RESPONSE OF EXOTIC TOMATO LINES TO DIFFERENT LIGHT INTENSITIES

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ABSTRACT

An experiment was conducted to study the response of exotic tomato lines under different light levels. Two different shading materials having 55% and 75% shade density were used in comparison with control (no shade). Eight different tomato lines were grown for their performance under these shades. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangements. The shades had substantial effects on different tomato lines concerning various growth parameters. Maximum plant height (130.3 cm), leaf number (23.6), days to flowering (35.4), days to fruiting (77.0), and fruit yield plot^{-1} (1.98 kg) were recorded in 75% shade. On the other hand, minimum plant height (70.1cm), leaf number (14.3), days to flowering (30.9), days to fruiting (68.8) and fruit yield plot^{-1} (1.20 kg) were recorded in control. Among the different tomato lines, maximum plant height (123.4 cm), days to fruiting (76) and fruit size (volume; 51 ml) were recorded in line 2. Maximum fruit number per plant (13.5) was observed in line 8. The interactions between shades and tomato lines were non significant for all the parameters studied.

Keywords: Exotic Tomatoes, Light Intensities, *Lycopersicon esculentum,* Peshawar

INTRODUCTION

Tomato (*Lycopersicon esculentum*) belongs to the Family Solanaceae and is one of the most popular, versatile and widely grown vegetables, ranking second in importance to potato in many countries. Tomato is native to South America and historical records show that tomatoes were taken to Europe by Cortex in 1523. As for Asia, the Spanish began introducing several agricultural commodities into the Philippines from Mexico in 1751, but it is possible that tomatoes had been taken from Spain to Asia much earlier, perhaps just a few years after the discovery of the Philippines by Ferdinand Magellan in 1521. Trade between the Philippines and the neighbouring countries of China, Japan and India may have been responsible for the spread of tomatoes into these countries. It is reported to have been introduced in the Indo- Pak sub-continent by the Europeans, in the second half of the nineteenth century. In the beginning, tomato was consumed in the subcontinent by the Europeans but later on it became popular amongst the rich classes of local population, and now almost every one uses it in one form or the other (Ibrahim, 1992).

In Pakistan, two crops of tomato are produced al fresco annually, one in summer, for which the seeds are sown in November and the seedlings are kept covered over the winter months to protect them from frost. In February-March when the frost danger is over, they are transplanted to field. Harvesting of this crop starts in May and continues till August. The other is winter crop, which is produced only in places where no frost occurs during winter. Seeds are sown in June and seedlings are transplanted in July-August. Harvesting of this crop starts in November**.** In plains of NWFP, tomato is grown in summer, while in some frost free zones like Dargai, Malakand Agency and Bara killa in Peshawar valley it is grown in winter. The area under cultivation in Pakistan during 2004-05 was 16672 hectares with a total production of 143727 tons (Agriculture Statistics of Pakistan, 2004-05).

Tomato is consumed fresh, as well as in processed forms. Only few vegetables can match the nutritive value of tomatoes. Tomato is the best source of vitamin C. It is one of the cheapest sources of important vitamins as well as minerals like iron and phosphorus. A ripened tomato of 135g contains about 94% water, 25 Calories of energy, 28 mg ascorbic acid, 0.07 mg thiamine, 0.05 mg riboflavin, 0.9 mg niacin, 1.0 g water soluble protein, 0.2 g fat, 0.8-0.9 mg of lycopene, 6.0 g carbohydrate, 16 mg calcium, 33 mg phosphorus 0.6 mg iron, 4 mg sodium and 300 mg potassium (Hafeez, 2001).

Botanically, tomato is a perennial vegetable but here it survives as a seasonal one because it can not withstand extreme temperatures. There is a possibility that the crop will grow round the year if the extreme temperatures (both hot and cold) are somehow attenuated. The use of shades, for this purpose, could be a viable option. The shades filter the incident solar radiation causing a reduction in light intensity and thereby decrease the crop temperature. Keeping in view this option, an experiment was conducted to study the performance of different tomato lines under various shades (light intensities). The aims were;

i. To compare the yields of tomato crop under different light levels.
ii. To study the survival of various tomato lines grown in different shades during the harsh summer months under the agro-climatic conditions of Peshawar.
iii. To select the best tomato variety from the proposed tomato lines.

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MATERIALS AND METHODS

The experiment on the response of some exotic tomato lines to different light intensities was carried out at Horticulture Farm, NWFP Agricultural University Peshawar during the year 2005. The experiment was laid down in two factors Randomized Complete Block Design (RCBD) with split plot arrangement. The experiment consisted of three different light intensities (main plots) and eight tomato lines (sub plots). The three different light intensities were maintained by using shading materials that provided 55% and 75% shades and a control where the plants were left uncovered.

A single layer of green polythene mesh was used for 55% shade and two layers of the same material were incorporated to acquire 75% shade. For putting the shading material, wooden frames of 8 × 3 × 2.5 m high were erected above each treatment. The shading material was put on top of the frame in such a way that it was draping on the sides, but not touching the ground to ensure ventilation. Two trenches each 7.5 m long having 0.3 m depth and 0.3 m width were dug out and filled with equal proportion of soil, silt and farmyard manure (FYM). This procedure was repeated twice to ensure two more replications in a similar fashion. Eight tomato lines were assigned randomly to the different subplots. They were;

L1 = CLN 2123 DCF1–111–17–21–2–12
L2 = CLN 2116 DCF1–180–31–10–25–8–10–12–0
L3 = CLN 2116 DCF1–180–31–10–25–16–2–0
L4 = CLN 2116 DCF1–180 –31–10–25–22–16–2
L5 = CLN 2114 DCF1–2–4–2–4–1–9–22–0
L6 = CLN 2114 DCF1–2–16–8–2–17–0
L7 = CLN 2116 DCF1–180–31–10–25–16–3–0
L8 = CLN 2114 DCF1–2–29–20–16–5–12–2

Light Intensity and Temperature Measurements

The actual light intensities inside the shade compartments as well as outside (control) were recorded with the help of light meter during mid day (12.00 to 1.00 pm) everyday for the months of May, June and July. The average light intensities in full sun (control), 55% and 75% shade were 120.0, 53.6 and 29.5 K lux respectively. Similarly the temperatures were also recorded at mid day suspending three thermometers simultaneously in all the three light intensities treatments during the above mentioned three months. The average temperatures recorded in control, 55% and 75% shade were 36, 35 and 34°C respectively.

Plant Materials and Culturing

Seeds of different tomato lines were obtained from Asian Vegetable Research and Development Centre (AVRDC), PO Box 42, Shanhua, Tainan 74199; Taiwan ROC. They were sown, on March 4, 2005, in separate pots having mixture of silt, soil and compost (1:1:1 ratio). After germination, when the seedlings were ready for transplanting, they were shifted to their respective treatments on April 9, 2005. Eight tomato lines were planted on ridges raised above the filled trenches in such a way that plant to plant distance was 30 cm and the tomato lines were separated by 60 cm distance from each other. Five plants of each tomato line were planted randomly. In this way, eight tomato lines were grown under each light intensity treatment, replicated three times. The plants were supported with cotton strings suspended from stretched steel wires, 2.5 m above each row. A single stem was allowed to grow and auxiliary buds were removed to discourage lateral growth.

Data were recorded for the plant height, number of leaves, leaf area, days to flowering, days to fruiting, fruit size (volume; average single fruit), fruit weight (average single fruit) and fruit yield plot^{-1}. All the data taken were analysed statistically using licensed version of MSTATC software (Michigan State University, USA).

RESULTS AND DISCUSSIONS

Various parameters regarding the growth, flowering and fruiting were recorded during the course of the experiment. The results were analysed statistically and a range of significant observations was obtained for the different parameters. The interactions between different light intensities and tomato lines were non significant for all the parameters studied. The main effects of light intensities and tomato lines along with their respective LSD values are summarized into table 1. The results acquired are presented and discussed in the following lines.

Plant height

The data regarding the plant height are presented in table 1. The statistical analysis of the data showed that plant height was significantly ($P \leq 0.01$) affected both in case of different shades i.e. light intensity and tomato lines. The means for the different shades showed that 75% shade produced the tallest plants (130.3 cm), which was followed by 55% shade (101.7 cm). The control (0% shade) produced the shortest plants (70.1 cm). It is obvious from the results that tomato plants responded positively to decreasing light intensities (0-75%). This response may be due to difference in Red (R): Far Red (FR) ratio perceived by the plants grown in different environments. The effect of R:FR ratio on phytochrome photoequilibrium and hence the plant height is well documented (Smith, 1982; Smith, 1995; Smith and Whitelam, 1997). As the shade material is transparent to FR radiation (700-800 nm wavelength) and partially filter the visible radiation (light i.e. 400-700 nm wavelength) including red light (600-700nm wavelength), it results in reducing the R:FR ratio, thereby increasing the plant height. These results are well in accordance with those of McLaren and Smith

(1978), El-Abd (1994) and Murakami *et al* (1997), who observed that red light interception caused low R:FR and as a result increased plant height. Halliday and Whitelam (2003), Mazeela *et al*. (2000) and Grey *et al*. (1998) reported that elevated ambient temperature enhanced elongated growth in *Arabidopsis* hypocotyls, and rosette inter nodes in responsive vegetative tissues. Smith (1994) investigated that species such as *Senecio vulgaris* and *Chenopodium album* adopted partially strong shade avoidance strategies and exhibit stem extension rate in response to low R:FR ratio light.

Among the tomato lines, line 2 produced the tallest plants (123.4 cm) closely followed by line 7 (110.4 cm) and line 4 (110.0 cm). Line 1 resulted in minimum plant height (86.0 cm), which was statistically similar to line 6, 5, 3, and 8 having plant heights of 91.7, 92.0, 95.7 and 96.3 cm, respectively. Though all the tomato lines were subjected to equal advantage of climate, soil nutrient, and cultural practices, the variation in the plant height might be due to their genetic constitution, whereby some lines had better adaptation to the existing conditions in terms of stem elongation.

Leaf Number

The statistical analysis of the data showed that tomato leaf number was significantly ($P \leq 0.01$) affected by shades. While, no significant differences were found among the different tomato lines. The means for the different shades (table 1) illustrate that 75% shade produced maximum (23.6) leaves per plant. The control (0% shade) and 55% shade were at par with each other, producing minimum leaf number i.e. 14.3 and 18.0 leaves per plant respectively. Again the increase in leaf number with shade density is against expectation, where the classical R:FR and phytochrome shade avoidance phenomenon would result in decreased leaf number with increased shade density. However, during the previous research work, these effects were observed at normal or low temperatures. This study, on the other hand, was conducted at high day temperature (exceeding 35ºC). It seems that at high ambient temperature, some other mechanisms may be involved that may have a different effect on plant growth regulation and development. This needs to be investigated and it is suggested that further tests should be conducted to see the effects of various shades under different temperature levels (especially higher temperatures).

Leaf Area

The statistical analysis of the data showed that different shade levels and tomato lines had no significant effect on leaf area. The means (table 1) show that 75% shade produced maximum leaf area (2390.4 cm^2), although it was not significantly different from the other two treatments. From the results it is obvious that 75% shade has sufficient potential to produce maximum leaf area, while the control has least capacity to produce this amount. The results coincide with the results of El-Abd (1994) who observed that leaf area and yield increased with increasing shading density. However, they are not in agreement with those of McLaren and Smith (1978), who observed that low R:FR ratio cause reduction in leaf area.

Day s to Flowering

The days to flowering were significantly affected in case of different shades ($P \leq 0.01$) and tomato lines ($P \leq 0.05$). The means for the different shades (table 1) showed that 75% shade took maximum (35.4) days to flowering, followed by 55% shade (32.6 days), while the control took minimum (30.9) days to produce flowers. Calvert (1959), Kinet (1977) and Dieleman and Heuvelink (1992) observed that the vegetative period in tomato increased with decreasing light intensity because the rate of leaf production before the first inflorescence decreased with reduction in light intensity. Runkle and Heins (2001) reported that FR-deficient environments effectively retard stem extension in many herbaceous plants, they can delay flower initiation in some long day plants.

Among the tomato lines, line 4, 2 and 8 took maximum days (35.4, 35.2, 34.9 respectively) to flowering followed by line 7, 5 and 3 which took 32.8, 32.4 and 32.3 days respectively. Line 6 and 7 resulted in minimum days to flowering i.e. 30.3 and 30.7 days respectively.

Days to Fruiting

The statistical analysis of the data showed that days to fruiting were significantly ($P \leq 0.001$) affected both in case of different light intensities and tomato lines. As far as the main effects are concerned, the means for the different shades (table 1) showed that 75% shade took maximum (77.0) days to fruiting. The control took minimum time (68.8 days) to fruiting which was also at par with 55% shade (71.2 days). The results coincide with those of Aldazabal and Zamora (2000), who grew tomatoes cv. Criollo Quivican under full sunlight or covered with sacking. They observed that fruit initiation was favoured by full sunlight, while number of flowers and fruits were generally higher under shade, Calvert (1959), Kinet (1977) and Dieleman and Heuvelink (1992) observed that the vegetative period in tomato increased with decreasing light intensity.

Among the tomato lines, line 2 and 3 took maximum days (76.0 and 75.7 respectively) to produce fruit, closely followed by line 7 (75.0

days). Line 6 resulted in minimum time to fruit (67.4 days), however it was also at par with line 1, 5, 8, 4, taking 68.8, 71.2, 72.2 and 72.5 days respectively.

Fruit Size (volume)

Analysis of the data showed that light intensity had no effect on fruit size, while it was significant in case of different tomato lines ($P \leq 0.01$). Among the tomato lines (table 1), line 2 and 7 produced the maximum fruit size (51.0 and 48.5 ml) followed by line 3, 4 and 8 (40.8, 39.3 and 38.1ml respectively). Lines 5 and 1 produced 32.7 ml and 37.1 ml fruits respectively, whereas line 6 resulted in minimum (23.1 ml) fruit size. These might be attributed to the genetic characteristics of the specific tomato lines that resulted in varying fruit volumes.

Fruit weight

Fruit weight was not significantly affected by shades, while it was significant ($P \leq 0.01$) for different tomato lines. The different shades did not exert any effect on the fruit weight of tomato lines meaning that statistically similar values were obtained at different light levels. The results are in an agreement with those of Ohta *et al (*1994) who also observed that fruit weight was not affected under different irradiance levels.

The means comparison of different tomato lines (Table I) revealed that line 7 produced the maximum single fruit weight (36.7g) closely followed by line 2 (34.3 g) and line 3 (31.0 g). Line 6 resulted in minimum fruit weight (19.6g), however it was also at par with line 5, 8, 1 and 4 producing fruit weights of 21.7, 26.9, 27.3, and 29.3 g respectively.

Fruit yield plot^{-1}

Fruit yield plot^{-1} was also significantly ($P \leq 0.05$) affected by different shades but not affected in case of tomato lines. The mean values for different shades (table 1) showed that plants under 75% shade produced maximum (1.98 kg) fruit yield per plot, closely followed by those under 55% shade (1.61 kg). Plants grown in full sunshine (control) gave minimum (1.20 kg) fruit yield per plot.

The reason for higher yield under dense shade (low light intensity) may be that it reduced temperature to a certain level which may have reduced the respiration rate – a carbohydrate burning process. Less carbohydrate burning means that more will be accumulated in the fruit and hence increase in yield will occur. The results are equivalent to those of El-Abd (1994), who observed that total fruit yield increased with the increase in shade density, but transpiration rate decreased. Similarly, Sumiati (1989) observed that mulching with plastic and shading gave the highest yields of 30.34 and 32.03 t ha^{-1}, respectively, compared with 19.35 t ha^{-1} in the control.

CONCLUSIONS

The experimental results lead us to the conclusions that shading tomato crop in summer considerably affected the growth and performance of crop. Increasing the shade density from full sun to 75% increased the vegetative growth, as well as, the fruit production in tomato, with 75% shade proving to be the best. The interactions between the different tomato lines and shade levels were largely non-significant, suggesting that the different shade densities would be similarly effective for all the tomato lines. However, the main purpose of the experiment was to get year round tomato production from the same plant, by reducing summer heat (which normally kills the plant) through shade. This could not be achieved as even the highest shade could not reduce the air temperature upto the required limit. The highest shade level (75%) reduced the temperature to 2ºC compared to control which was still too high for the plant to survive.

RECOMMENDATIONS

It is suggested that further studies should be conducted on tomatoes, growing them in completely covered shade houses, fitted with some economical cooling system, to further reduce the temperature during the harsh summer months.

Table 1. ***Effect of different light intensities on the growth and yield of exotic tomato lines.***

Tomato Lines	Plant height (cm)	Number of leaves	Leaf area (cm^2)	Days to flowering	Days to fruiting	Fruit size (ml)	Fruit weight (g)	Yield per plot (kg)
L1	86.0 C	18.6	2889.4	30.7 b	68.8 CD	31.7 BC	27.3 BCD	1.54
L2	123.4 A	20.1	1919.1	35.2 a	76.0 A	51.0 A	34.3 AB	1.72
L3	95.7 BC	17.0	1714.0	32.3 ab	75.7 A	40.8 AB	31.0 ABC	1.45
L4	110.0 AB	18.1	1405.9	35.4 a	72.5 ABC	39.3 AB	29.3 BC	1.37
L5	92.0 C	18.2	1924.3	32.4 ab	71.2 BCD	32.7 BC	21.7 DE	1.52
L6	91.7 C	20.1	2390.0	30.3 b	67.4 D	23.1 C	19.6 E	1.40
L7	110.4 AB	18.9	2258.3	32.8 ab	75.0 AB	48.5 A	36.7 A	1.83
L8	96.3 BC	18.1	2122.4	34.9 a	72.2 ABC	38.1 AB	26.9 CDE	1.93
Significance	***	*NS*	*NS*	*	***	***	***	*NS*
LSD Values	*17.3*			*3.5*	*4.3*	*14.9*	*7.4*	
Light Intensity								
Control	70.1 B	14.3 B	1970.2	30.9 C	68.8 B	38.2	24.4	1.20 b
50% shade	101.7 AB	18.0 B	1873.2	32.6 B	71.2 B	41.3	34.0	1.61 ab
75% shade	130.3 A	23.6 A	2390.4	35.4 A	77.0 A	35.0	26.6	1.98 a
Significance	**	**	*NS*	**	**	*NS*	*NS*	*
LSD Values	*33.6*	*4.4*		*1.6*	*4.1*			*0.53*
Interaction								
Lines × Shades	NS	NS	NS	NS	NS	NS	NS	NS

***NS* = Non significant; * = Significant at P≤0.05; ** = Significant at P≤0.01 *** = Significant at P≤0.001**

Values followed by different letters are significantly different at P≤0.05 (lower case) and P≤0.01 (upper case) level of significance according Least Significant Difference (LSD) test.

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