.21fgh	262.60 ± 36.71cd
T_2V_3	73.25 ± 2.36bcd	202.67 ± 11.64cd	16.79 ± 2.90ef	196.00 ± 26.17ef
T_2V_4	91.08 ± 2.52a	198.00 ± 13.87cd	41.58 ± 1.61c	550.87 ± 39.49a
T_3V_1	42.98 ± 14.68g	180.73 ± 28.17de	9.28 ± 2.23ghi	186.20 ± 25.58ef
T_3V_2	69.06 ± 3.46cde	246.33 ± 9.13ab	14.65 ±1.96fg	278.40 ± 20.44cd
T_3V_3	65.67 ± 3.96de	187.47 ± 5.20cde	22.57 ± 4.06de	182.20 ± 22.61ef
T_3V_4	71.77 ± 10.79bcd	247.33 ± 20.10ab	35.54 ± 4.70c	404.87 ± 37.51b
T_4V_1	44.53 ± 0.37fg	128.13 ± 3.38g	23.70 ± 0.31d	234.93 ± 0.76def
T_4V_2	64.39 ± 0.40de	140.13 ± 0.20fg	51.86 ± 0.37b	321.40 ± 0.18c
T_4V_3	87.94 ± 4.04ab	170.53 ± 0.55def	50.25 ± 0.43b	276.00 ± 0.29cd
T_4V_4	85.47± 0.49abc	170.87 ± 0.27def	78.05 ± 0.06a	592.00 ± 0.50a
$LSD_{(0.05)}$	16.86	37.57	6.08	61.64
CV(%)	15.20	11.46	14.86	13.74

Values (mean ± SE) for treatment and a variety of combinations were attained from three replications ($n = 3$). Different alphabetical letters showed a statistically significant level ($P < 0.05$) among the treatments, following a least significant difference (LSD) test.

TABLE Ⅳ: MEAN EFFECT OF RADISH VARIETIES ON LEAF & ROOT DRY WEIGHT AND TOTAL DRY WEIGHT IN AONLA BASED MULTISTORIED AGROFORESTRY SYSTEM AT 30 DAS AND 60 DAS

Variety	Leaf dry weight (g)		Root dry weight (g)		Total dry weight
	30DAS	60DAS	30DAS	60DAS	60 DAS
BU mula 1	3.91 ± 0.19a	15.94 ± 0.63a	0.66 ± 0.04c	12.91 ± 1.36c	28.85 ± 3.77 a
BARI Mula-1	3.48 ± 0.19a	11.25 ± 0.70b	1.29 ± 0.22b	19.59 ± 1.81ab	30.84 ± 4.75a
BARI Mula-2	3.61 ± 0.29a	11.00 ± 2.05b	1.49 ± 0.13b	16.26 ± 1.88bc	27.26 ± 2.15a
Rocky 45	3.90 ± 0.27a	8.87 ± 1.16b	2.09 ± 0.29a	22.95 ± 2.64a	31.824 ± 2.61a
$LSD_{(0.05)}$	0.64	2.84	0.21	3.74	2.756
CV(%)	20.46	28.95	17.92	25.04	22.73

Different alphabetical letters showed a statistically significant level ($P < 0.05$) among the varieties, following a least significant difference (LSD) test.

TABLE Ⅴ: INTERACTION EFFECT OF AGROFORESTRY SYSTEM AND VARIETY ON LEAF DRY WEIGHT, ROOT DRY WEIGHT, AND TOTAL DRY WEIGHT OF RADISH AT 30DAS AND 60 DAS

Treatment interaction	Leaf dry weight (g)		Root dry weight (g)		Total dry weight
	30DAS	60DAS	30DAS	60DAS	60 DAS
T_1V_1	2.38 ± 0.23f	11.14 ± 1.17cde	0.33 ± 0.03g	7.15 ± 0.29h	18.29 ± 0.89gh
T_1V_2	2.98 ± 4.27def	12.13 ± 0.60cde	0.43 ± 0.07g	11.14 ± 1.79e-h	21.06± 1.26fgh
T_1V_3	4.04 ± 0.58bcd	19.76 ± 0.60ab	0.48 ± 0.09fg	14.39 ± 2.03d-h	25.37± 1.86e-h
T_1V_4	6.25 ± 0.25a	20.73 ± 0.55a	1.41 ± 0.06d	18.97 ± 1.60bcd	24.16± 1.94e-h
T_2V_1	2.75 ± 0.44ef	11.40 ± 1.47cde	0.35 ± 0.08g	9.66 ± 1.73fgh	23.27± 3.16e-h
T_2V_2	3.26 ± 0.10def	10.61 ± 2.04cde	0.66 ± 0.09efg	18.06 ± 4.97b-e	28.67± 3.60c-g
T_2V_3	3.84 ± 0.57cde	7.97 ± 0.32de	0.85 ± 0.29defg	8.99 ± 1.29gh	26.05± 1.00e-h
T_2V_4	4.07 ± 0.24bcd	15.02 ± 0.93bc	3.03 ± 0.32b	41.65 ± 3.47a	30.46± 4.26c-f
T_3V_1	2.64 ± 0.97ef	10.94 ± 6.39cde	0.43 ± 0.20g	14.42 ± 6.21d-h	34.15± 12.54b-e
T_3V_2	3.78 ± 0.35cde	10.08 ± 1.43cde	1.21 ± 0.09def	15.97 ± 1.27c-g	16.96± 1.15h
T_3V_3	3.90 ± 0.03b-e	10.04 ± 2.46cde	1.34 ± 0.12de	9.99 ± 1.50fgh	20.03± 3.89fgh
T_3V_4	4.12 ± 0.71bcd	12.94 ± 0.81cd	3.12 ± 0.15b	24.657 ± 2.88b	27.95± 2.50d-h
T_4V_1	2.68 ± 0.12ef	7.06 ± 0.16e	0.51 ± 0.04fg	17.10 ± 0.13c-f	39.70± 0.16bc
T_4V_2	3.12 ± 0.04def	8.46 ± 0.04de	2.17 ± 0.03c	22.00 ± 0.25bc	56.67± 0.29a
T_4V_3	4.71 ± 0.01bc	9.72 ± 0.09cde	1.52 ± 0.02cd	18.233 ± 0.25b-e	37.59± 0.32bcd
T_4V_4	5.12 ± 0.02ab	10.25 ± 0.14cde	4.12 ± 0.03a	34.47 ± 0.22a	44.72± 0.34b
$LSD_{(0.05)}$	1.27	5.68	0.4127	7.4862	5.51
CV(%)	20.46	28.95	17.92	25.04	22.73

Values (mean ± SE) for treatment and a variety of combinations were attained from three replications ($n = 3$). Different alphabetical letters showed a statistically significant level ($P < 0.05$) among the treatments, following a least significant difference (LSD) test.

However, root dry weight was found the highest in Rocky 45 on both sampling dates. At 30 DAS, root dry weight did not vary between BARI Mula-1 and BARI Mula-2. Root dry weight was found the lowest in BU mula-1 at both sampling dates. The maximum total dry matter was found in Rocky 45 (31.83 g) that did not vary with the noticed value in BARI Mula-1 and BARI Mula-2 at harvesting time. However, the minimum total dry matter was found in BARI mula-2 (27.26 g).

c) Interaction effect

The interaction effect of the agroforestry system and varieties on the leaf dry weight and root dry weight of radish was significant (Table IV).

The result showed that at 30 DAS, the highest leaf dry weight was produced by Rocky 45 (6.25 g) in aonla + carambola based system (T_1V_4) and it did not vary with value observed in T_4V_4. However, the lowest value recorded in T_1V_1 which was statistically similar to the value recorded in T_1V_2, T_2V_1, T_2V_2, T_3V_1, T_4V_1, T_4V_2. At 60 DAS, the highest leaf dry weight (20.73 g) was produced by Rocky 45 in aonla + carambola based system (T_1V_4) but it did not vary with the value recorded in T_1V_3. On the other hand, the lowest leaf dry weight was recorded in T_4V_1 but it did not vary with the value recorded in all other treatments except T_1V_3, T_1V_4, T_2V_4, T_3V_4. At 30 DAS, Rocky 45 produced the highest root dry weight (4.12 g) in an open field (T_4V_4). In contrast, the lowest root dry weight was found in T_1V_1 but it did not vary with the value recorded in all other treatments except T_1V_4, T_2V_4, T_3V_2, T_3V_3, T_3V_4, T_4V_2, T_4V_3, T_4V_4. At 60 DAS, Rocky 45 produced the highest root dry weight (34.47 g) in aonla + lemon based system (T_2V_4) but it did not vary with the value recorded in T_4V_4. In contrast, the lowest root dry weight was found in T_1V_1 but it did not vary with the value recorded in all other treatments except T_1V_2, T_1V_3, T_2V_1, T_2V_3, T_3V_1, T_3V_3. Result showed the maximum total dry matter (56.67 g) was produced by BARI Mula-1 in an open field (T_4V_2). However, the minimum total dry matter (16.96 g) recorded in T_3V_2 was statistically similar to the value recorded in all treatment combinations except T_2V_2, T_2V_4, T_3V_1, T_4V_1, T_4V_3, T_4V_4. Rest of the treatment combinations showed a statistically different result. A similar result was found in wheat in aonla and wheat based agroforestry systems [24]. Under heavy shade may be associated with the lower mobilization of reserve assimilation to reproductive organs [16]. Fruit weight plant-1, single fruit weight, and dry weight were all highest in sole cropping of okra hybrid variety, while Litchi + Local okra variety had the lowest fruit weight plant-1, single fruit weight, and dry weight [16]. Plants and fruits with the less dry matter have also been recorded by [25].

D. Yield Performance of Radish

a) Effect of agroforestry system

Leaf yield and root yield (t/ha) of radish were significantly influenced by different agroforestry systems and open field conditions (Fig. 4). It is evident that at 30 DAS, the highest leaf yield (5.72 t/ha) was observed in an open field (T_4) which was significantly different from other treatments. In contrast, the lowest leaf yield (2.96 t/ha) was found in aonla + carambola based system (T_1). At 60 DAS, the highest leaf yield (14.88 t/ha) was noticed in an open field (T_4) while leaf yield was observed in T_2 and T_3 did not vary significantly. In contrast, the lowest leaf yield (10.57 t/ha) was found in aonla + carambola based system (T_1).

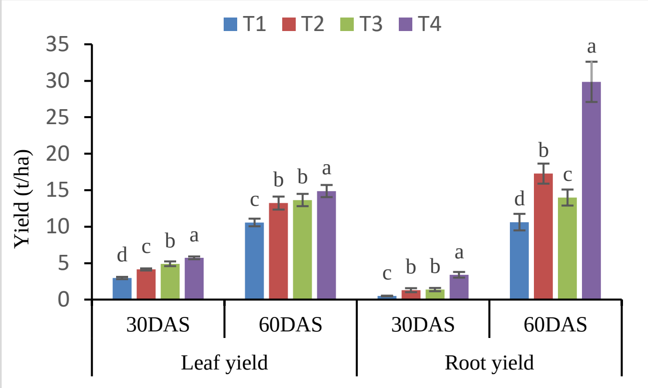

Fig. 4. Mean effect of different agroforestry systems on leaf & root yield.

Root yield was found the highest in an open field (T_4) at both sampling dates (3.40 and 29.85 t/ha respectively). However, the lowest root yield was noticed in T_1 (0.49 t/ha) at 30 DAS. At 60 DAS, the lowest leaf yield (10.62 t/ha) was recorded in aonla + carambola based system (T_1). Lower root length was found in the agroforestry system than in open fields due to the shade effect. Lower light conditions decreased the sink activities of lamina and petiole of the leaf ultimately decreasing the root length [26].

b) Responses of varieties

Leaf yield and root yield (t/ha) of different radish varieties is presented in Table Ⅴ. Results showed that leaf yield did not vary among four varieties at 30 DAS. On the other hand, at 60 DAS, the highest leaf yield was noticed in BU mula-1 (15.53 t/ha) which did not vary with the recorded value in BARI Mula-2. In contrast, the lowest leaf yield was found in Rocky 45 (10.16 t/ha). At 30 DAS, the highest root yield (2.75 t/ha) was noticed in Rocky 45 and the lowest root yield was found in BU mula-1 (0.75 t/ha). At 60 DAS, Rocky 45 gained the highest amount of root yield (23.24 t/ha). Root yield did not vary between BARI Mula-1and BARI Mula-2 at both sampling dates. On the other hand, root yield was found the lowest in BU mula-1 (11.75 t/ha).

c) Interaction effect

The interaction effect of the agroforestry system and varieties on the leaf and root yield of radish was significant (Table VI). The result showed that at 30 DAS, the highest leaf yield was produced by Rocky 45 (6.36 t/ha) in aonla + lemon based system (T_2V_4) and it did not vary with value observed in T_1V_4, T_4V_4, T_4V_3. However, the lowest value was recorded in T_3V_1 (2.87 t/ha) but it did not vary with the value recorded in T_1V_1, T_1V_2, T_2V_1, T_4V_1. At 60 DAS, the highest leaf yield (18.43 t/ha) was produced by Rocky 45 in open field condition (T_4V_1) and it did not vary with the value observed in T_3V_1, T_4V_3, T_2V_3. However, the lowest leaf yield was recorded in T_1V_4 (8.54 t/ha) but it did not vary with the value recorded in T_2V_4, T_1V_2. At 30 DAS, the highest root yield (5.20 t/ha) was produced by Rocky 45 in an open field (T_4V_4). In contrast, the lowest root yield (0.36 t/ha) was recorded in BU Mula-1 at aonla + carambola based system (T_1V_1) but it did not vary with the value recorded in T_1V_2, T_1V_3, T_1V_4, T_2V_1, T_3V_1. At 60 DAS, the highest root yield (39.47 t/ha) was produced by Rocky 45 in an open field (T_4V_4) but it did not

TABLE V: MEAN EFFECT OF RADISH VARIETIES ON LEAF AND ROOT YIELD (T/HA) IN AONLA BASED MULTISTORIED AGROFORESTRY SYSTEM AT 30 DAS AND 60 DAS

Variety	Leaf yield (t/ha)		Root yield (t/ha)	
	30DAS	60DAS	30DAS	60DAS
BU mula 1	4.71 ± 0.45a	15.53 ± 0.92a	0.75 ± 0.15c	11.75 ± 1.07c
BARI Mula-1	4.54 ± 0.34a	12.37 ± 0.55b	1.43 ± 0.36b	18.72 ± 3.37b
BARI Mula-2	4.33 ± 0.32a	14.36 ± 0.66a	1.62 ± 0.33b	17.53 ± 1.90b
Rocky 45	4.16 ± 0.39a	10.16 ± 0.52c	2.75 ± 0.49a	23.74 ± 2.92a
$LSD_{(0.05)}$	0.64	1.2525	0.21	2.0549
CV(%)	15.20	11.46	14.83	13.74

Different alphabetical letters showed statistically significance level ($P < 0.05$) among the varieties, following a least significant difference (LSD) test.

TABLE VI: INTERACTION EFFECT OF AGROFORESTRY SYSTEM AND VARIETY ON LEAF YIELD AND ROOT YIELD OF RADISH AT HARVESTING TIME

Treatment interaction	Leaf yield (t/ha)		Root yield (t/ha)	
	30 DAS	60 DAS	30 DAS	60 DAS
T_1V_1	2.90 ± 0.22g	11.59 ±0.65def	0.36 ± 0.03i	6.840 ± 0.45h
T_1V_2	3.55 ± 0.43efg	10.10 ±1.22efg	0.44 ± 0.08hi	7.560 ± 0.67gh
T_1V_3	4.53 ± 0.49de	12.05 ±0.38de	0.50 ± 0.11hi	12.413 ± 1.13ef
T_1V_4	6.36 ± 0.14a	8.54 ± 0.47g	0.67 ± 0.08ghi	15.660 ± 0.38def
T_2V_1	3.12 ± 0.31fg	14.88 ± 0.87bc	0.45 ± 0.05hi	11.607 ± 0.04fg
T_2V_2	4.08 ± 0.08def	12.647 ± 1.06cd	0.83 ± 0.15fgh	17.507 ± 2.45cd
T_2V_3	4.88 ± 0.16bcd	16.423 ± 0.78ab	1.12 ± 0.19ef	18.560 ± 1.74cd
T_2V_4	6.07 ± 0.17a	9.340 ± 0.92fg	2.77 ± 0.11c	21.423 ± 2.63c
T_3V_1	2.87 ± 0.98g	17.240 ± 1.88ab	0.62 ± 0.15ghi	12.350 ± 1.71ef
T_3V_2	4.60 ± 0.23cde	13.510 ± 0.61cd	0.98 ± 0.13fg	13.067 ± 1.36ef
T_3V_3	4.38 ± 0.26de	12.497 ± 0.35cde	1.50 ± 0.27de	12.147 ± 1.51ef
T_3V_4	4.79 ± 0.72bcd	11.370 ± 1.34def	2.37 ± 0.31c	18.400 ± 2.50cd
T_4V_1	2.97 ± 0.02fg	18.430 ± 0.23a	1.58 ± 0.02d	16.213 ± 0.05de
T_4V_2	4.29 ± 0.03de	13.203 ± 0.01cd	3.46 ± 0.02b	36.727 ± 0.01a
T_4V_3	5.86 ± 0.27ab	16.490 ± 0.04ab	3.35 ± 0.03b	26.993 ± 0.02b
T_4V_4	5.70 ± 0.03abc	11.390 ± 0.02def	5.20 ± 0.0a	39.467 ± 0.03a
$LSD_{(0.05)}$	16.86	2.5049	6.08	4.1099
CV(%)	15.20	11.46	14.86	13.74

Values (mean ± SE) for treatment and a variety of combinations were attained from three replications ($n = 3$). Different alphabetical letters showed a statistically significant level ($P < 0.05$) among the treatments, following a least significant difference (LSD) test.

vary with the value recorded in T_4V_2. In contrast, the lowest root yield was recorded in T_1V_1 (6.84 t/ha) which did not vary significantly from the value recorded in T_1V_2.

The study revealed that agroforestry systems had a strong influence on radish yield. A similar result was observed by [27] in okra [28]-[30] in Mungbean. Lower yield in shaded conditions in cotton was reported by [31]. In the case of higher leaf yield in shade conditions, it has been postulated that shading increased the quantity of chlorophyll and thus increases the photosynthetic efficiency of the plants, and ultimately the leaf yield increases [32]. [33] carried out an experiment on tomato plants under two shade conditions (light shade and heavy shade) and reported that the total fresh weight of tomato fruits was reduced by 7.5% under light shade and 19.95% was reduced in heavy shade. Competition for light, moisture, and nutrient were important factors in influencing yield contributing attributes in crops grown under trees as the shade of trees induce stress conditions for crop [34].

IV. CONCLUSIONS

The results of the study revealed that mean seasonal light availability over the radish crops was 727.02 µmol m^{-2} s^{-1} in an open field (T_4), 538.97 µmol m^{-2} s^{-1} in aonla + lemon based system (T_2), 476.68 µmol m^{-2} s^{-1} in aonla based system (T_3) and 383.67 µmol m^{-2} s^{-1} in aonla + carambola based system (T_1). The light availability of aonla + lemon based system, aonla based system, aonla + carambola based system was 78.38, 65.97, and 57.94%, respectively of open field conditions and it has been concluded that among four agroforestry systems radish yield was found the highest in open field condition followed by aonla + lemon, only aonla and aonla + carambola based system. Based on yield performance, Rocky 45 proved its superiority over other varieties irrespective of systems while BU mula 1 gave the lowest yield. Though Rocky 45 and BARI Mula-1 gave a better yield (39.47 and 36.73 t/ha, respectively) in open field conditions, Rocky 45 gave comparatively more yield than BARI Mula-1 in aonla + lemon based system (21.42 t/ha), aonla based system (18.4 t/ha) and aonla + lemon + carambola based system (15.66 t/ha). So, Rocky 45 could be a suitable variety for all aonla based agroforestry systems. Radish can be grown in aonla based multistoried agroforestry system though different varieties respond differently.

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