Growth, Yield and Biochemical Characteristics of Tomato (*Solanum lycopersicum* L.) Genotypes under Seasonal Heat Stress

T. R. Chapagain*, A. K. Shrestha, M. D. Sharma, K. Mishra Tripathi and A. Srivastva

*Department of Horticulture, Agriculture and Forestry University, Rampur, Chitwan, Nepal.

Authors’ contributions

This work was carried out in collaboration among all authors. Author TRC designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author AKS managed the analyses of the study. Authors MDS, KMT and AS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAHR/2020/v6i230069

Editor(s): (1) Dr. Paola A. Deligios, University of Sassari, Italy.

Reviewer(s): (1) Sami Ullah Khan, The University of Haripur, Pakistan. (2) Neha Gupta, Punjab Agricultural University, India.

Complete Peer review History: http://www.sdiarticle4.com/review-history/58648

Received 18 April 2020
Accepted 24 June 2020
Published 06 July 2020

**ABSTRACT**

This field study was conducted to evaluate yield and fruit quality of tomato genotypes under seasonal heat stress condition (April-June) in plains of Chitwan valley, Nepal for two consecutive years in 2018 and 2019 at research farm, of Agriculture and Forestry University, Rampur, Nepal. Nine tomato genotypes were evaluated for their morphological, flowering, yield and biochemical traits in a randomized complete block design with four replications. Results showed significant differences (P = 0.05) among all genotypes for all traits evaluated. Genotypes AVTO-9304 and AVTO-9801 were early flowering and flowered within 28 days after transplanting. The highest marketable fruit yield of 110.6 and 92.6 t ha⁻¹ was recorded in genotype TO-1057 in 2018 and 2019, respectively with the mean yield of 101.6 t ha⁻¹ whereas genotype AVTO-9802 produced the lowest fruit yield in both years (34.0 and 32.0 t ha⁻¹ in 2018 and 2019, respectively) with the mean yield of 32.9 t ha⁻¹. The highest amount of total soluble solid content (4.90 °Brix) was observed in genotype AVTO-9803. Genotype ‘AVTO-1314’ had a significantly higher amount (12.60 mg 100 g⁻¹) of ascorbic acid but statistically at par with AVTO-9801, TO-1057 and Pariposa-4102. This study identified genotype TO-1057 as a highly productive genotype suitable for
Keywords: Bio-chemical; fruit quality; heat stress; high temperature; tomato.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops which is extensively grown all over the globe. Among the food commodities, tomato is ranked at a ninth position and is the second most essential vegetable crop around the world next to potato [1]. It is also widely grown in both the Terai and hills of Nepal [2]. It covers around 20046 ha area with production of 386824.6 tons and productivity of 19.3 t ha⁻¹ in Nepal [3]. In the Terai, tomato production is restricted to the cooler months of September to March, since production is constrained by high temperature, low fruit set, low flowering, bacterial wilt etc. [4]. Moreover, seasonal heat, heavy rains and humid conditions, result in poor flower development and low fruit set in tomato [5].

Earlier research results have established that heat stress can occur in tomato at mean daily temperatures of 28-29°C, which are just a few degrees above the optimum temperature range of 21-24°C [6]. Moreover, fruit set in tomato markedly reduced when average maximum day temperature exceeds 32°C [7]. In Rampur, Chitwan, the average mean daily temperature exceeds 29°C from April and maximum mean temperature exceeds 32°C from March [8]. However, several studies have identified heat tolerance in tomatoes by evaluating them for flowering and fruit set, since these two factors are sensitive to heat and relate directly to yield [5].

The aim of this study was to identify high temperature tolerant tomato genotypes having high yield potentiality suitable for summer season production (March to July) in plains of Chitwan, Nepal. Additionally, it also characterized the fruit quality parameters of tested genotypes preferable to consumers. It helps to understand flowering and fruiting behavior during natural heat stress and also provides varietal options to the farmers.

2. MATERIALS AND METHODS

2.1 Experimental Site and Materials

The field experiments were conducted at the Department of Horticulture, Agriculture and Forestry University, Rampur, Nepal (located in southern inner Tarai, 27°37’N latitude and at an altitude of 256 meter above sea level) during February to July for consecutive years of 2018 and 2019. Climatically, the site is characterized by sub-tropical conditions with an annual precipitation of 1372.70 mm, mean annual temperature of 24.6°C and mean relative humidity of 84.9%. Mean ambient temperature during flowering to harvesting ranged from 22°C in March to 29°C in May, with the highest temperature of 38.1°C in May. The recorded rainfall during the crop period was 406 and 484 mm in 2018 and 2019, respectively.

2.2 Experimental Design and Treatments

The experiment was laid out in a randomized complete block design (RCBD) with nine tomato genotypes as treatments replicated four times in 3 m × 3 m plots. Details of genotypes used in the experiment are given in Table 1. Seeds were sown in the 1st week of January in both the years. Seedlings were raised in plastic tunnel which was made inside plastic nursery shed to ensure proper germination in winter. Seedlings of one month old were transplanted at a distance of 0.75 m between rows and 0.60 m within row spacing.

The recommended dose of farm yard manure (FYM) i.e. 30 t ha⁻¹ and 150:100:100 N:P₂O₅:K₂O kg ha⁻¹ was applied. Half dose of N and full dose of P₂O₅ and K₂O along with Borax 10 kg ha⁻¹ and zinc sulphate 50 kg ha⁻¹, respectively was applied as basal dose. The half of recommended dose of nitrogen was applied in two split doses as top dressings on 30 and 60 days after transplanting. Nitrogen and phosphorous was supplied through Di-Ammonium Phosphate (DAP) containing 18% N and 46% P₂O₅, remaining dose of nitrogen was supplied through urea containing 46% N and potash was supplied through Muriate of Potash (MoP) containing 60% K₂O. Weeding was carried out manually and irrigation was applied as per crop requirement. The field was covered with 100 gauge white plastic before transplanting for two months for solarization from September to October in both the years.
| Characteristics | Genotypes |
|-----------------|-----------|
|                 | AVTO-9304 AVTO-1314 AVTO-9801 AVTO-9802 Florida-91 Celebrity 4102 TO-1057 Srijana |
| Heat tolerance  | Good     Good     Good     Good     Good     -         -       Good     -         |
| Maturity        | Early    Early    Early    Early    Medium  Early    Early  Early    Early    |
| Growth habit    | D        SD        D        D        D        SD       SD      SD       ID       |
| Fruit weight (g)| 35-40    80        40       65       10 oz    10 oz    80-100  50-60    |
| Fruit shape     | Round    Round    Plum     Globe    Flattened globe Flattened globe Flattened flattened square  |
| Fruit colour    | Red      Red       Red       Red       Red       Red       Red     Red      Red      |
| Genotypes       | OP       OP        OP        OP       F1       F1       F1      F1       F1       |
| Origin          | Taiwan   Taiwan   Taiwan   Taiwan   USA      USA      India   India    Nepal    |

=D = Determinate, SD = Semi-determinate and ID = Indeterminate growth habits of tomato
2.3 Biochemical Properties

Fruit juice was extracted by crushing tomato fruit pulps and digital refractometer was used for measuring total soluble solids (TSS) and expressed in °Brix. Ascorbic acid was analyzed by volumetric method using 2,6-dichlorophenol-indophenol visual titration as described by Sadasivam and Manickam [9]. The titrable acidity (as anhydrous citric acid) was determined by titrating the sample solution with 0.1 N of NaOH using Phenolphthalein as an indicator. pH of the fruit juice was determined by using pH meter. The vitamin-C content was determined by 2,6-dichlorophenol-indophenol visual titration method [10].

2.4 Data Collection and Analysis

Individual plants as well as plot base data were collected for plant height, flowering and fruiting traits and final yield. Fruit quality parameters like ascorbic acid content, total soluble solids (TSS), titratable acidity (TA) and pH were also measured. Analysis of variance for the pooled data of evaluated traits were carried out using Statistical Tool for Agricultural Research (STAR, Version 2.0.1, 2014) software. The level of significance used in 'F' test was P = 0.05. When the treatment effects were found significant, means were separated using Duncan’s Multiple Range Test (DMRT).

3. RESULTS

3.1 Morphology and Flowering Characteristics

Plant height (cm), days to 50% flowering and days to first harvest differed significantly among genotypes (Table 2). Srijana, the tallest genotype, attained the maximum height of 176.0 cm at final harvest whereas AVTO-9304, the most dwarf, attained the height 61.2 cm only and at par with AVTO-9801. AVTO-9304 and AVTO-9801 flowered at 28 days after transplanting (DAT). Celebrity flowered at 34 DAT and was at par with the others except two early flowering genotypes. Similarly, fruits were harvested early at 74 DAT from AVTO-9801. Despite Celebrity flowered late, Florida-91 took longer period for first harvest.

3.2 Fruit Characteristics

Fruit diameter (cm), fruit weight (gm) and fruit yield per plant (kg plant⁻¹) differed significantly among tomato genotypes (Table 3). Florida-91 had the biggest fruit size of 7.5 cm diameter and its individual fruit weighed 158.9 g. AVTO-9801 and AVTO-9304 had smaller fruits of 4.1 cm diameter.

3.3 Marketable Fruit Yield (t ha⁻¹)

Tomato genotypes differed significantly for marketable fruit yield in 2018, 2019 and on pooled basis (Table 4). TO-1057 produced the highest fruit yield (110.6 t ha⁻¹ in 2018, 92.6 t ha⁻¹ in 2019 and 101.6 t ha⁻¹ combined over years) whereas AVTO-9802 yielded the lowest fruit yield, 34.0 t ha⁻¹ in 2018, 32.0 t ha⁻¹ in 2019 and 32.9 t ha⁻¹ combined over years. Relatively lower fruit yield harvested in the 2nd year in comparison to 1st year in all genotypes except AVTO-1314.

3.4 Biochemical Properties

Fruit quality parameters were significantly different among tomato genotypes (Table 5). The highest Titrable acidity (TA) (0.48%) was in AVTO-9304 which was at par with AVTO-9801(0.45%) and Celebrity (0.46%). The pH value was in the range of 4.10 to 4.48 across the genotypes. TSS content observed in tomato genotypes varied between 3.70 - 4.90 °Brix.

There is a wide variation of ascorbic acid content in different genotypes. In our experiment, Vitamin C content significantly varied among tested genotypes. It ranged from 12.60 to 7.07 mg 100g⁻¹ (Table 5). According to our data, the genotype ‘AVTO-1314’ had a significantly higher amount of ascorbic acid but statistically at par with AVTO-9801, TO-1057 and Pariposa-4102. The least amount of ascorbic acid was found in the genotype ‘Florida-91’.

4. DISCUSSION

Plant height in tomato is mainly determined by its growth habit which is characterized as determinate, semi-determinate and indeterminate. Chapagain et al., [2] had observed variation from 92.2 to 120.5 cm in plant height among seven tomato genotypes at an altitude of 1640 m. According to them, tomato genotype Srijana attained height of 118.4 cm at final harvest but in our study, Srijana reached to 130.68 cm within 75 DAT. Moreover, Soti [11] observed 84.04 cm and 101.00 cm height of Srijana at 75 and 135 DAT in a control and inside pest exclusion net with black plastic mulch in
normal planting season at similar altitude to our experimental area, respectively. Srijana is an indeterminate genotype that continues to grow in favorable growing condition. Most of the open pollinated genotypes were dwarf than hybrids except AVTO-1314. But it does not mean that hybrid cultivars should be taller or indeterminate. It depends on the character of parental lines of hybrid cultivars [12]. Those varieties exhibited dwarf nature in our study were determinate type. Wide variation has been observed in tomato yield among genotypes. Devkota et al., [13] found yield variation from 54.39 to 80.83 t ha⁻¹ among 13 genotypes evaluated at an altitude of 1317 m. Whereas Chapagain et al., [2] reported tomato yield ranging from 71.4 to 105.8 t ha⁻¹ among six genotypes at an altitude of 1640 m. Likewise, Soti [11] found yield ranging from 68.31 to 100.91 t ha⁻¹ from cv. Srijana in a plastic mulch experiment from normal season transplanting in the same area where our experiment conducted. Moreover, tomato cv. Srijana evaluated in all the experiments provided varying fruit yield viz. 62.33 t ha⁻¹ [13], 86.8 t ha⁻¹ [2] and 68.31 t ha⁻¹ [11]. In our study, the fruit yield of the same genotype was 53.75 t ha⁻¹ could be attributed to altitude and growing season. It clearly suggests that yield is not only a genetic factor, it is also governed by growing environment.

Total soluble solids are one of the main components in tomato flavor and influences consumer preferences and industrial performance [14]. Acidity contributes to both taste and food safety as it hinders the spoilage of food by microorganisms. Fruit pH generally has an inverse relationship with Titrable acidity. Tomatoes are still classified as an acidic fruit (pH <4.6). Low pH is associated with high fruit quality [15]. Tomato is considered acidic if it has a pH of less than 4.5 [16] and it is a desirable trait.

| Genotypes   | Plant height (cm) | Days to 50% flowering | Days to first Harvest |
|-------------|-------------------|------------------------|----------------------|
| AVTO-9304   | 61.2ef            | 28.0b                  | 75.0cd               |
| AVTO -1314  | 92.6bcd           | 33.0a                  | 79.0b                |
| AVTO -9801  | 68.5e             | 28.0b                  | 74.0c                |
| AVTO -9802  | 83.9d             | 33.0a                  | 79.0b                |
| Florida -91 | 88.6cd            | 33.0a                  | 85.0a                |
| Celebrity   | 103.0bc           | 34.0a                  | 79.0b                |
| Pariposa- 4102 | 106.0b           | 33.0a                  | 79.0b                |
| TO -1057    | 104.0b            | 33.0a                  | 80.0b                |
| Srijana     | 176.0a            | 33.0a                  | 78.0b                |
| Mean        | 98.0              | 32.0                   | 78.0                 |
| F-test      | ***               | ***                    | ***                  |
| CV%         | 9.05              | 3.75                   | 2.72                 |

Values in a column with different letter(s) are significantly different at 0.05 level of significance by DMRT

| Genotypes   | Diameter (cm) | Fruit weight (g) | Fruit yield (kg plant⁻¹) |
|-------------|---------------|------------------|--------------------------|
| AVTO-9304   | 4.1d          | 26.4f            | 1.6de                    |
| AVTO -1314  | 5.2c          | 61.2c            | 1.9de                    |
| AVTO -9801  | 4.1d          | 26.2f            | 1.5de                    |
| AVTO -9802  | 5.2c          | 45.3de           | 1.5e                     |
| Florida -91 | 7.5a          | 158.9a           | 3.2bc                    |
| Celebrity   | 6.9b          | 121.8b           | 3.2bc                    |
| Pariposa-4102 | 5.2c          | 61.9c            | 3.5b                     |
| TO -1057    | 5.0c          | 58.1cd           | 4.6a                     |
| Srijana     | 5.0c          | 40.5e            | 2.4cd                    |
| Mean        | 5.4           | 66.7             | 2.6                      |
| F-test      | ***           | ***              | ***                      |
| CV%         | 5.36          | 13.12            | 21.9                     |

Values in a column with different letter(s) are significantly different at 0.05 level of significance by DMRT
because it halts proliferation of microorganisms in processed product [17]. All the tested genotypes in our study had pH lower than 4.5 and most of the South Asian consumer prefer sour taste in fresh tomato.

The sugars are the largest contributor to the total soluble solids (TSS) content in tomato fruits [18]. In our study, TSS content observed in tomato genotypes varied between 3.70–4.90 °Brix. In general, TSS ranged from 4 to 6 °Brix in tomato fruits of different genotypes. The change in the glucose to fructose ratio and the organic acids content in the tomatoes is the main cause for changes in the TSS. Moreover, for the taste of tomatoes, TSS was reported as a beneficial indicator [19]. TSS reflects dry matter content and is inversely proportionate to fruit size [20]. TSS in large beefsteak tomatoes ranges from 3 to 5%, in medium-sized fruit from 5 to 7% and cherry tomato fruit from 9 to 15% [21].

A long term study conducted by a Lithuanian scientist showed that the average amount of ascorbic acid was 16.20 mg 100 g⁻¹ in different tomato cultivars [22]. In fully ripened tomato fruits, the average amount of ascorbic acid varies from 10 to 20 mg 100 g⁻¹ [23]. However, some scientists note that the average amount of ascorbic acid is 25 mg 100 g⁻¹ in fresh tomatoes [24]. Chapagain et al., [2] reported that average ascorbic acid content in different tomato genotypes was 20.42 mg 100 g⁻¹. However, Viskelis et al., [25] found slight change in ascorbic acid content in cv. ‘Milžinai during different ripening stages and varied from 3.8 to 4.2 mg 100 g⁻¹. In our study, average ascorbic acid content among nine genotypes was 10 mg
100 g\(^{-1}\). Viskelis et al., [25] concluded that the amount of ascorbic acid mainly depends on tomato genotype and less influenced by fruit ripening stage. In our study as well, the variation in ascorbic acid content from 7.07 to 12.60 mg 100 g\(^{-1}\) (Table 5) was genotypic characteristics.

5. CONCLUSION

Results of the present study indicated that morphological, yield and biochemical parameters were significantly different among the evaluated tomato genotypes. All tested genotypes had higher yield than the national average productivity of tomato (19.3 t ha\(^{-1}\)) in Nepal. Genotype TO-1057 produced fruit yield of almost six times higher as compared to Nepal's average productivity of tomato. Srijana, only released F1 of Nepal, also showed promising result. This study provides the varietal options to farmers to produce tomato in summer season in plain area of Chitwan condition. Though, the World Vegetable Center lines are developed for heat tolerance, they did not perform well as compared to Indian hybrids. All of the tested genotypes had good fruit quality. Due to significantly high fruit yield, medium size fruit and moderate in vitamin C content TO-1057 is recommended for summer season cultivation in plains of Chitwan, Nepal.

AKNOWLEDGEMENTS

The authors would like to thank Agriculture and Food Security Project, Nepal, and Nepal Agricultural Research Council for funding the research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lokesha AN, Shivashankara KS, Laxman RH, Geetha GA, Shankar AG. Effect of high temperature on fruit quality parameters of contrasting tomato genotypes. International Journal of Current Microbiology and Applied Sciences. 2019;8 (3):2319-7706.

2. Chapagain TR, Tiwari DN, Adhikari RC, Shrestha MB. Physicochemical properties and yield of tomato varieties under plastic house condition. Nepal Journal of Science and Technology. 2014;15(2):17-22.

3. Ministry of Agriculture and Cooperatives (MOAD). Statistical Information on Nepalese Agriculture 2015/2016; 2016.

4. Pandey YR, Pun AB, Upadhyay KP. Participatory varietal evaluation of rainy season tomato under plastic house condition. Nepal Agriculture Research Journal. 2006;7:11-15.

5. Sato S, Peet MM, Thomas JF. Physiological factors limit fruit set of tomato (Lycopersicon esculentum Mill.) under chronic, mild heat stress. Plant, cell & Environment. 2000;23(7):719-726.

6. Hazra P, Samsul HA, Sikder D, Peter KV. Breeding tomato (Lycopersicon esculentum Mill) resistant to high temperature stress. International Journal of Plant Breeding. 2007;1(1):31-40.

7. Hazra P, Som MG. Vegetable Science. New Delhi: Kalyani Publication; 2006.

8. NMREP. Annual Report. National Maize Research Program, Nepal Agricultural Research Council, Rampur, Chitwan, Nepal; 2016.

9. Sadasivam S, Manickam A. Biochemical methods (3\textsuperscript{rd} Ed). New Delhi: New Age International Publishers; 2008.

10. Nirupama P, Gol NB, Rao TR. Effect of postharvest treatments on physicochemical characteristics and shelf life of tomato (Lycopersicon esculentum Mill.) fruits during storage. American-Eurasian Journal of Agricultural & Environmental Sciences. 2010;9(5):470-479.

11. Soti A. Effect of net house and mulching on insect pest incidence of tomato in Chitwan, Nepal. Master thesis. Agriculture and Forestry University, Rampur, Nepal; 2018.

12. Shrestha SL, Sah RL. Evaluation of tomato cultivars for Central Terai of Nepal. Nepal Journal of Science and Technology. 2014;15(2):11-16.

13. Devkota S, Shrestha SL, Dhakal DD, Shakya SM, Pandey J. Evaluation of tomato hybrids for yield attributes under khumaltar condition. Journal of Institute of Agriculture Animal Science. 2018;35:191-196.

14. Graca AJ, Amaral Júnior AT, Rodrigues R, Gonçalves LS, Sudré CP, Vivas M, Melo PC. Heterosis and combining ability of dualpurpose tomato hybrids developed to meet family farmers' needs in Brazil and Mozambique. Horticulture Brasilia. 2015;33(3):339-344.
Available:http://dx.doi.org/10.1590/ S0102-05362015000200010

15. Ilic ZS, Milenkovic L, Sunic L, Stanojevic L, Bodroza-Solarov M, Marinkovic D. Tomato fruits quality as affected by light intensity using color shade nets. Proceedings. 47th Croatian and 7th International Symposium on Agriculture. Opatija Croatia. 2014; 414:418.

16. Hernández-Suárez MH, Rodríguez ER, Romero CD. Chemical composition of tomato (Lycopersicon esculentum L.) from Tenerife, the Canary Islands. Food Chemistry. 2008;106(3):1046-1056.

17. Aboagye-Nuamah F, Hussein YA, Ackun A. Properties of six varieties of tomato from Brong Ahafo Region of Ghana as influenced by the ripening condition and drying. African Journal of Food Agriculture and Nutritional Development. 2018;18(1):13095-13109.

18. Selahle MK, Sivakumar D, Soundy P. Effect of photo-selective nettings on post-harvest quality and bioactive compounds in selected tomato cultivars. Journal of Science Food and Agriculture. 2014;94: 2187–2195.

19. Klunklin W, Savage G. Effect of quality characteristics of tomatoes grown under well-watered and drought stress conditions. Foods. 2017;6(8):56-65.

20. Beckles DM. Factors affecting the postharvest soluble solids and sugar content of tomato (Solanum lycopersicum L.) fruit. Postharvest Biology and Technology. 2012;63:120-140.

21. Gautier H, Lopez-Lauri F, Massot C, Murshed R, Marty I, Grassselly D, Keller C, Sallanon H, Genard M. Impact of ripening and salinity on tomato fruit ascorbate content and enzymatic activities related to ascorbate recycling. Functional Plant Science and Biotechnology. 2010;4:66-75.

22. Mathews RF, Crill P, Burgis DS. Ascorbic acid content of tomato varieties. Florida State Horticultural Society. 1973;86:242-245.

23. Viskelis P, Radzevicius A, Urbonaviciene D, Viskelis J, Karkleliene R, Bobinas C. Biochemical parameters in tomato fruits from different cultivars as functional foods for agricultural, industrial, and pharmaceutical uses. Plant for the Future. 2015;45-77. Available:http://dx.doi.org/10.5772/60873

24. Stern DJ, Buttery RG, Teranishi R, Ling L, Scott K, Cantwell M. Effect of storage and ripening on fresh tomato quality. Food Chemistry. 1994;49(3):225-231.

25. Viskelis P, Jankauskiene J, Bobinaite R. Influence of ripeness on tomato fruit quality. Sodininkyste Daržininkyste. 2007; 26(4):278-288.

© 2020 Chapagain et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/58648