Plant Archives Vol. 15 No. 1, 2015 pp. 171-175 *ISSN 0972-5210*

STUDIES ON EFFECT OF MILD TEMPERATURE INCREASE ON TOMATO (*LYCOPERSICON ESCULENTUM*) HYBRID ARKA ANANYA

H. Mamatha, N. K. Srinivasa Rao*, R. H. Laxman, T. Vijayalakshmi[1]

Division of Plant Physiology and Biochemistry, Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bangalore – 560 089 (Karnataka), India.

[1]Department of Environmental Science, Jawaharlal Nehru Technological University, Hyderabad-500 085 (A. P.), India.

Abstract

A study was conducted to evaluate the performance of tomato hybrid Arka Ananya to mild temperature stress in temperature gradient tunnels (TGT). Gas exchange characteristics *viz*., photosynthesis rate (P_N), stomatal conductance (g_s) and leaf transpiration (E) and parameters, leaf area (LA), leaf area index (LAI), total dry mass (TDM) were recorded at peak fruiting and harvesting stage. Yield and yield components were also recorded. Reduction in P_N was observed as the average leaf temperature increased from 28.4°C to 29.9°C at peak fruiting stage and 26.8 to 28.5°C at final harvest stage. Similarly, the reductions in g_s were observed at both the stages. However, the mild temperature increase did not influence the E, both at peak fruiting and final harvest stages. Mild temperatures increase from 27.4°C to 29.7°C at peak fruiting stage and 27.6°C to 30.0°C at final harvesting stage reduced the LA, LAI and TDM content. There was also a reduction in average fruit weight and total fruit yield per plant as the temperature increased from 27.6°C to 30°C.

Key words : Temperature gradient tunnel, photosynthesis rate, stomatal conductance, leaf transpiration, total dry mass, yield.

Introduction

Tomato is one of the most consumed vegetables worldwide with an estimated global production of over 159.023 MT. In India, it is an important vegetable crop with a production of 19.10 MT (NHB, 2013-14). It is a good source of vitamin C, carotenoids and pro vitamin A (Stommel, 2007) with a good antioxidant potential including lycopene, ascorbic acid, phenolics, flavonoids and vitamin E (Kaur *et al*., 2004). Poor fruit set and development directly related to high temperatures is one of the key problems (Kuo *et al*., 1986). Although, tomato is a warm season crop (Wester field, 2012), the optimum temperature for tomato production is 21°C to 25°C with an average monthly maximum temperature of 27°C (Araki *et al*., 2000).

Exposure of tomato plants to high temperature may lead to reduction in photosynthesis rate and dry mass production (Camejo *et al*., 2005; Islam, 2011 and Abdelmaged *et al*., 2003). The most heat sensitive physiological activity photosynthesis can be completely inhibited by high temperature before detection of other symptoms (Berry and Bjorkman, 1980). High temperature strongly affects the vegetative and reproductive organs and tissues of tomato plants (Abdelmaged *et al*., 2003). At high temperature chlorophyll, lutein, carotenoid content decrease and the ratio of various pigments also changes with direct effect on absorption of light energy mainly the activity of PS II, which further influences the electron transport chain (Islam, 2011 and Havaux *et al*., 1996). High temperature impairs reproductive processes *viz*., pollen production, ovule development, fertilization and fruit initiation and limits fruit set in tomato (Ahmadi and Stevens, 1979; Levy *et al*., 1978; Stevens and Rudich, 1978). High temperature prevents normal polyamine biosynthesis in germinating pollen, leading to a decrease in endogenous polyamines below a critical level (Song *et al*., 1999).

In addition to high temperature stress, mild temperature increase is also known to influence the physiology, growth and yield of tomato plants. Abdelmageed and Gruda (2009) reported that in a study on effect of two temperature regimes, 37/27°C and 37/22°C, the reduction in photosynthesis rate among eight tomato genotypes was more at high temperature regime. Subjecting tomato plants to moderately high temperature of 35°C for eight hours caused decreased photosynthetic

***Author for correspondence:** E-mail: nksraoiihr@gmail.com

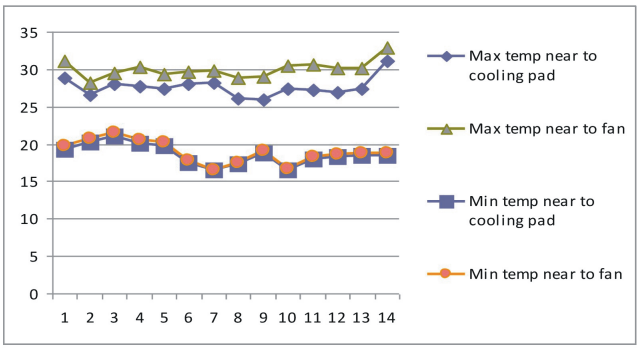


Fig. 1

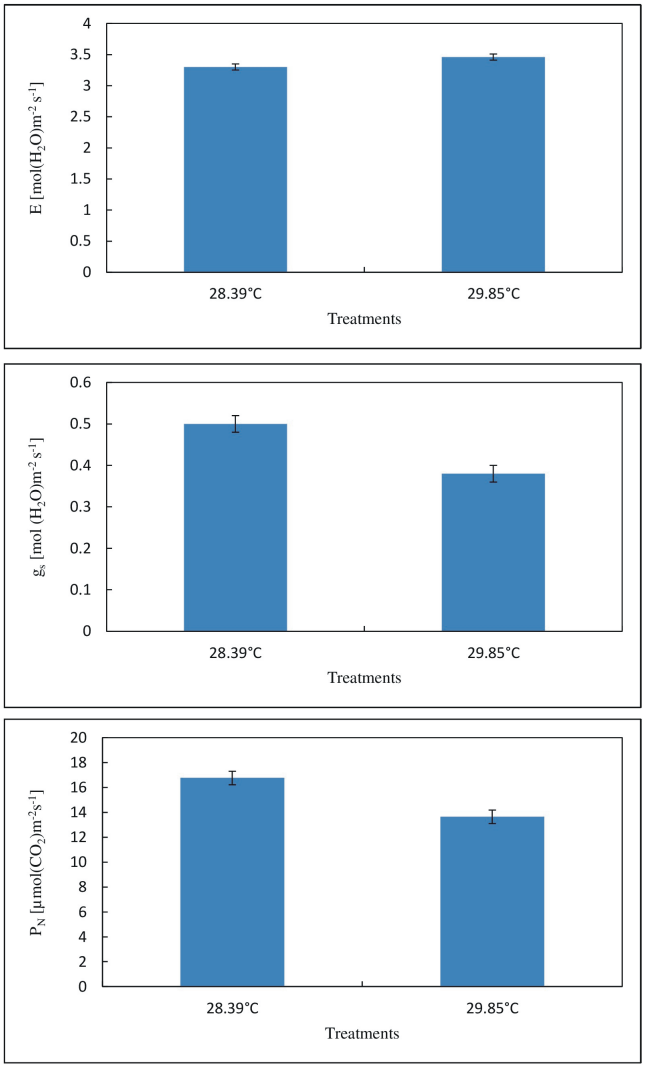


Fig. 2

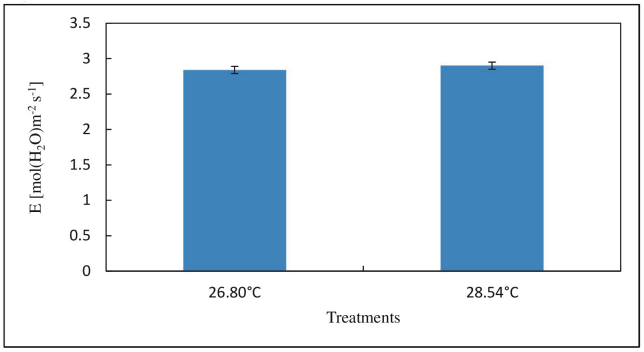
activity and changes in carbohydrate metabolism (Zhang *et al*., 2012). The optimum temperature for tomato vegetative growth is 18-25°C (Hurd and Cooper, 1970). The temperature above 25°C can reduce the fruit production in tomatoes (Charles and Harris, 1972). Yield related characters sharply decline as the temperature rise from 25 to 29°C (Peet *et al*., 1998). Hence, the present investigation was undertaken to study the effect of mild temperature increase on gas exchange characteristics, biomass production and yield of tomato hybrid Arka Ananya.

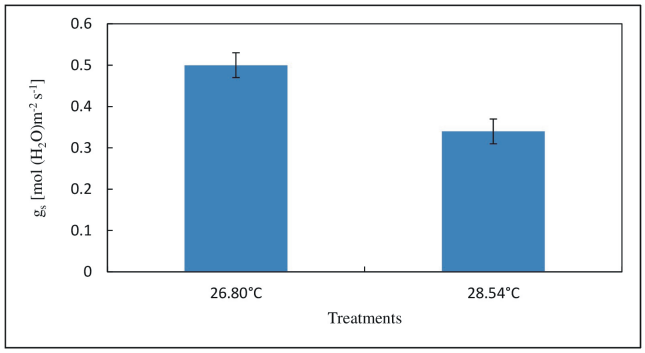
Materials and Methods

The experiment was conducted during *Rabi* season, October 2010 to January 2011 at Indian Institute of Horticulture Research (IIHR), Bangalore (Karnataka), India, situated at latitude 13.15° N and longitude of 77.49° E and 890 m altitude. Twenty five day old seedlings of tomato hybrid, Arka Ananya suitable for cultivation during *Rabi* and summer seasons were transplanted in the temperature gradient tunnel (TGT) with a spacing of 60 cm between the rows and 50 cm between the plants. The TGT has dimensions of 18m length, 4.5m width and 3m height and is covered with polycarbonate sheet. Two temperature gradients were maintained inside the TGT. During the experimental period the average maximum mean temperatures recorded near to cooling pad and towards fan were 27.6°C and 30.0°C, respectively. Similarly, the average minimum mean temperature recorded near to cooling pad and towards fan were 18.6°C and 18.9°C, respectively. Mean temperatures recorded between transplanting and peak fruiting stage was 27.38°C near to cooling pad and 29.73°C towards fan. Similarly, mean temperatures recorded between transplanting and final harvest stage was 27.61°C near to cooling pad and 30.01°C towards fan. Observations on gas exchange characteristics, Total dry mass (TDM), Leaf area (LA) and Leaf area index (LAI) were recorded at these two stages (fig. 1).

Gas exchange parameters were recorded from the uppermost fully expanded leaf between 9:30 h to 11:30 h using portable photosynthesis system (LC Pro ADC Bio-scientific, UK) at peak fruiting stage (72 DAT) and at harvesting stage (107 DAT). A total of seven measurements were taken from seven plants in each temperature gradient. Leaf was held in the chamber for three minutes to obtain stable readings. Photosynthesis rate (P_N), stomatal conductance (g_s) and transpiration rate (E) were calculated by the software and were expressed as µmol (CO_2) $m^{-2}s^{-1}$, mol (H_2O) $m^{-2}s^{-1}$ and mol (H_2O) $m^{-2}s^{-1}$, respectively.

Whole plants were uprooted and kept for oven drying at 80°C and dry weights were recorded after 78 hours. Growth characteristics *viz*., total dry mass (TDM), leaf area (LA) and leaf area index (LAI) were recorded at peak fruiting (72 DAT) and at harvesting stage (107 DAT). Leaf area per plant was calculated by taking leaf discs and their dry weight and was estimated for the





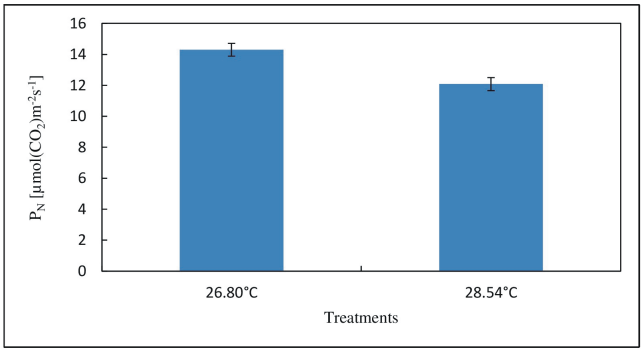
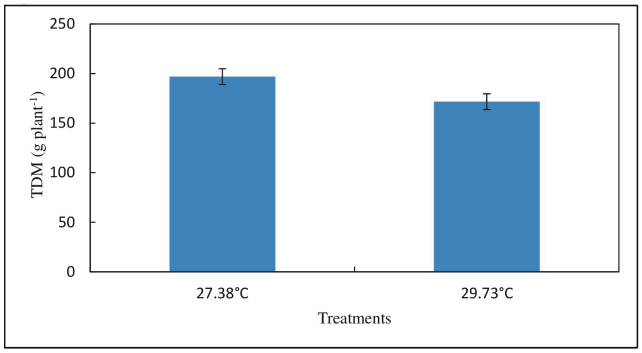
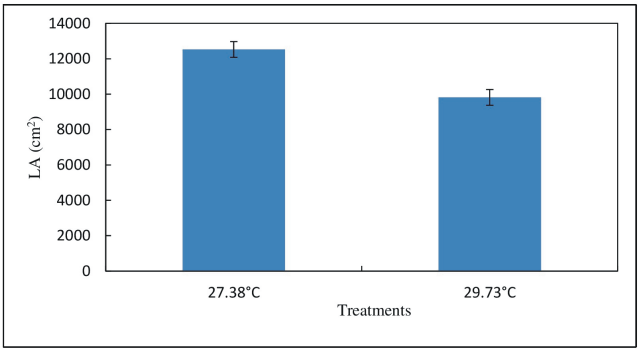


Fig. 3





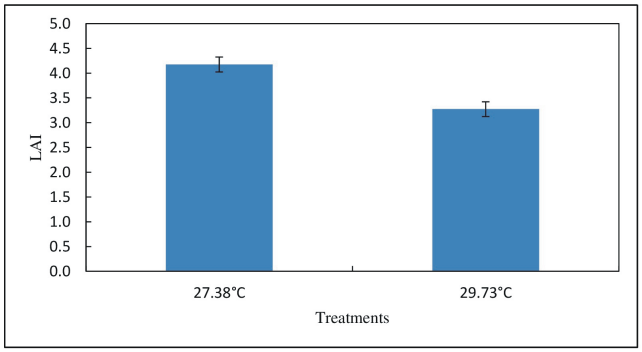


Fig. 4

whole plant based on the total leaf dry weight. Leaf area per plant was expressed as cm^2 $plant^{-1}$. LAI was calculated using ratio of leaf area per plant to the area occupied by each plant. Fruit number and fruit yield per plant were recorded by pooling the yield of 21 plants from each treatment. Fruit yield was expressed as grams per $plant^{-1}$.

Statistical analysis

Standard error of mean (SEM) was calculated from standard deviation for comparison between the treatments.

Results

The mild temperature increase had considerable effect on P_N of tomato cv. Arka Ananya at peak fruiting and final harvest stages. At peak fruiting stage, the P_N decreased by 18.6% as the average leaf temperature increased from 28.4°C to 29.9°C during the time of recording gas exchange characteristics (fig. 2). Further at final harvest stage, reduction was 15.5% when the average leaf temperature increased from 26.8 to 28.5°C (fig. 3). However, the mild temperature increase did not influence the transpiration rate (E) both at peak fruiting and final harvest stages. But, the reductions in stomatal conductance (g_s) were observed at both the stages. At peak fruiting stage, 1.5°C temperature increase caused 24% reduction and at final harvest stage 1.7°C temperature increase caused 32% reduction.

The leaf area per plant and leaf area index (LAI) was significantly affected by mild temperature increase. The reduction in leaf area and LAI were 21.6 and 21.8% at peak fruiting stage (fig. 4). Later at final harvest stage also the effect of mild temperature increase on leaf area and LAI was evident. The reductions in leaf area and LAI were 25.7 and 25.6%, respectively. Consequently, in the present study total dry mass (TDM) per plant also was significantly affected by the exposure of tomato cv. Arka Ananya plants continuously to higher average

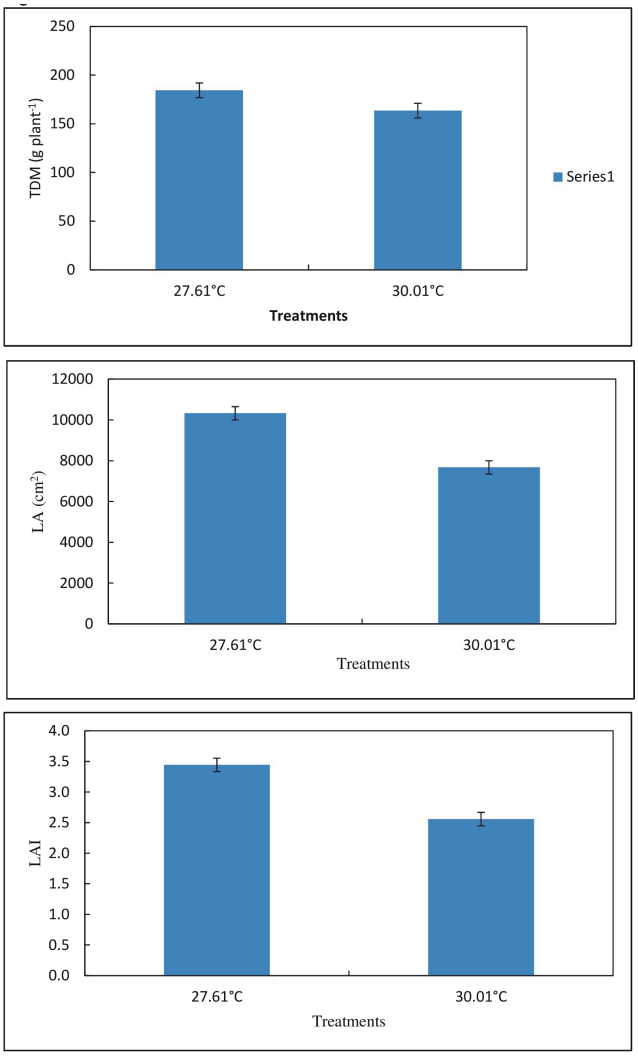


Fig. 5

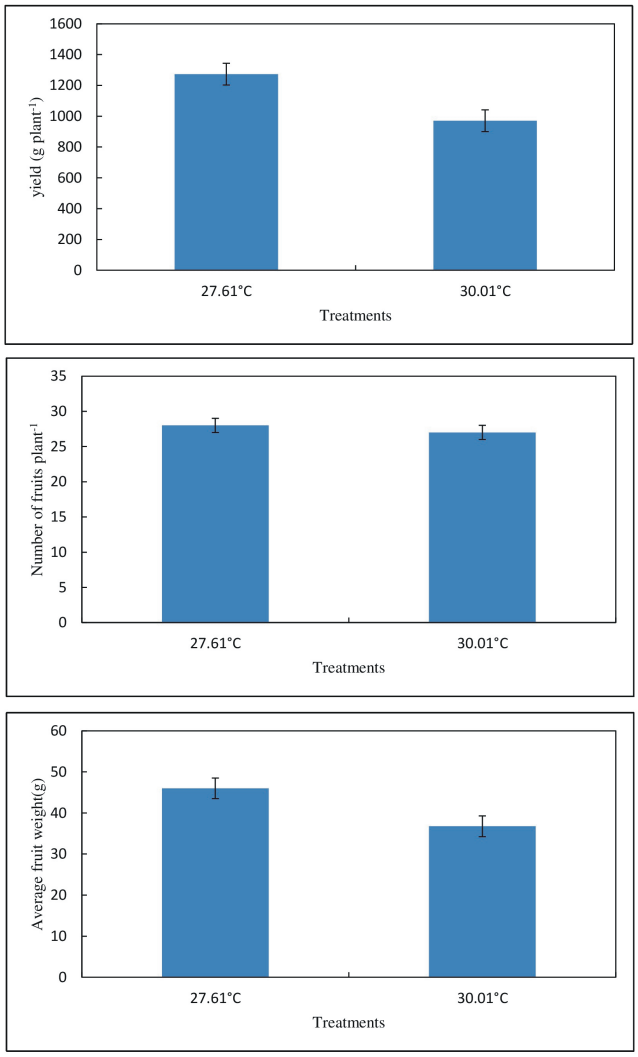


Fig. 6

temperatures right from transplanting. The reduction in TDM was 12.8% at peak fruiting stage, when the average temperature from transplanting to peak fruiting stage increased to 29.7°C from 27.4°C. The reduction in TDM was 11.3%, by final harvest stage, when the average temperature from transplanting to final harvest stage increased to 30°C from 27.6°C (fig. 5). Though, the number of fruits per plant was not significantly affected, the average fruit weight and total fruit yield per plant were significantly affected due to the mild temperature increase. The average fruit weight was reduced by 20.1% and total fruit yield per plant by 23.8%, when the temperatures during growing period increased from 27.6°C to 30°C (fig. 6).

Discussion

Mild heat stress inhibits net CO_2 uptake mainly by reversible conformational changes in thylakoids leading to a shift in the distribution of the absorbed light in favour of PSI (Weis, 1983) and deactivation of some Calvin cycle enzymes (Weis, 1981). Moderately elevated temperatures have a direct effect on the distribution and form of activase, the biochemical component controlling Rubisco activation (Feller *et al*., 1998). The decreased pn at slightly higher temperature in the present experiment may be due to inhibition of most thermally labile component of electron transport chain, PSII (Havaux *et al*., 1996). Membrane disintegration due to increased temperature may also be a cause for the inactivation of photosynthesis (Camejo *et al*., 2005). The optimum temperature for dry mass accumulation decreases with plant age (Went, 1985). In the present study, the mild temperature increase through its effect on photosynthesis rate caused reductions in leaf area per plant. The reductions in photosynthesis rate and the leaf area, which is the source for photosynthates, affected the TDM. Our results on dry mass accumulation is in confirmation with the findings of Plogue and Heuvelink (2005), where they reviewed at

high temperatures, the RGR is initially high, but decreases rapidly with time and was because of faster internal shading at high temperature.

Fruit set of tomato decreased when mean daily temperatures were as little as 2-4°C above the optimal temperature of 25°C (Peet *et al*., 1997). Lower fruit yield at higher temperature is due to limited carbohydrate supply (Islam, 2011). In the present experiment, decreased average fruit weight at moderately high temperature resulted in decreased yield. Thus, the present study clearly indicated that the mild temperature increase influenced the yield per plant by causing reductions in photosynthetic capacity and the source of photosynthates in tomato hybrid Arka Ananya.

References

Abdelmageed, A. H., N. Gruda and B. Geyer (2003). Effect of High Temperature on Tomato (*Lycopersicon esculentum*) Genotypes under Controlled Conditions. Conference on International Agricultural Research for Development. *Deutscher Tropentag*, October 8-10, Gottingen.

Abdelmageed, A. H. and N. Gruda (2009). Influence of High Temperatures on Gas Exchange Rate and Growth of Eight Tomato Cultivars under Controlled Heat Stress Conditions. *Europ. J. Hort. Sci*., **74** : 152–159.

Anonymous (2014). *Indian Horticulture Database* (2013). National Horticulture Board.

Araki, T., M. Kitano and H. Equchi (2000). Dynamics of fruit growth and photoassimilation translocation in tomato plant under controlled environment. *Acta Hortic*., **534** : 85-92.

Berry, J. and O. Bjorkman (1980). Photosynthetic response and adaptation to temperature in higher plants. *Annu. Rev. Plant Physiol*., **31** : 491 – 543.

Camejoa, D., P. Rodrigueza, M. A. Morales, J. M. D. Amicoa, A. Torrecillas and J. J. Alarcon (2005). High temperature effects on photosynthetic activity of two tomato cultivars with different heat susceptibility. *J. Plant. Physiol*., **162** : 281- 289.

Charles, W. B. and R. E. Harris (1972). Tomato fruit-set at high and low temperatures. *Can. J. Plant Sci*., **52** : 497 - 506.

El Ahmadi, A. B. and M. A. Stevens (1979). Reproductive responses of heat tolerant tomatoes to high temperatures. *J. Am. Society for Hortic. Sci*., **104** : 686-691.

Feller, U., Steven, J. Crafts-Brandner and Michel E. Salvucci (1998). Moderately high temperature inhibit ribulose - 1,5-bis phosphate carboxylase/oxygenas (Rubisco) activase mediated activation of rubisco. *Plant Physiol*., **116** : 539 - 546.

Havaux, M. and F. Tardy (1996). Temperature dependent adjustment of the thermal stability of photosystem II *in vivo* : possible involvement of xanthophylls-cycle pigments. *Planta*, **198** : 324-333.

Hurd, R. G. and A. J. Cooper (1970). The effect of early low temperature treatment on the yield of single inflorescence tomatoes. *J. Hortic. Sci*., **45** : 19-27.

Islam, M. T. (2011). Effect of temperature on photosynthesis, yield attributes and yield of tomato genotypes. *Int. J. Expt. Agric*., **2** : 8-11.

Kaur, C., B. George, N. Deepa, B. Singh and H. C. Kapoor (2004). Antioxidant status of fresh and processed tomato. *Rev. J. Food Sci. Tech*., **41** : 479-486.

Kuo, C. G., H. M. Chen and H. C. Chen (1986). Plant hormones in tomato fruit set and develop at high temperatures. In: *Plant growth regulators in agriculture*. AVRDC, Taiwan, 53–70.

Levy, H., H. O. Rabinowitch and N. Kedar (1978). Morphological and physiological characters affecting flower drop and fruit set of tomatoes at high temperature. *Euphytica*, **27** : 211-218.

Ministry of Agriculture, Government of India, New Delhi.

Peet, M. M., S. Sato and R. G. Gardner (1998). Comparing heat stress effects on male-fertile and male-sterile tomatoes. *Plant Cell Environ*., **21** : 225–231.

Peet, M. M., D. H. Willits and R. Gardner (1997). Response of ovule development and post-pollen production processes in male-sterile tomatoes to chronic, sub-acute high temperature stress. *J. Exp. Bot*., **48** : 101–112.

Robert, R. Westerfield (2012). Georgia Home Grown Tomatoes, *UGA extension Bulletin*, **1271** : 1- 4.

Song, J., K. Nada and S. Tachibana (1999). Ameliorative effect of polyamines on the high temperature inhibition of *in vitro* pollen germination in tomato (*Lycopersicon esculentum* Mill.). *Sci. Hortic*., **80** : 203-212.

Stevens and Rudich (1978). Genetic potential for overcoming physiological limitation on adaptability, yield and quality in the tomato. *Hortscience*, **13** : 673-678.

Stommel, J. R. (2007). Genetic enhancement of tomato fruit nutritive value. In: genetic improvement of solanaceous crops, *V.2. Tomato (Ed. Razdan and Mattoo, A.K) Science publishers, Enfield, USA*, 193-238.

Vander Ploeg, A. and E. Heuvelink (2005). Influence of sub optimal temperature on tomato growth and yield. *Rev. J. Hortic. Sci. Biotech*., **80** : 652-659.

Weis, E. (1981). Reversible heat inactivation of the calvin cycle. A possible mechanism of the temperature regulation of photosynthesis. *Planta*, **151** : 33-9.

Weis, E. (1983). Investigations on the heat sensitivity of thylakoid membranes in spinach leaves. the influence of light and short - time acclimation to high temperatures. In: effects of stress on photosynthesis. Eds. R. Marcelle, clijsters and M. Van Poucke, Martinus nijhoff, Dordrecht, 295 - 304.

Zhang, J., X. Jiang, T. Li and Z. Yang (2012). Effect of moderately high temperature stress on photosynthesis and carbohydrate metabolism in tomato (*Lycopersicon esculentum* L.) leaves. *Afr. J. Agril. Res*., **7** : 487-492.