Journal of Scientific Research & Reports

26(10): 8-24, 2020; Article no.JSRR.63704
ISSN: 2320-0227

Study on the Effect of Shading on Performance of Leafy Vegetables

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ZFBH and MRH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NN managed the analyses of the study. Author AH managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2020/v26i1030318
Editor(s):
(1) Dr. Chen Chin Chang, Hunan Women's University, China.
Reviewers:
(1) Tauane Catilza Lopes Fernandes, University Federal of Ceará, Brazil.
(2) Mohammad Baig Mohammad, Andhra Loyola institute of Engineering and Technology, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/63704

Original Research Article

Received 25 October 2020
Accepted 29 December 2020
Published 31 December 2020

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Sher-e-Bangla, Dhaka, Bangladesh during the period from March, 2019 to June, 2019. The aim of the study was to select best summer leafy vegetables, suitable for holding under different shade condition in agroforestry systems. The selected vegetables were also grown in control i.e., open field condition or in full sunlight. The vegetables were Indian Spinach, Stem Amaranth, and Red Amaranth and treatments were T_0= planting summer leafy vegetables under full sunlight, T_1= planting summer leafy vegetables under 50% shade condition (reduced light intensity) and T_2 = planting summer leafy vegetables under 75% shade condition (reduced light intensity). The experiment was laid out following single factor RCBD design. Three replications were used for each treatment for each crop. During the study period maximum light intensity reduction was recorded in Red Amaranth (48.28%) in 75% shade condition and minimum light intensity was reduced in case of Indian Spinach (26.14%) under 50% shade condition. The reduced light intensity had substantial effects on various growth parameters of the summer leafy vegetables. From the experiment, significant result was observed in all morphological characteristics for all leafy vegetables under reduced light

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intensity. Apart from this, highest yield was found in Stem Amaranth (22.33 ton/ha) and Indian Spinach (13.83 ton/ha) in 75% shade condition. Highest yield of Indian Spinach (19.40 ton/ha), Stem Amaranth (27.25 ton/ha) and Red Amaranth (11.30 ton/ha) was recorded under full sunlight. Considering shade condition, Stem Amaranth and Indian Spinach were best suitable for growing in Agroforestry systems.

Keywords: Shade; light intensity; leafy vegetables; agroforestry; yield.

1. INTRODUCTION

Bangladesh is the most densely and over populated countries of the world struggling hard to feed her 16.48 crore people [1]. Population will be increased to 180 million by the year 2025, and the country will face huge problems to feed her population if the present population growth rate (1.37%) continues. The economy of the country describes its capacity and durability mostly from agriculture sector for about 13.60% of GDP (Fiscal Year 2018- 2019). About 63.33% of the total population live in rural areas and are directly dependent on agriculture for their day to day live [2]. The country has only a land area of 14.39 million hectares, but due to the ever growing population, per capita land area is decreasing at an average rate of 0.05 ha/cap/year since 1989 [3] and therefore steadily declining the land: man ratio.

In Bangladesh, besides agriculture, forest land is also decreasing day by day with the increasing population at an alarming rate. But a country needs 25% of forest land of its total area for ecological stability and sustainability. Unfortunately, Bangladesh is possessed with only 17% [4] of forest lands.

In Bangladesh, the per capita intake of vegetable is only 53 g, which is very lower than the recommended daily requirement of 200 g/head/day. The low intake of vegetables creates a remarkable influence over cereals and also reasons for malnutrition leading to different kinds of health hazards and creates many diseases. Leafy vegetables are not cultivated evenly throughout the year in Bangladesh. About 35% of the vegetables are cultivated in summer season and the rest are produced in the winter season. In summer season, many problems causes in the vegetable production like cloudy sky, low light intensity and excess rainfall are the major problems for vegetable production. The development of high yielding summer leafy vegetables could be one of the attainable efforts to rescue such problems. On the other hand, there is very little scope to increase cultivation area in Bangladesh. So we need to find out other alternatives that can increase the production.

Agroforestry system is the integration of tree and crop or vegetables on the same area of land is a promising or hopeful production system for increasing yield [5] and sustaining amiable environment. Growing of crops or vegetables in association with trees is becoming very popular day by day in case of their maximum productivity, multipurpose use and environmental consciousness among the peoples. Leafy vegetables or upperstorey crops can be integrated with forestry, orchard, or other in agroforestry systems. But farmers face problems of growing leafy vegetables after 4-5 years of tree plantations and even sometimes fail to grow vegetables under and around trees because in agroforestry systems. In agroforestry systems, different types of species are grown in association. Therefore, there is an inevitable competition for the growth resources like light availability, water and nutrients that may reduce the productivity of the understorey in particular.

Among different production limitations, light availability may be the most important limitation to the performance of the crops or vegetables particularly where an upperstorey perennial forms a continuous overstorey canopy [6]. However, under a given site condition, light availability to the understory crops/vegetables is dependent on the tree characteristics such as crown shape and density, size of the tree and tree management practices.

In Bangladesh, most of the vegetables grow in winter. Among the very few summer leafy vegetables Indian Spinach, Stem Amaranth and Red Amaranth are very common. During the year 2017-2018, the production of Indian Spinach was 81,903 metric tons covering with 25,611 acres of land [1]. In the year 2018, total area covered by Stem Amaranth was 26,881 acres with the production of 74,899 metric tons [7]. Red Amaranth covered 29403 acres with the production of 59,150 metric tons [8]. A multiple cropping system is a complex system, however, which requires knowledge of several types of crops and their interactions. When several crops are grown simultaneously on a single piece of land, between-crop interactions must be considered. One such interaction which can have substantial effects on productivity is that of shading by an associated crop, a problem which occurs when crops of different heights are grown together [9,10].

A broader scientific knowledge of the effects of shading can be helpful in developing cropping systems and planting methods which will optimize productivity. The deliberate shading of soil, seedlings, plants, and crops is carried out world-wide and especially by smallholders in developing countries to protect them from environmental stresses. The yield capacity of plants can be improved through shading for a number of reasons. Shading by trees can prevent water stresses through evapotranspiration and nutrient stresses by matching growth to available nutrients, stabilize differences in day and night temperatures and protect against rain, hail, and wind impact. A decrease in airflow can beneficially influence the transport of water vapor, heat, movement of CO2 from or to surfaces, and reduce weed growth and sun scorch. If crops are planted under trees, the leaf litter can form mulch, which decomposes to release plant nutrients, reduce evaporation from the soil, and help to curb soil erosion. Pests and diseases are often discouraged by shade [11]. Trials which use artificial methods (industrially-produced materials) to reproduce natural shade are commonly used to investigate the effects of shade on plant growth.

In Bangladesh, unfortunately very few studies have been found in relation to screening out different summer vegetables in terms of their adaptability and yield under shade condition. In this situation, the present study of interaction performance of three summer leafy vegetables under reduced light level will be a pioneer study to introduce higher yielding and partial shade tolerant summer.

2. MATERIALS AND METHODS

2.1 Experimental Period and Site

The experiment was conducted at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from March to June, 2019. The experimental site was located between 23°74′N latitude and 90°35′E longitudes with an altitude of 8.2 m. (Anon., 1989). The experimental site belongs to the agro-ecological zone of “Madhupur Tract”, AEZ-28 (Anon., 1988). The soil was sandy loam with pH 5.6 and Cation Exchange Capacity (CEC) 2.64 meq 100 g soil^{-1}, respectively (Analyzed from Soil Resources Development Institute, Dhaka). The geographical location of the experimental site was under the sub-tropical climate characterized by three particular seasons namely the monsoon or rainy season broadening from May to October which is associated with high temperature, high humidity and heavy rainfall.

2.2 Shade and Plant Materials

In this experiment artificial shading was created by dark green colored mosquito net. Four pieces of bamboo stakes were pegged at four corners of the shade treatment plots. The dark green colored mosquito net was then spread over the stakes to cover the plants from all sides. Care was taken to keep the mosquito net shade in appropriate condition with dynamic pace of development and yield of the plants. As leafy vegetable V_1= Indian Spinach, V_2= Stem Amaranth (Danta), V_3= Red Amaranth were used and the seeds of these vegetables were collected from Siddique Bazar, Dhaka. These three summer leafy vegetables were used as planting materials in this experiment.

2.3 Experimental Treatments

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1. T0 - Planting summer leafy vegetables under full sunlight (open field condition)
2. T1 – Planting summer leafy vegetables under reduced light intensity (50% shaded condition).

3. T2 – Planting summer leafy vegetables under reduced light intensity (75% shaded condition). In treatment T0 - sunlight was allowed to fall over the leafy vegetables without any barrier which was considered as full sunlight level.

In treatment T1 and T2 - plants were grown under light purple and dark green colored mosquito net which permitted reduced light intensity or PAR (Photo synthetically Active Radiation) to reach to the vegetables under artificial shade.

2.4 Experimental Design and Layout

Three summer leafy vegetables viz. Indian Spinach, Danta (Stem Amaranth) and Red Amaranth were sown under full sunlight (100% PAR) and shade following the Randomized Complete Block Design (RCBD) with single factor experiment. Three treatments were used in this experiment. Three replications were used for each treatment for each crop. So, there were in total 9 (3×3) treatment combinations such as V1T1, V1T2, V2T1, V2T2, V3T1, V3T2, V1T0, V2T0, V3T0 and total 27 (9×3) plots were set up. Individual plot sizes for vegetables were 2.85 m × 2 m. Adjacent plots and neighboring blocks were separated by 0.5 m and 1 m respectively.

2.5 Crop Establishment and Management

Healthy seeds were selected and sown directly on the experimental field on 25th March, 2019. The leafy vegetable (Indian Spinach, Danta, Red Amaranth) seeds were sown maintaining the spacing of 50 cm from one line to another. Recommended dose of well decomposed cowdung 5 ton/hectare were applied for all the crop species. Chemical fertilizers (220-80-70 kg/hectare) were applied as per the Islam and Haque [12] recommendation fertilizers of this crop. Full amount of TSP, MP and well decomposed cowdung was incorporated during the final land preparation. Urea fertilizers were applied in three equal installments. Different intercultural operations (Thinning, gap filling, removal of weed and plant protection measures) were done as per when needed.

2.6 Recording of Data

Plant height, number of leaves per plant, number of branches per plant, plant diameter, leaf chlorophyll content, height from base to crown, width of crown was recorded at 15, 30, 45 and 60 DAS (Days After Sowing).In case of Indian Spinach yield/plot and yield/hectare was recorded at 30, 45 and 60 DAS. In case of Stem Amaranth yield/plot and yield/hectare was recorded at 60 DAS. Soil temperature, soil moisture and leaf chlorophyll were recorded during the crop establishment.

2.7 Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of summer leafy vegetables under different shading conditions. The mean values of all the characters were calculated and analysis of variance techniques to obtain the level of significance by using a computer program STATISTIX 10. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability.

3. RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained from the present study. The results have been presented, discussed and possible interpretations were given in tabular and graphical forms. The results obtained from the experiment have been presented under separate headings and sub-headings as follows:

3.1 Climatic Parameters

3.1.1 Light availability on crops

Plants need daylight for their photosynthesis, and their development rate is relative to the amount got, taking into account that other environmental attributes are not constraining for their development and improvement. Noticeable light is a composite of frequencies somewhere in the range of 400 and 700 nanometers (nm), and this particular waveband is characterized as PAR (photosynthetically active radiation). PAR comprises of frequencies that are used by the plant in the procedures of photosynthesis to change over light energy into biomass (i.e; carbon molecules (sugars) that are then used to build progressively complex compound, and eventually plant cells and organs (root, leaf, stem, flower, fruit).

Light availability was estimated to decide the degree of limiting radiation by conceal or shade net on the understorey vegetable lines. Light for various crops in sun and shade conditions which was estimated as introduced in Table 1.

From Table 1 it is observed that during the study period maximum light intensity reduction was recorded in Red amaranth (48.28%) in 75% shaded condition and minimum light intensity was recorded in Indian Spinach (26.14%) under 50% shade. This may happen as Red amaranth plants don't grow well in 75% shaded condition and absorbs little light in 75% shade. On the other hand Indian Spinach absorbs maximum light and grows well in 50% shaded condition.

3.2 Soil Temperature

In March, the mean monthly soil temperature was 32.0°C in the 50% shade compared to 30.3°C in the 75% shade and 33.6°C in the open. The maximum temperature was recorded in April- 35.7°C in full sun light and 34.2°C in 50% shade and 33.5°C in 75% shaded condition. In the months of May and June soil temperature was diminished from 35.1°C to 34.5°C in open condition and from 34.0°C to 32.9°C in 50% shaded condition and 33.3°C to 32.1°C in 75% shaded condition. This has been presented as the graphical presentation as Fig. 1.

3.3 Soil Moisture

In March, mean monthly soil moisture was 15.6% in the 50% shaded condition compared to 14.8% in the 75% shaded condition and 19.3% in the open. In April, the soil moisture was reduced in sun to 14.2% and increased to 15.7% in the 50% shaded condition and 17.1% in the 75% shaded condition. The highest soil moisture was recorded in June among in open, 50% shade and 75% shade as 38.3%, 32.6% and 28.5% followed by May where soil moisture were 29.8%, 25.1% and 22.3% in sun, 50% shade and 75% shade respectively. This is presented as the graphical presentation as Fig. 2.

Table 1. Light availability in the different crops from March to June 2019

Light condition (kilolux)	Indian Spinach (cm)	Stem Amaranth (cm)	Red Amaranth (cm)
50% Shade	52.02	48.27	46.01
75% Shade	40.08	36.08	33.50
Full Sun	70.43	68.96	64.78
Reduction of light	26.14% , 43.09%	30.00%, 47.67%	28.97%, 48.28%

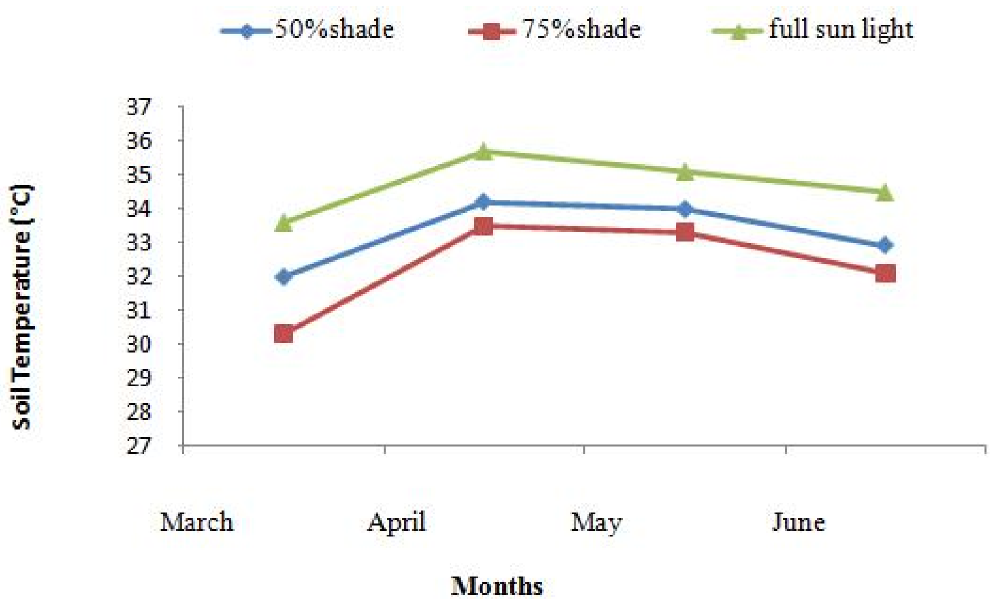

Fig. 1. Full Sun Light and Shade effects on soil temperature from the months of March to June 2019

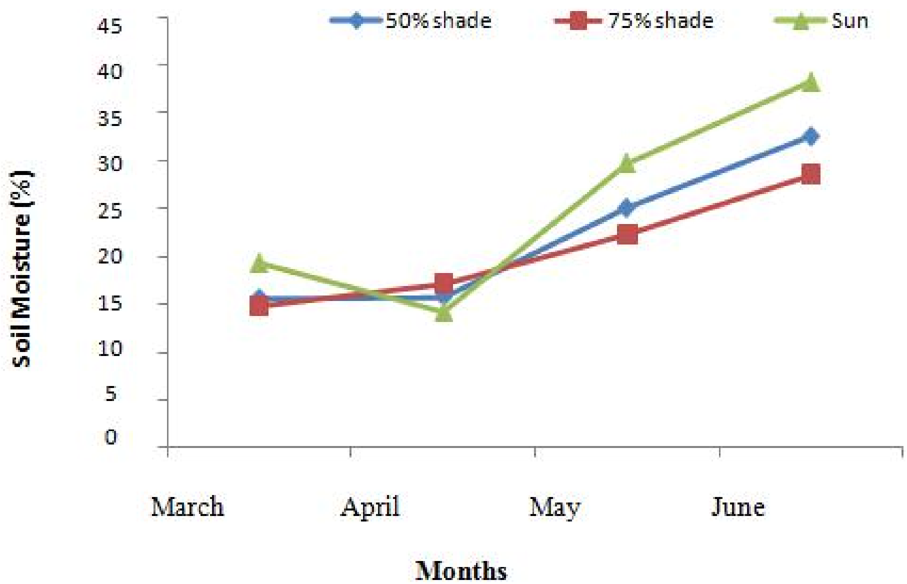

Fig. 2. Full sun light and shade effects on soil moisture from the months of March to June 2019

3.3.1 Soil moisture and temperature effects on three summer leafy vegetables in May 2019

Impacts of Sun and shade on soil moisture and ultimate effect on Indian spinach, Stem Amaranth and Red Amaranth were recorded and significant variations were found. In case of Indian Spinach, highest soil moisture in 75% shaded condition 28.3% was observed while the highest soil moisture in 50% shaded condition and in open or sun was recorded in Red amaranth 22.1% and 20.3%. In sun, the lowest soil moisture was recorded in Stem amaranth 19.0% while in 50% shaded condition was recorded 21.5% (Fig. 3).

Impacts of sun and shade in soil temperature on Indian spinach, Stem amaranth and Red amaranth were recorded and found significant differences. In sun, the highest soil temperature was recorded in Stem amaranth 34.6°C. In 50% shaded condition, the highest soil temperature was recorded in Red amaranth 32.2°C and in 75% shaded condition the highest soil temperature was recorded in Stem amaranth 30.5°C (Fig. 3).

Soil moisture and temperature effects on three summer vegetables in May 2019 was recorded which has been shown as the graphical presentation as Fig. 3.

3.3.2 Morphological features of the three summer leafy vegetables under different shading condition

3.3.2.1 Indian spinach

Plant height:

Significant effect on plant height of Indian Spinach was found in reduced light condition based agroforestry system. Indian Spinach grew under shade condition produced more vigorously than those cultivated in the open field. It was found significantly the highest plant height in shaded condition. The highest plant height of Indian Spinach was found in T2 (58.80 cm) which was reduced significantly as the shading condition reduced. This was occurred probably due to the higher apical dominance under shade condition [13]. With the increase of shade levels plant height increased significantly. The minimum plant height (45.00 cm) was found in T0 which was full sunlight condition under this study (Table 2). Same results observed in mungbean as crop showed higher plant height under shaded condition was in mungbean [14] and in chickpea [15]. This result may be attributed due to the stimulation of cellular expansion and cell division under reduced light levels [16].

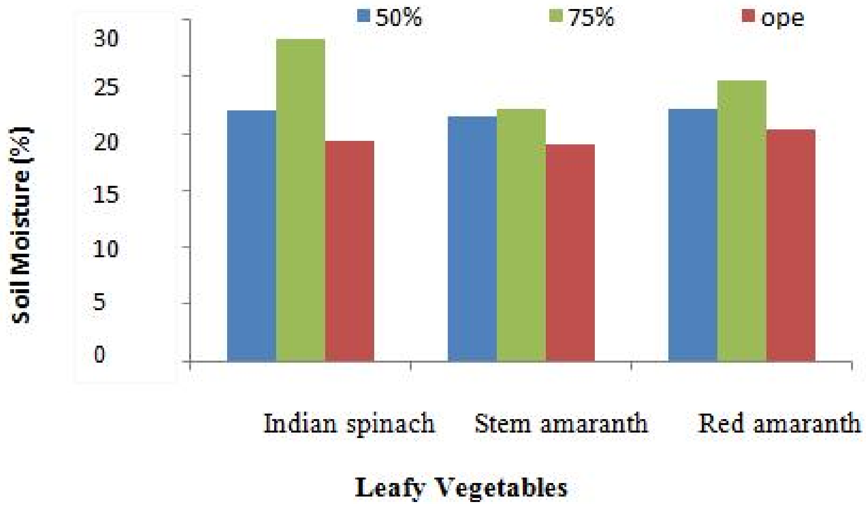

Fig. 3. Soil moisture effects on three summer leafy vegetables in May 2019

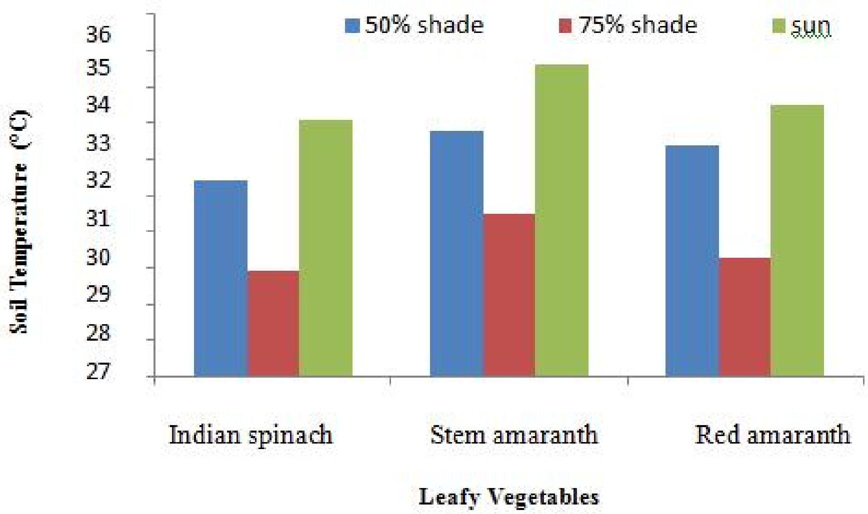

Fig. 4.Soil temperature effects on three summer leafy vegetables in May 2019

Number of leaves per plant:

Total number of leaves per plant of Indian spinach was also significantly influenced by different shade condition (Table 2). This characteristic showed an inverse trend to that of plant height as it decreased with decreasing shade condition. The higher number of leaves per plant was found in T0 (190.00) compared to that of T1 and T2 (117.36 and 110.80). The number of leaves per plant decrease at reduced sunlight may be due to the lower production of photosynthates under shade conditions for a longer period.

Number of branches per plant:

The effect of shade on the number of branch per plant was almost similar to the number of leaves per plant (Table 2), where the higher number of branches was recorded under T0 (7.65) compared to T1 (6.42) and T2 (5.87). The lower number of branches under different shaded condition might be due to higher Auxin production in plant grown under different shaded condition which ultimately suppressed the growth of lateral branches [17].

Table 2. Growth and yield contributing attributes of Indian spinach under control (full sunlight) and reduced light

Treatment	Plant height (cm)	No. of leaves / plant	No. of branch /plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	Yield (kg/ plot)	Yield (ton/ha)
T0	45.00	190.00	7.65	18.00	41.73	16.36	24.23	7.20	19.40
T1	50.28	117.36	6.42	15.60	50.37	16.58	35.20	6.53	15.67
T2	58.80	110.80	5.87	13.50	54.00	16.95	42.58	5.70	13.83
CV%	7.17	11.38	7.46	8.31	7.53	7.33	7.86	13.80	8.32
LSD0.05	3.00	12.95	0.40	1.07	2.99	0.99	2.18	0.72	1.11
Level of significance	*	**	**	*	*	NS	**	*	*

*T0 = Planting summer vegetables under full sunlight; T1 = Planting summer vegetables under 50% shade condition; T2 = Planting summer vegetables under 75% shade condition; * = 5% level of significance; ** = 1% level of significance*

Plant diameter:

Plant diameter was significantly influenced by shade in Indian spinach (Table 2). Plant diameter of Indian spinach grown under T0 was recorded as 18.00 mm but it was decreased when grown under T1 (15.60 mm) and T2 (13.50 mm).

Leaf chlorophyll content:

Significant difference was found in leaf chlorophyll content on Indian Spinach. Leaf chlorophyll content was lower (41.73 SPAD unit) in T0 level than that of T1 (50.37 SPAD unit) and T2 (54.00 SPAD unit). This may be due to in severe shaded condition the leaves of Indian spinach were more green for a longer period of time than full sunlight condition.

Height from base to crown (cm):

There were no significant responses on height to base of crown in Indian spinach statistically under the different shade condition. Highest height to base of crown was found in T2 (16.95 cm) and lowest height to base of crown was observed in T0 (16.36 cm)

Width of crown (cm):

Significant influence was found on the width of crown in Indian Spinach under different shade condition. The highest width of crown was found in T2 condition (42.58 cm) and the lowest width of crown was found in T0 condition (24.23cm).

Yield per plot and per hectare:

Significant variations were found in Indian spinach in respect of yield/plot and yield/hectare under different shade condition. The highest yield/plot were found in T0 (7.20 kg) and yield/hectare (19.40 t) were found when Indian spinach grown under full sunlight condition (T0). On the other hand, the lowest yield/plot (5.70 kg) and yield/hectare (13.83 t) were recorded in T2 when Indian spinach was cultivated under 75% shade condition (T2).

Stem Amaranth (Danta) Plant height:

Significant effect on plant height of Stem Amaranth was found in shade:

Condition based agroforestry system (Table 3). The plant height increased with increased shade level. This was occurred probably due to higher apical dominance under different shade condition [13]. In 100% light or in full sunlight (T0) plant height was 82.26 cm whereas in 50% shade condition (T1) it was increased to 100.11 cm and it was further increased in 75% shade condition (T2) to 109.90 cm. Leonardo [18] observed increased plant height, stomata density, transpiration rate and photosynthesis rate in Peppers at low PAR condition or in shade condition. This may be occurred due to the stimulation of cellular expansion and cell division under different shaded condition [16].

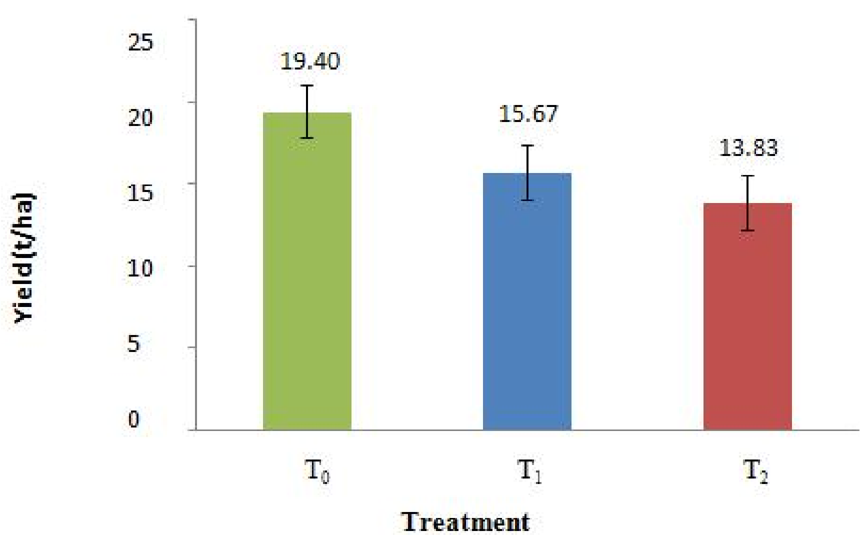

Fig. 5. Yield of Indian spinach at Full sunlight (T0), 50% shade condition (T1) and 75% shade condition (T2)

Plate 1. Indian spinach in full sunlight condition

Number of leaves per plant:

Significant differences were found in number of leaves per plant of Danta or Stem amaranth due to the effect of shade (T1 and T2 = Planting summer vegetables under partial and severe PAR). The higher number of leaves per plant was recorded in T0 (114.00) compared to that of T1 (84.33) and T_2 (74.10). The number of leaves per plant decreased with reduced light condition. This may be occurred due to the lower production of photosynthetic under different shade conditions or low light conditions for a longer period of time.

Number of branches per plant:

The effect of shade on the number of branch per plant was significantly different (Table 3), where the higher number of branches was recorded under 100% light level (T0) (24.29) compared to that of shaded (T1 and T2) condition (19.04 and 16.00). The number of branches decreased with the reduced light levels. This condition might be occurred due to higher Auxin production in plant grown under different shaded condition which ultimately suppressed the growth of lateral branches [17].

Stem diameter:

Plant diameter of Stem amaranth was significantly influenced by shade condition (Table 3). Maximum stem diameter of Stem amaranth was observed under full sunlight (T0) as 34.80 mm and minimum plant diameter was found when reduced light levels. The minimum stem diameter was found in (T2) level (22.69 mm).

Leaf chlorophyll content:

Significant effect on leaf chlorophyll content was found in Stem amaranth under different shade condition. Leaf chlorophyll content of Stem amaranth was lower (44.72 SPAD unit) in full sunlight (T0) than that of shade condition (reduced light level under T1 and T2) 51.20 and 55.00 SPAD unit respectively. This phenomenon may be occurred due to in partial or severe shaded condition leaves were greener for a longer period of time than in full sunlight condition. In full sunlight leaves were gained in more light so they became yellowed.

Height from base to crown (cm):

Significantly influence was observed on height from base to crown in case of Stem amaranth by shade condition (Table 3). Highest height from base to crown (51.29 cm) was found under severe shade condition under the treatment (T2) while the lowest height to base of crown (43.13 cm) was observed in full sunlight condition under the treatment T0.

Width of crown (cm):

Significant effect on the width of crown of Stem amaranth was observed in reduced light level. From the Table 3 it was found that the highest width of crown (48.80 cm) was found in severe shade (T2) condition and lowest (36.87 cm) in full sunlight level under the treatment T0.

Table 3. Growth and yield contributing characters of Stem Amaranth under control (full sunlight) and under reduced light

Treatment	Plant height (cm)	No. of leaves / plant	No. of branch /plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	Yield (kg/plot)	Yield (ton/ha)
T0	82.26	114.00	24.29	34.80	44.72	43.13	36.87	13.83	27.25
T1	100.11	84.33	19.04	25.21	51.20	46.23	44.72	12.78	25.77
T2	109.90	74.10	16.00	22.69	55.05	51.29	48.80	10.69	22.33
CV%	7.85	7.25	7.52	7.30	11.23	11.78	8.40	9.03	12.01
LSD0.05	6.28	5.37	1.21	7.75	4.61	4.51	2.98	0.92	2.46
Level of significance	*	**	**	*	*	NS	*	*	*

*T_0 = Planting summer vegetables under full sunlight; T_1 = Planting summer vegetables under 50% shade condition; T_2 = Planting summer vegetables under 75% shade condition; * = 5% level of significance; ** = 1% level of significance*

Yield per plot and per hectare:

Significant difference was found in yield per plot of Stem amaranth under different light levels. The highest yield per plot (13.83 kg) was found when Stem amaranth cultivated under full sunlight condition (T0). On the other hand, the lowest yield per plot (10.69 kg) was recorded when Stem amaranth was cultivated under severe shade condition (T2) (Table 3). As well as yield per hectare was significantly respond with the shade treatment (T1 and T2). Highest yield per hectare (27.25 ton) was recorded in full sunlight (T0) and lowest (22.33 ton) was in T2 or in severe shade condition.

Red Amaranth (Lal shak) Plant height:

Plant height of Red Amaranth cultivated under different light levels was Influenced significantly (Table 4). The plant height decreased with increased shade level. This was occurred probably due to lower apical dominance under shade condition [13]. In 100% light or in sunlight (T0) plant height was 30.85 cm whereas in shade condition (T1 and T2) it was decreased to 25.77 cm to 18.69 cm. Leonardo [18] found decreased plant height, stomata density, transpiration rate and photosynthesis rate in Peppers at low PAR condition.

Number of leaves per plant:

Significant differences due to the effect of reduced light on number of leaves per plant of Red amaranth was recorded and found. The higher number of leaves per plant was observed in sunlight T0 (16.49) compared to that of different shade condition T1 (11.27) and T2 (9.61). The number of leaves per plant decreased at reduced light condition may be due to the lower production of photosynthesis under low light conditions for a longer period of time.

Number of branches per plant:

The impact of reduced light level on the number of branch per plant was significantly difference to the number of leaves per plant (Table 4), where the higher number of branches was recorded under 100% light level (T0) (8.88) compared to that of different shaded (T1) condition (7.69) and T2 (6.20). The lower number of branches under different shaded condition might be due to higher Auxin production in plant cultivated under shaded condition which ultimately suppressed the growth of the lateral branches [17].

Plant diameter:

Plant diameter of Red amaranth was significantly affected by shade condition (Table 4). Maximum plant diameter of Red amaranth was seen under full sun light (T0) as 20.34 mm and minimum plant diameter was found when grown under shade (T2) condition (15.52 mm).

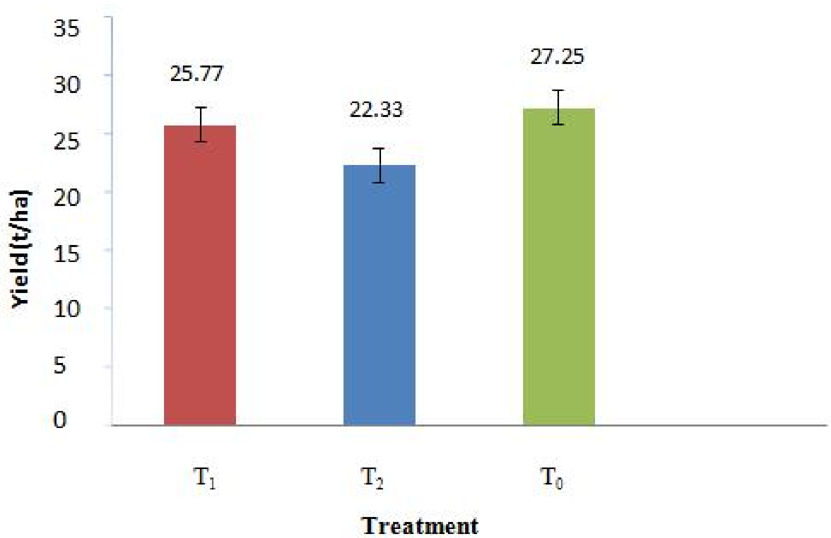

Fig. 6. Yield of Stem Amaranth at full sunlight (T0), 50% shade condition (T1) and 75% shade condition (T2)

Table 4. Growth and yield contributing characters of Red Amaranth under control (full sunlight) and reduced light

Treatment	Plant height (cm)	No. of leaves / plant	No. of branch /plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	Yield (kg/plot)	Yield (ton/ha)
T0	30.85	16.49	8.88	20.34	47.53	18.69	15.27	4.77	11.30
T1	25.77	11.27	7.69	18.90	49.28	15.43	13.53	4.00	9.10
T2	18.69	9.61	6.20	15.52	55.60	12.06	11.00	3.30	7.60
CV%	6.16	7.10	8.12	7.30	13.93	6.53	8.84	9.88	2.69
LSD0.05	3.48	2.63	0.50	0.32	5.77	2.43	2.57	0.32	2.52
Level of significance	*	*	**	*	NS	*	NS	*	*

*T_0 = Planting summer vegetables under full sunlight; T_1 = Planting summer vegetables under 50% shade condition; T_2 = Planting summer vegetables under 75% shade condition; * = 5% level of significance; ** = 1% level of significance*

Plate 2 (a). Data (Stem amaranth) plants growing under 75% shade condition

Leaf chlorophyll content:

Significant effect on leaf chlorophyll content was found in Red amaranth under different shade condition. Leaf chlorophyll content of Red amaranth was lower (47.53 SPAD unit) in full sunlight (T0) than that of shade condition reduced light level treatment under T1 (49.28 SPAD unit) and T2 (55.60 SPAD unit) respectively. This phenomenon may be occurred due to in partial or severe shaded condition leaves were greener for a longer period of time than in full sunlight condition. In full sunlight leaves were gained in more light so they became yellowed.

Height from base to crown (cm):

Height from base to crown was significantly affected in case of Red amaranth by reduced light level or shade condition (Table 4). Highest height from base to crown (18.69 cm) was found under full sunlight condition under the treatment T0 while the lowest height to base of crown (12.06 cm) was observed in severe shade condition under the treatment T2.

Width of crown (cm):

Significant influence on the width of crown of Red amaranth was found under reduced light level. From the Table 4 it was observed that the highest width of crown (15.27 cm) was seen in full sunlight (T0) condition and lowest (11.00 cm) in reduced light level- severe shade condition under the treatment T2.

Yield per plot and per hectare:

Yield per plot of Red amaranth was significantly with the different light levels. The highest yield per plot (4.77 kg) was found when Red amaranth cultivated under full sunlight condition (T0). On the other hand, the lowest yield per plot (3.30 kg) was recorded when Red amaranth was grown under severe shade condition (T2) (Table 4). As well as yield per hectare was significantly respond with the different shade treatment. Highest yield per hectare (11.30 ton) was recorded in full sunlight (T0) and lowest (7.60 ton) was in shade condition (T2).

3.3.3 Comparative yield performance of the three summer leafy vegetables under reduced light and sunlight condition

In Fig. 7, comparative yield performance of three summer leafy vegetables under reduced light and sunlight condition was shown. From the figure, it is clear that among leafy vegetables Stem Amaranth gave the highest yield (27.25 ton/ha) in the full sunlight condition (T0). Among leafy vegetables Stem Amaranth gave the highest yield (22.33 ton/ha) in severe shade treatment (T2). Stem amaranth showed promising result both in sunlight (27.25 ton/ha) and partial (T1) and severe shade (22.33 ton/ha and 25.77 ton/ha) condition. Yield of Indian spinach (19.40 ton/ha) in full sunlight (T0) and (15.67 ton/ha) and (13.83 ton/ha) was significantly different under partial shade (T1) and severe shade (T2) level. So, Indian Spinach and Stem Amaranth under agro forestry systems allowing reduced light intensity might be encouraged in rural Bangladesh.

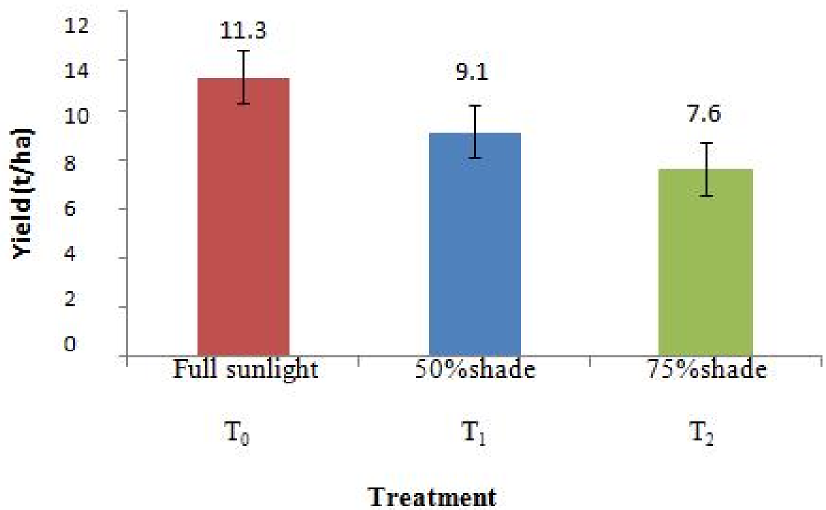

Fig. 7. Yield of Red Amaranth at full sunlight (T0), 50% shade condition (T1) and 75% shade condition (T2)

Plate 2 (b). Red amaranth plants growing under full sunlight condition

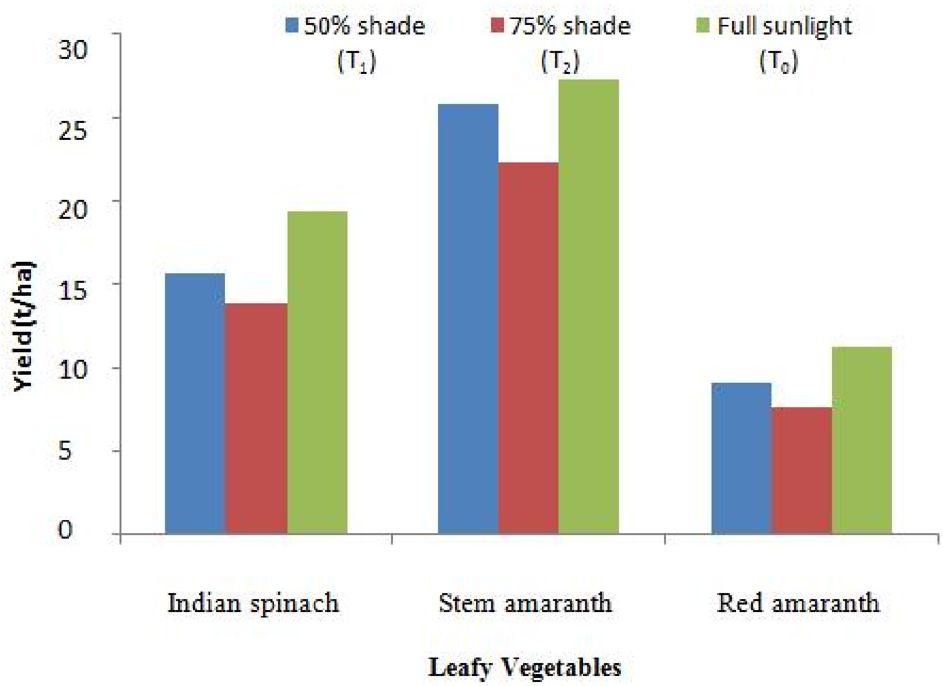

Fig. 8. Comparative yield performance of three summer leafy vegetables under reduced light and sunlight condition

4. CONCLUSION

From the experiment it is clear that among leafy vegetables Stem Amaranth gave the highest yield in the open field condition or in full sunlight. Stem Amaranth and Indian Spinach showed promising result both in sunlight and reduced light condition. Red Amaranth cannot grow well in reduced light levels. So, Stem Amaranth and Indian Spinach should be encouraged to cultivate under reduced light levels as agroforestry systems. Further studies are suggested at different agro-ecological regions of Bangladesh to evaluate the compatible summer leafy vegetables production under reduced light conditions for regional adaptability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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