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EFFECT OF SHADE LEVELS ON MICROCLIMATE, GROWTH AND PRODUCTIVITY OF SUMMER TOMATO UNDER POLY TUNNEL

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Abstract: The experiment was conducted at Vegetable Research field of Horticulture Research centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during May to September, 2017. The experiment consisted of five different light intensities maintained by using shade net at20%, 30%, 40%, 50% shade levels and a control (no shade). Shading treatments affected all environmental variables. Reduced values of photo synthetically active radiation (17.33-46.73%), temperature (1.25-3.1^{0}C) and elevated values of relative humidity (2.0-7.7%) were found due to shading compared to no shade condition. Plant height, days to flowering and fruit-set were significantly influenced by shading. The tallest plant height was measured from 50 % shade treatment at all growth stages. The earliest flowering (at 45 days) was observed in the treatment 20 % shade and fruit set was the highest (37.89 %) in 30 % shade. Yield contributing characters were also greatly influenced by shade treatments. The highest number of marketable fruits per plant(36.1) and the lowest (1.7) number of non-marketable fruits per plant were recorded from 30 % shade treatment which also produced significantly the highest yield (44.6 t/ha). Shading had also significant effect on fruit characters. Maximum length (4.48 cm), diameter (4.58 cm) and individual weight (47.1 g) of fruit were obtained from 30 % shade treatment. Shade influenced the rate of photosynthesis significantly and higher photosynthesis rate was observed in 20 % to 30 % shade conditions.

Key words: *Summer tomato, shade, PAR, RH, yield*

Introduction

The main constraint of summer tomato production in Bangladesh is high temperature associated with high rainfall during the growing period. Poly tunnel is used to protect the crop from rain. Though use of poly tunnel structure helps increase production but high temperature under the tunnel results in poor fruit set and yield. High day and/or night temperatures interfere with tomato fruit set (Berry and Uddin, 1988). Incorporating genetic resistance against detrimental effects of high temperature on tomato fruit set has not had uniform success. Thus, cultural method like shading may be one option to overcome this problem.

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It is known that the range of optimum air temperature is from 13-14 to 27-28°C and upper limit of air temperature is 30°C for growing tomato plants. However, air temperature over 30°C in summer can cause leaf scorch, low fruit set, and the incidence of small fruits. Growth and yield of crops are also related to the amount of solar radiation received during the growing period (Challa & Bakker, 1998). In summer season, climatic restrictions to plant growth have been attributed mainly to the effects of high temperatures on photosynthesis and respiration (Lapuerta, 1995). High air temperature and strong solar radiation also cause sunscald or uneven ripening in tomato fruits and thus high light condition also affects fruit quality of tomatoes (Yanagi *et al*., 1995). Being tomato an important vegetable crop in Bangladesh, research on every aspect of its cultivation to improve its productivity becomes essential. Shading technique by using shade nets or shading materials over the poly tunnels to reduce light intensity as well as temperature can be a good option to successful cultivation of this nutritious vegetable during summer.

Shading confers less light penetration and temperature in tunnel which create higher production with quality fruits (Tiwari *et al*., 2002). It was reported that shading increased the leaf area index and total marketable yield, decreased the tomato cracking by 50% and accordingly, the marketable tomato production was 50% higher under shading conditions than under non shading conditions (Kittas *et al.,* 2009).

But a very few reports are available on the effects of solar radiation on yield and quality of tomato fruits grown during summer season. So, the present study was undertaken to determine the yield and quality of tomato fruits under different levels of shades during summer season.

Materials and Methods

The experiment was conducted at Vegetable Research field of Horticulture Research centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during May 2017 to September 2017. The experiment consisted of five different light intensities. The five different light intensities were maintained by using shade net at 20%, 30%, 40%,50% shade levels and a control (no shade).The experiment was laid out in a randomized complete block design (RCBD) with three replications. The treatments were randomly allotted in each block. Unit plot size was 4×1 m and spacing followed was 60x40 cm. Each unit plot contained two rows and 20 plants. The spaces in between blocks and unit plots were 75 and 50 cm, respectively. The tomato variety BARI hybrid tomato 4 was used in the experiment as planting material. Tomato Seeds were sown in seed bed on 1 May 2017. Eight to 10 days after sowing, the young seedlings were transferred to a second seedbed at a spacing of 5×5cm. The seedlings were transplanted in the main field on 26 May 2017.Commercial shade net was used over the poly tunnel. Air temperature and humidity inside the polythene tunnel were measured by digital temperature and moisture meter. Data were recorded everyday at 12 o'clock to 1 o'clock at noon. Light intensity inside the poly tunnels were recorded with the help of Wide Range Light Meter, model EA 30, Extech Instruments Corporation, USA, in foot-candles. For standardization, all readings were taken in the middle of tunnel at 1 m height on a clear sunny day within 12 o'clock to 1 o'clock at noon. In each unit plots five plants were selected randomly for recording data on different morphological, vegetative, reproductive and yield contributing attributes. The data on plant height (cm), days to flowering, fruit set (%),number of fruits per plant, individual fruit weight (g), fruit length (cm), fruit diameter (cm), fruits plant^{-1}, yield plant^{-1} (g), yield (t ha^{-1}), marketable fruits and non marketable fruits per plant were recorded.

Instantaneous net photosynthesis was measured in three tomato plants per replication, with a portable LCpro+ photosynthesis system (ADC Bio-scientific Ltd, UK). Each measurement started with the photosynthetic rate once a steady state was reached (variable time).The readings were taken only at 11:00 to 1:00 o'clock at noon. In all cases, readings were taken on the terminal leaflet of the third leaf, counted from the plant apex.

The recorded quantitative data were analyzed statistically by using MSTAT-C a computer based program. Treatment means were compared by Least Significant Difference (LSD) Test.

Results and Discussion

Different environmental modifications inside poly tunnel covered with shade nets were documented which might help to predict or interpret specific plant responses.

Photo synthetically Active Radiation(PAR)

All shade treatments reduced PAR compared to control during the growing period (May to October). Observed PAR values(mmol.m^{-2}.s^{-1}) were reduced most under50% shading and least under 20% shading (Figure 1).

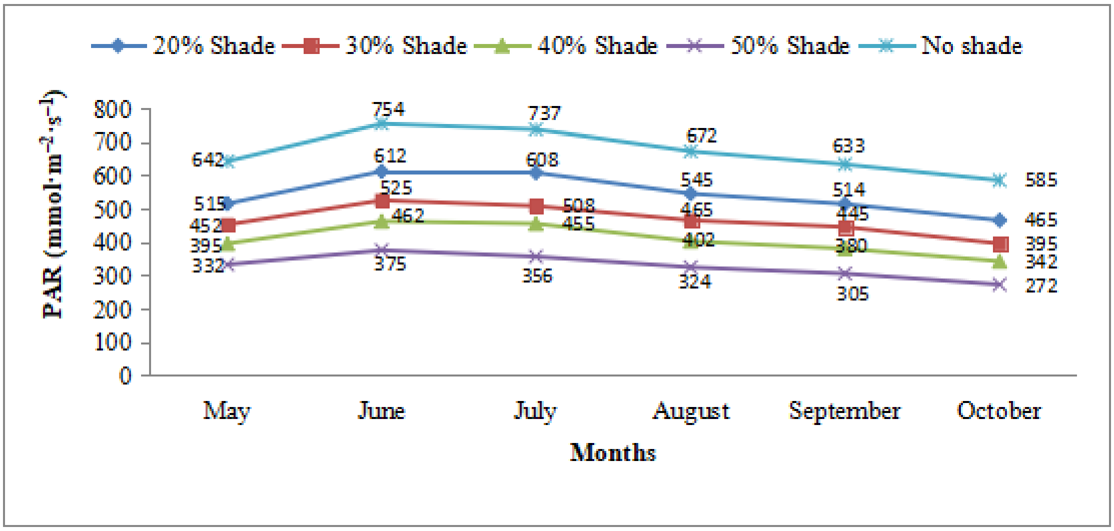

Fig. 1. Photo synthetically active radiation (PAR) measured at solar noon (mmol.m^{-2}.s^{-1}, 400 to 700 nm) inside the tunnels.

Calculated reduction of PAR values over control were 17.33% in 20% shading treatment, 27.54% in 30% shading treatment, 37.76% in 40% shading treatment and 46.73% in 50% shading treatment (Table 1). The reduced PAR in the treatments may be considered an artifact of the net manufacturing process, suggesting that nominal shade factor designations do not necessarily precisely determine actual PAR. The data showed that although transmitted PAR may be sufficient for plant growth under shading during the summer months, lower values in 50% shading treatment may be limiting for growth and yield of tomato. Kittas *et al.* (2009) stated that the reduction of solar radiation above the apple trees were proportional to the shading intensity of the net. The similar results were observed in the present study.

Temperature

The average daily maximum air temperature was lower inside tunnel with shade nets compared with no shade. Reduction of air temperatures recorded under different shade treatments over control ranged from 1.25 to 3.1 ^{0}C.The maximum 3.1 ^{0}C temperature was recorded in 50% shading treatment and the minimum 1.25 ^{0}C in 20% shading treatment (Table 1). Shahak *et al.* (2004) observed general reduction of the daily maximal air temperatures by 1-5^{o}C under 30% shading nets. This is in close agreement with the findings of the present study. Reduction of air temperatures under the tunnels with different shading treatments was proportional to the shading intensity (Kittas *et al.*, 2009).

Table 1. Mean photo synthetically active radiation (PAR), temperature, relative humidity over the growing period and their change due to shading effect.

Treatment	PAR		Max. Temperature (^{0}C)		Max. Humidity (%)	
	Mean PAR	Reduction over no shade (%)	Mean Temperature (^{0}C)	Reduction over no shade (^{0}C)	Mean Humidity (%)	Increased over no shade (%)
20% Shade	554	17.33	33.5	1.25	89.6	2.0
30% Shade	486	27.54	32.5	2.25	90.8	3.2
40% Shade	417	37.76	32.1	2.70	92.7	5.1
50% Shade	357	46.73	31.7	3.10	95.3	7.7
No shade	671	-	34.8	-	87.6	-

Relative Humidity (RH)

In addition to light, shade nets modify relative humidity inside the canopy. The differences in RH values were observed among the treatments, which remained within 87.6 to 95.3%.Elevated values of RH were found due to shading compared to non shade condition. The maximum 7.7% increase was recorded in 50% shading treatment while minimum 2.0% in 20% shading treatment (Table 1). Shahak *et al.* (2004) observed simultaneously about 3-10% increase in the minimal daily relative humidity under various 30% shading nets which is in accordance with the findings of the present study.

Photosynthesis(μ mol CO^2 $m^{-2}s^{-1}$)

Shade influenced the rate of photosynthesis significantly at 50, 60, 70, 80, 90, 100 and 110 DAT (Figure 2). It revealed that lower shade intensity i.e. 20 to 30% shade increased the photosynthesis rate compared to no shade condition and higher shade intensity (40 to 50%) reduced the rate of photosynthesis. The highest photosynthesis rate of 18.54, 19.85, 19.35 and 20.38 μ mol CO^2 $m^{-2}s^{-1}$were observed in 20%shade at 50, 60, 70 and 80 DAT respectively, while at later stages (90, 100 and 110 DAT) of growth, the maximum of 18.23, 13.56 and 10.28 μ mol CO^2 $m^{-2}s^{-1}$ of photosynthesis rate were observed under 30% shade. The minimum photosynthesis rate was observed in plants grown in 50% shade at all stages of growth. Photosynthesis is one of the most important physiological processes that determine plant growth. Shading directly or indirectly modifies the optical and fluorescence properties of sun light that affected the photosynthetic performance of the leaves. Plants exposed to excessive sunlight can sustain damage to their photosynthetic apparatus, leading to reduced net photosynthesis in many species. Under high irradiance, photo inhibition often occurs. In contrast, under low irradiance, insufficient adenosine tri phosphate (ATP) is produced to sustain carbon fixation and carbohydrate biosynthesis (Dai *et al*., 2009) thus photosynthesis rate decreased. Similar results were observed in the present study, where up to 30% shade, photosynthesis rate was increased but above that range (40% and 50% shade) photosynthesis rate was decreased. Liu and Shaozhong (2002) studied the effects of shading levels on tomato leaf photosynthesis and observed that the photosynthetic rates were increased in 40% shading treated leaves and reduced in 75% shading treatment compared to the no shaded treatment.

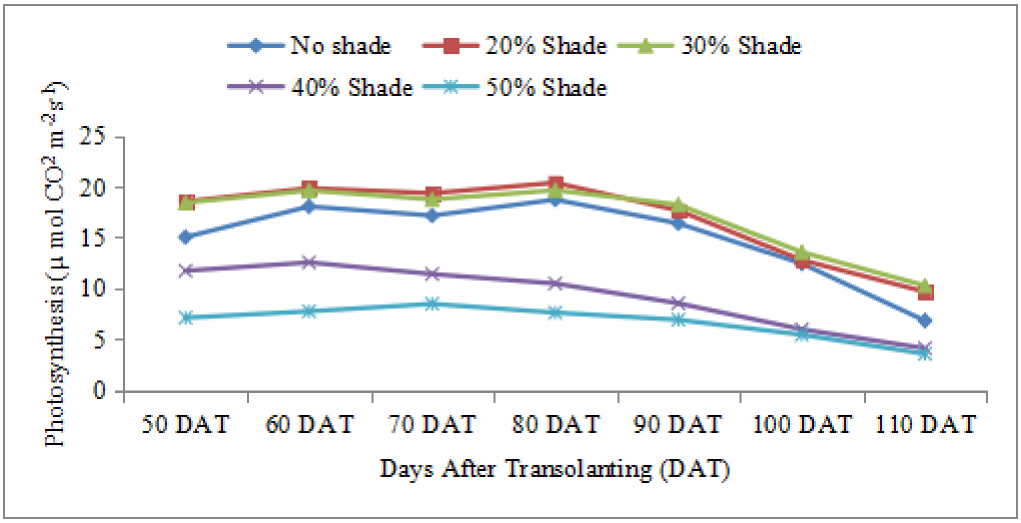

Fig. 2. Effect of shading on photosynthesis (μ mol CO^2 $m^{-2}s^{-1}$) of summer tomato at different growth stages.

Plant height (cm)

Plant height was recorded at 20, 40, 60, 80 days after transplanting (DAT)and at last harvest. Plant height varied significantly due to different shade levels at all stages of growth (Figure 3). Height of plants grown in the tunnel without shade was significantly lower than the plants grown in tunnel with shade at each stages of growth which revealed that the plant height increased with the increasing of shade intensity. The tallest plant was measured from 50% shade treatment at all growth stages. This might be due to the impact of apical dominance of plants under shade. The results are in agreement with Sharma and Tiwari (1993) who found the higher plant height under shade. Khattak *et al.* (2007) studied the response of tomato under different light levels and observed that shades had substantial effects on various growth parameters of tomato and recorded maximum plant height in 55% shade that supported the present findings.

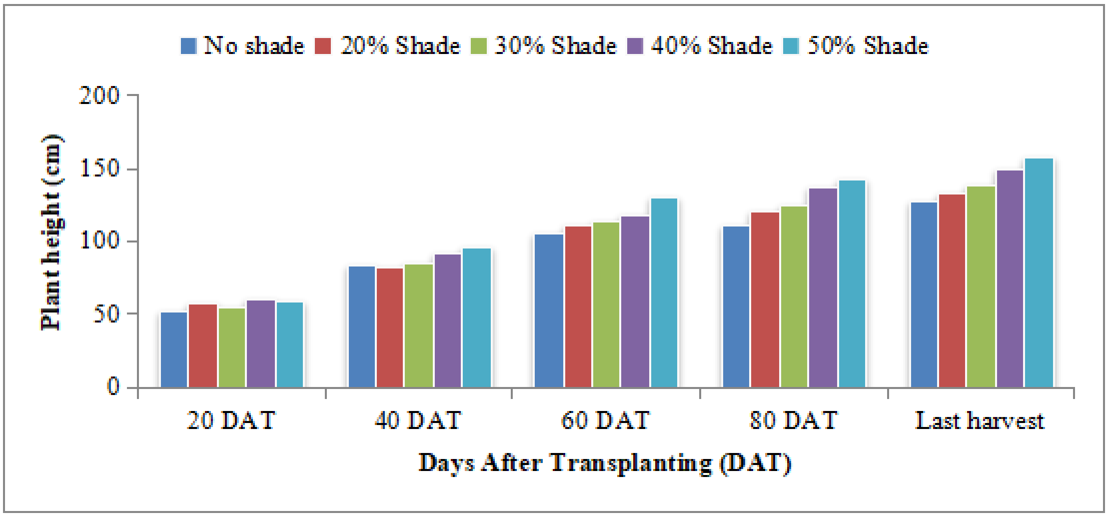

Fig. 3. Effect of shading on plant height of summer tomato at different days after transplanting (DAT)

Days to 50% flowering

Number of days to 50% flowering was much influenced by shade intensity (Table 2). Significantly the earliest flowering (at 45 days) was observed in 20% shade treatment. Maximum days(55)were required under 50% shade while the plants without shade took 47 days to 50% flowering. Plants grown under lower shade intensity (20-30%) exhibited better plant growth which might be enhanced in early flowering but intense shade (above 40%) delayed flowering. The results of the present study are in full support with Thangam and Thamburaj(2008).

Fruit-set (%)

Percent fruit-set was significantly varied due to different treatments. It was the highest (37.89 %) in 30% shade and the lowest (25.20 %) in 50% shade (Table 2).The percent fruit set was found 32.25 when grown without shade. It was observed that up to certain level, percent fruit set increased with the increase of shade intensity and then declined when shade intensity rose above the level. This might be due to the fact that shade lowered air temperature which probably results better fruit set. El-Gizawy *et al.* (1993) reported that in hot climates, shade has a beneficial effect over no shade in that it increases flower number per plant, fruit set, and yield.

Table 2. Effect of shade on flowering, fruit set, harvest and fruit number per plant of summer tomato

Treatment	Days to 50% flowering	Fruit set (%)	Days to first harvest	Number of marketable fruits	Number of non-marketable fruits
20% Shade	45	35.62	82	32.1	2.3
30% Shade	46	37.89	84	36.2	1.7
40% Shade	52	28.81	92	25.2	3.6
50% Shade	55	25.20	96	19.3	4.2
No shade	47	32.25	85	24.2	7.4
LSD	6.71	4.73	9.69	9.29	0.50
CV%	7.27	5.41	5.86	12.38	4.73

Days to first harvest

Effect of shading on days to first harvest was found significant. The earliest harvest (at 82 days) was done in 20% shade treatment. The maximum 96 days were required in50% shade and 85 days in the treatment of without shade to first harvest (Table 2). It revealed that minimum shade (20-30%) resulted 1-3 days earlier to first harvest than no shade but delayed by 7 and 11 days in 40% and 50% shade treatment respectively. Thangam and Thamburaj(2008) also noticed delayed flowering under shade in summer tomato.

Number of marketable fruits per plant

Shade treatments influenced the number of marketable fruits per plant (Table 2). The maximum (36.2) and minimum (19.3) number of marketable fruits were obtained in the plants grown under 30% and 50% shade respectively. The plants grown without shade produced 24.2 marketable fruits per plant. The results indicated that some levels of shading in hot summer season increased number of marketable fruits per plant. The results are in agreement with Wada *et al.* (2006) who reported that the marketable fruit yields increased by some levels (30% and 55%) of shading during the summer compared with the control (no shading).

Number of non-marketable fruits per plant

Non marketable fruits per plant was found significant due to the effect of shade. Maximum non-marketable fruits (7.4) were obtained from the plants grown without shade and minimum (1.7) in the plants grown under 30% shade. Wada *et al.* (2006) reported that shading decreased the incidence of cracked fruit.

Individual fruit weight (g)

The shade levels had an influence on individual fruit weight significantly (Table 3). Maximum fruit weight (47.1g) was found in 30% shade treatment followed by 20% shade treatment (46.3g) and no shade treatment (46.2g).The minimum weight of individual fruit (34.8g) was found in 50% shade treatment. There had not have significant variation among the treatments no shade, 20% shade and 30% shade. It was revealed that low levels of shade help improving the fruit size. The result was in agreement with El-Gizawy *et al*, (1993) who observed maximum fruit weight from plants grown under 35% shading. Higher shade (50%) condition reduced light transmittance as well as photosynthetic activity and carbohydrate production were supposed to be decreased which results in small fruits.

Table 3.Effect of shading on yield and yield components of summer tomato.

Treatment	Individual fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Yield per plant (kg)	Yield (t/ha)
20% Shade	46.3	4.13	4.24	1.62	43.62
30% Shade	47.1	4.48	4.58	1.68	44.60
40% Shade	40.5	3.94	4.08	0.92	24.84
50% Shade	34.8	3.73	4.05	0.74	18.35
No shade	46.2	4.34	4.45	1.35	35.46
LSD	7.50	0.57	0.37	0.26	10.28
CV%	6.37	5.07	4.54	7.61	11.24

Fruit length (cm)

Significant variation was observed in fruit length among the treatments (Table 3).The highest fruit length (4.48 cm) was measured in 30% shade and the lowest length (3.73 cm) was measured in 50% shade where 4.34 cm fruit length was obtained in no shade treatment. Results of the present study are closely related to El-Gizawy *et al.* (1993), who reported that shading of plants significantly improved the physical characteristics of tomato fruits and obtained the highest weight, length, diameter and volume of fruits from plants grown under 35% shading.

Fruit diameter (cm)

Fruit diameter recorded from different treatments was statistically similar (Table 3). The highest fruit diameter (4.58 cm) was measured in 30% shade treatment while the lowest diameter (4.05 cm) was measured in 50% shade treatment. No shade treatment gave 4.45 cm fruit diameter. Sharma and Tiwari (1993) reported higher fruit diameter of tomato under shade.

Yield per plant (kg)

Marked variation was observed in plant yield due to different shade levels(Table 3).The highest 1.68kg fruit per plant was produced by the plants grown under 30% shade condition and was statistically similar to 20% shade (1.62 kg) and the lowest 0.74kg fruit was produced by the plants grown under 50% shade condition while 1.35kg fruits per plant was produced in no shade condition. Russo (1993) reported that shade increased total fruit yield of plants. El-Gizawy *et al*, (1993) observed maximum yield of tomato in 40% shade whereas, Sharma and Tiwari (1993) observed that shade significantly increased the yield of tomato. At higher shade (50%)

condition light transmittance reduced as well as photosynthetic activity and carbohydrate production decreased which results lower yield.

Yield (t/ha)

Significantly the highest yield (44.60t/ha) was produced by 30% shade followed by 20% shade (43.62t/ha) which were statistically at par(Table 3).The lowest fruit yield (18.25t/ha) was produced in plants grown at 50% shade and 35.46 t/ha fruit yield was recorded in without shade treatment. Abdel-Mawgoud *et al*. (1996) observed that tomato plants grown in Egypt for the entire season under shade (30% to 40% of sunlight) had higher yields and more fruits than those grown without shade which is in agreement with the present findings.

In conclusion, it may be said that shading in tomato crops during summer season considerably enhanced the growth and performance of the crop. Growth and yield of summer tomato were found to be the highest when grown at 30% shade level under poly tunnel.

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