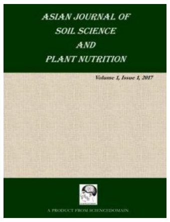

Asian Journal of Soil Science and Plant Nutrition

1(4): 1-9, 2017; Article no.AJSSPN.36061

Responses of Fruit Yield and Quality of Tomato to Water Deficit and Fertigation Levels under Greenhouse Condition

K. A. Elzopy[1*], M. S. Biradar[2], H. T. Channal[2], M. V. Manjunath[2], Y. B. Palled[2], B. M. Radder[2] and P. L. Patil[2]

[1]*Saba-Basha College of Agriculture, Alexandria University, Egypt.*
[2]*University of Agricultural Sciences, Dharwad - 580 005, India.*

Authors' contributions

This work was carried out in collaboration between all authors. Authors KAE, MSB and HTC designed the study, wrote the protocol, performed the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Authors MVM, YBP, BMR and PLP contributed to the protocol writing and managed the analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI:10.9734/AJSSPN/2017/36061
Editor(s):
(1) Zhihui Cheng, Department of Vegetable Science, College of Horticulture, Northwest A&F University, Yangling, China.
Reviewers:
(1) M. Yuvaraj, Tamil Nadu Agricultural University, India.
(2) Fabrício Correia de Oliveira, Federal University of Grande Dourados, Brazil.
(3) Fidanka Trajkova, Goce Delcev Univeristy-Stip, Republic of Macedonia.
Complete Peer review History: http://www.sciencedomain.org/review-history/20874

Original Research Article

Received 11th August 2017
Accepted 30th August 2017
Published 8th September 2017

ABSTRACT

Field experiments were conducted for two seasons during 2012-2013 at Hi-Tech-Horticulture unit, University of Agricultural Sciences, Dharwad,Karnataka, India to evaluate the effect of drip irrigation and fertigation levels on tomato hybrid STH-801 under polyhouse condition. Three drip irrigation regimes (40, 60 and 80% ETc) were based on crop evapotranspiration (ETc) that was computed using Class A pan evaporation data and three fertigation levels (50, 75 and 100% RDF) in the form of water soluble fertilizer were laid out in factorial RCBD design and replicated thrice with one absolute control (drip irrigation at 100% ETc and soil application of 100% RDF in the form of conventional fertilizer). Drip irrigation at 40% ETc gave higher TSS, ascorbic acid, titratable acidity, total phenol andlycopene content over 60 and 80% ETc. However, yield recorded by 60 and 80% ETc irrigation regimes were on par and significantly higher as compares to 40% ETc irrigation regimes. Fertigation at 100% RDF recorded maximum TSS, ascorbic acid, titratable acidity, total phenol, lycopene content and yield which was par with 75% RDF and significantly

**Corresponding author: Email: karam2016@alexu.edu.eg;*

superior over 50% RDF. Application of fertilizers through fertigation in the form of water soluble fertilizer enhanced yield and quality of fruits as compared with soil application of conventional fertilizer.

Keywords: Polyhouse; fertigation; drip irrigation; water stress; fruit quality.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the second most important vegetable crop next to potato throughout the world and grown in a wide range of climatic conditions. Studies have shown that high consumption of tomato is consistently correlated with a reduced risk of some types of cancer [1] and may account for a low incidence of ischemic heart disease [2]. The defensive role has been attributed to the carotenoid constituents, particularly lycopene and β-carotene that accumulate in plasma and tissues in relation to tomato intake [3]. In addition to carotenoids, tomato contains a variety of natural antioxidants [4]. Antioxidants are compounds that can delay or inhibit the oxidation of lipids or other molecules by inhibiting the initiation or propagation of oxidative chain reactions [5]. The antioxidant content of tomato mostly depends on genetic and environmental factors, and the ripening stage [6]. A regular intake of phenolic compounds is believed to decrease the incidence of certain forms of cancer, and for that reason they are commonly regarded as chemopreventive agents, the flavonoids have been confirmed as a group of polyphenols important in conferring antioxidant benefits [7].

Ascorbic acid (vitamin C) is known as an antioxidant, plays a crucial role in several biochemical processes in the human body. A dietary daily intake of this vitamin lowers the incidence of several chronic diseases, such as, diabetes, cardiovascular and cancer [8]. Total soluble solid content and titratable acidity, the main components responsible for tomato flavor [9], are properties of the tomato most likely to match the consumer perception of internal quality [10]. High ascorbic acid is synonymous with high nutritive values and high values of total soluble solids means lesser quantities of tomatoes will be needed for processing. Moreover, higher total soluble solid is known to improve the taste of tomatoes [11].

Fertilization and irrigation are important management practices to improve crop quality and productivity. A correct determination of irrigation scheduling is one of the main factors in achieving high yields and avoiding loss of quality in greenhouse tomato [12]. The appropriate deficit irrigation should guarantee the sustainability of marketable fruit yield of tomato and also should have positive effects on fruit quality [13,14]. The effect of water deficit on fruit contents is comparatively positive due to lesser amount of water available to fruits which caused osmotic adjustment in the pericarp of tomato and resulted in higher concentrations of TSS,carotene and ascorbic acid content over well irrigated plants [15-17], whereas size of fruits is smaller. Smaller fruits might partially contribute to higher lycopene content. Tomato skin is rich in lycopene, lycopene in tomato skin accounts for 37 per cent on average of total lycopene [18]. Small fruits have a relatively large skin area per unit of fruit volume compared with large fruits, thus leading to relatively higher lycopene content [19]. Similarly, in fertigation through drip system where fertilizer is placed to the active plant root zone improves fertilizer use efficiency and helps to attain higher yield and better quality produce than conventional practice. Therefore, the present study was conducted to determine the optimum irrigation regime and fertigation level for attaining higher yield and quality of tomato under greenhouse condition.

2. MATERIALS AND METHODS

2.1 Site Characteristics

A field experiment was carried out for two seasons during 2012-2013 at Hi-Tech-Horticulture unit, Agricultural Research Station, Saidapur, University of Agricultural Sciences, Dharwad to study the effect of irrigation regimes and fertigation levels on tomato hybrid STH-801 in tomato-tomato cropping sequence under naturally ventilated polyhouse condition. Dharwad is situated in Northern Transitional Tract of Karnataka state at 15^{o}-26' N latitude and 75^{o}-7' E longitude at an altitude of 731.5 m above mean sea level. The experimental field was sandy loam in texture with a pH of 7.3 and EC of 1.75 dSm^{-1}, low in available nitrogen (240 kg ha^{-1}), medium in available phosphorus (24 kg ha^{-1}) and high in available potassium (311 kg ha^{-1}). The recommended dose of fertilizers (RDF) for tomato hybrid STH-801 is 250:250:250 kg N, P_2O_5 and K_2O per ha and 38 tonnes FYM per ha as per package of practices.

2.2 Experimental Treatments and Design

The experiment was laid out in Factorial RCBD in which three irrigation regimes (40, 60 and 80% of ETc) were based on crop evapotranspiration (ETc) that was computed using Class A pan evaporation data (Fig. 1) and three fertigation levels (50, 75 and 100% of RDF) in the form of water soluble fertilizer were applied to 9 treatment combinations and replicated three times with one absolute control (drip irrigationat 100 % ETc and soil application of 100%RDF).

During initial growth stage, all the experimental plots received equal amount of irrigation water (100% ETc) to ensure proper establishment of tomato seedlings. Afterwards, water was applied according to drip irrigation regimes at 2 days irrigation interval.

For fertigation treatments, 20 per cent of RDF (50:50:50 kg N, P_2O_5 and K_2O ha^{-1}) in the form of conventional fertilizers (urea, diammonium phosphate and muriate of potash) + 38 tonnes of FYM per ha was applied as basal dose. The remaining fertilizers for F_1 (30 %), F_2 (55 %) and F_3 (80%) were applied in the form of water soluble fertilizer (19:19:19) in equal doses for 16 times (15 DAP to 120 DAP).

2.3 Experimental Procedure

The experiment was carried out in a naturally ventilated polyhouse (NVP) which was oriented in North-South direction with a size of 28 m length × 20 m width with central height of 6 m. Land area inside the polyhouse was thoroughly dug to a depth of 30 cm. All the weeds, stones etc. were removed. The land was incorporated with farmyard manure, urea, diammonium phosphate, muriate of potash also applied as basal dose. Raised beds of 30 cm height and 100 cm width to a length of 25 m were prepared with the walking space between beds. Paired row system of planting with zigzag manner was followed to have more aeration between the plants. 50 cm between the rows and 60 cm between plants in the row was followed for planting. Raised bed of 30 cm height and 1 m wide was prepared with 50 cm gap between beds. Tomato seedlings transplanted in the playhouse on 29th September 2012 and 7th April 2013 for first and second season, respectively.Vigorous and uniform size seedlings (22 day old) were selected for planting. Seedlings were transplanted at recommended spacing and were watered after transplanting every day until they were established. Plants were tied along the

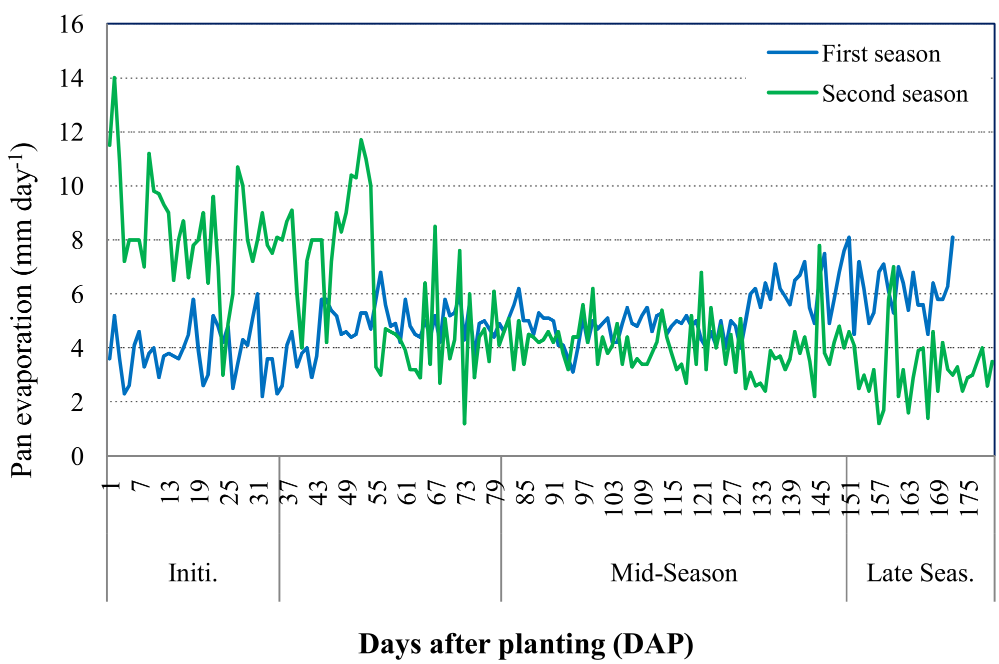

Fig. 1. Daily measured pan evaporation (mm day^{-1}) during the two seasons

plastic twine. Separate plastic twine was provided to each branch so that branches do not break up. Two stems were trained by removing the rest of the branches. Tying of the plants to plastic twin started from fourth week after transplanting and tying was done at weekly intervals along with pruning operation. Fruits were harvested at color breaking stage. Harvesting of tomato fruits started at 90 days after transplanting and continued till 172 and 180 days after transplanting for first and second season, respectively. Total soluble solids (TSS), pH, titratable acidity, ascorbic acid content, total phenol content and lycopene content were determined using standard procedure.

3. RESULTS

3.1 Fruits Quality Parameters

Results showed that fruits quality parameters like TSS, ascorbic acid content, titratable acidity, total phenol content andlycopene content differed markedly among irrigation regimes (Table 1). Drip irrigation at I_1 (40% ETc) recorded significantly higher TSS (5.52 and 5.64° brix), ascorbic acid content (25.91 and 26.19 mg 100 ml^{-1} of juice), titratable acidity (0.490 and 0.488%), total phenol content (0.539 and 0.563 mg g^{-1}) andlycopene content (4.51 and 4.61 mg 100 g^{-1} in first and second season, respectively) in fruits over I_2 (60% ETc) and I_3 (80% ETc). However, no significant difference was recorded between I_2 (60% ETc) and I_3 (80% ETc) in these parameters.

The fruits quality parameters were conspicuously influenced by fertigation levels (Table 2). Among them, highest TSS (5.14 and 5.38^{o} brix), ascorbic acid content (24.90 and 25.36 mg 100 ml^{-1} of juice), titratable acidity (0.448 and 0.451%), total phenol content (0.492 and 0.515 mg g^{-1}) andlycopene content (4.11 and 4.20 mg 100 g^{-1} in first and second season, respectively) were recorded with F_3 (100% RDF) which was on par with F_2 (75% RDF). However, fertigation at F_1 (50%RDF) recorded significantly lower TSS (4.71 and 4.79^{o} brix), ascorbic acid content (23.54 and 24.10 mg 100 ml^{-1} of juice), titratable acidity (0.414 and 0.413%), total phenol content (0.452 and 0.457 mg g^{-1}) andlycopene content (3.74 and 3.76 mg 100 g^{-1} in first and second season, respectively).

The interaction effect between irrigation regimes and fertigation levels did not differ significantly with respect to TSS, ascorbic acid, titratable acidity, total phenol and lycopene content in tomato fruits (Table 3). The results also revealed that quality parameters of tomato fruits were significantly influenced by fertigation treatments over conventional soil application. Soil application of recommended dose of fertilizers recorded significantly lower TSS (4.13 and 4.33° brix), ascorbic acid content (22.07 and 22.73 mg 100 ml^{-1} of juice), titratable acidity(0.387 and 0.376%) and total phenol content (0.393 and 0.405 mg g^{-1} in first and second season, respectively) as compared to I_1F_2, I_1F_2 and I_1F_3 treatments and it was on par with the rest treatments. Whereas, the treatment combination of I_1F_2, I_1F_2, I_1F_3, I_2F_2, I_2F_3, I_3F_2 and I_3F_3 resulted in higher lycopene content as compared to control (3.02 and 3.05mg 100 g^{-1}in first and second season, respectively).

3.2 Yield

Significant variations were recorded in tomato yield due to irrigation regimes (Table 1). The highest yield (115.14 and 89.56 tonnes ha^{-1} in first and second season, respectively) was recorded with I_3 (80% ETc) followed by I_2 (60% ETc) (114.97 and 89.26 tonnes ha^{-1} in first and second season, respectively). However, they were on par and significantly superior over I_1 (40 ETc) (102.00 and 76.57 tonnes ha^{-1} in first and second season, respectively).

Tomato yield differed significantly due to fertigation levels (Table 2). Application of F_3 (100% RDF) recorded the highest yield (113.75 and 87.50 tonnes ha^{-1} in first and second season, respectively) which was on par with F_2 (75% RDF). However, fertigation at F_1 (50% RDF) recorded significantly lower yield (105.05 and 81.05 tonnes ha^{-1} in first and second season, respectively) as compared with other fertigation levels.

However, the interaction effect was also significant with respect to yield (Table 3). Treatment combination of I_2F_3 registered the highest yield (120.73 and 93.67 tonnes ha^{-1} in first and second season, respectively) which was on par with I_2F_2, I_3F_2 and I_3F_3, but significantly superior over other fertigation treatments. However, the lowest yield (101.10 and 75.29 tonnes ha^{-1} in first and second season, respectively) was recorded with I_1F_3 which was on par with I_1F_1, I_1F_2, I_2F_1 and I_3F_1. In addition, fertigation treatments recorded significantly higher yield as compared to conventional soil application of fertilizers with drip irrigation (control) (74.70 and 57.58 tonnes ha^{-1} in first and second season, respectively).

Table 1. Effect of irrigation regimes on quality and yield of tomato

Irrigation regimes	TSS (° brix)	Ascorbic acid content (mg 100 ml^{-1} of juice)	Titratable acidity (%)	Total phenol content (mg g^{-1})	Lycopene content (mg 100 g^{-1})	Yield (tonnes ha^{-1})
First season						
I_1	5.52	25.91	0.490	0.539	4.51	102.00
I_2	4.88	23.77	0.412	0.450	3.68	114.97
I_3	4.58	23.36	0.405	0.444	3.75	115.14
SEm±	0.12	0.36	0.010	0.011	0.10	1.57
CD (p = 0.05)	0.37	1.08	0.030	0.033	0.31	4.69
Second season						
I_1	5.64	26.19	0.488	0.563	4.61	76.57
I_2	4.93	24.23	0.417	0.460	3.75	89.26
I_3	4.92	23.78	0.407	0.458	3.77	89.56
SEm±	0.17	0.32	0.010	0.012	0.11	1.46
CD (p = 0.05)	0.52	0.96	0.030	0.035	0.33	4.38

Table 2. Effect of fertigation levels on quality and yield of tomato

Fertigation levels	TSS (° brix)	Ascorbic acid content (mg 100 ml^{-1} of juice)	Titratable acidity (%)	Total phenol content (mg g^{-1})	Lycopene content (mg 100 g^{-1})	Yield (tonnes ha^{-1})
First season						
F_1	4.71	23.54	0.414	0.452	3.74	105.05
F_2	5.12	24.59	0.445	0.489	4.09	113.31
F_3	5.14	24.90	0.448	0.492	4.11	113.75
SEm±	0.12	0.36	0.010	0.011	0.10	1.57
CD (p = 0.05)	0.37	1.08	0.030	0.033	0.31	4.69
Second season						
F_1	4.79	24.10	0.413	0.457	3.76	81.05
F_2	5.33	24.74	0.448	0.508	4.17	86.84
F_3	5.38	25.36	0.451	0.515	4.20	87.50
SEm±	0.17	0.32	0.010	0.012	0.11	1.46
CD (p = 0.05)	0.52	0.96	0.030	0.035	0.33	4.38

Table 3. Effect of interaction (I×F) and control on quality and yield of tomato

Treatments	TSS (° brix)		Ascorbic acid content (mg 100 ml^{-1} of juice)		Titratable acidity (%)		Total phenol content (mg g^{-1})		Lycopene content (mg 100 g^{-1})		Yield (tonnes ha^{-1})	
	First season	Second season	First season	Second season	First season	Second season	First season	Second season	First season	Second season	First season	Second season
I_1F_1	5.03	4.87	25.23	25.63	0.484	0.477	0.547	0.555	4.45	4.59	103.01	78.36
I_1F_2	5.83	6.17	26.03	26.27	0.489	0.495	0.532	0.561	4.58	4.55	101.90	76.07
I_1F_3	5.70	5.90	26.47	26.67	0.498	0.490	0.538	0.573	4.50	4.69	101.10	75.29
I_2F_1	4.57	4.73	22.67	23.53	0.386	0.385	0.411	0.416	3.32	3.28	105.22	82.09
I_2F_2	4.93	4.83	24.17	23.97	0.422	0.430	0.467	0.482	3.76	4.02	118.94	92.02
I_2F_3	5.13	5.23	24.47	25.20	0.429	0.435	0.472	0.483	3.94	3.95	120.73	93.67
I_3F_1	4.53	4.77	22.73	23.13	0.373	0.375	0.397	0.400	3.44	3.41	106.93	82.70
I_3F_2	4.60	5.00	23.57	24.00	0.423	0.421	0.469	0.481	3.92	3.94	119.09	92.43
I_3F_3	4.60	5.00	23.77	24.20	0.418	0.426	0.466	0.491	3.90	3.95	119.41	93.55
Control	4.13	4.33	22.07	22.73	0.387	0.376	0.393	0.405	3.02	3.05	74.70	57.58
Interaction (I×F)												
SEm±	0.22	0.30	0.63	0.55	0.017	0.017	0.019	0.020	0.18	0.19	2.71	2.53
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	8.13	7.58
Control vs. Rest treatments												
SEm±	0.22	0.29	0.61	0.61	0.018	0.017	0.021	0.020	0.17	0.18	2.74	3.43
CD (p = 0.05)	0.98	1.19	2.53	2.56	0.076	0.072	0.089	0.082	0.72	0.75	11.43	14.33

4. DISCUSSION

The higher fruits quality parameters at lower irrigation level (I_1) could be attributed to the reduction of fruit water accumulation while the net dry matter accumulation was less affected which caused osmotic adjustment in the pericarp of tomato. Small fruits in I_1 (40% ETc) have a relatively large pericarp per unit of fruit volume compared with large fruits, thus leading to relatively higher quality parameters content. The skin fraction of tomato fruits had significantly higher levels of total phenolics, total flavonoids, lycopene, ascorbic acid and antioxidant activity compared to their pulp and seed fractions [18]. The major advantage of deficit irrigation was improvement in quality in terms of total soluble solid, ascorbic acid, acidity and lycopene content though the fruit size was affected [13,14,20].

The higher fruits quality parameters at 100 and 75 per cent fertigation level might be due to enhanced vegetative growth, leading to enhanced accumulation of solids and more conversion of organic acids to sugar with increase in nutrient level [21]. Fertigation treatments may have provided NPK at consistent levels throughout the plant growth period as compared to conventional soil application. Similarly, the injection of nutrients directly around plant-root system with drip fertigation became quite useful as there was no leaching loss and the optimum soil moisture which was prevailing resulted in a better utilization of applied nutrients. Therefore, it can be said that availability of nutrients evenly with water soluble fertilizers through fertigation was responsible for the improvement of TSS, pH, ascorbic acid, titratable acidity, total phenol andlycopene content.

The significant yield reduction in irrigation regime I_1 (40% ETc) as compared with I_2 (60% ETc) (11.28 and 14.21% in first and second season, respectively) and I_3 (80% ETc) (11.41 and 14.50% in first and second season, respectively) was probably due to inadequate amount of irrigation water. Irrigation at I_2 (60% ETc) and I_3 (80% ETc) resulted in favorable microclimate and kept constantly soil moisture near to field capacity which helped in higher nutrient uptake, better crop growth and thus resulting in higher yield. The adverse effect of water stress on yield components of tomato may be attributed to the decrease in photosynthetic rates and growth parameters. Tomato fruit contains at least 92 per cent water, most of which is transported to the fruit through the phloem. Water transport is reduced during a mild water stress although photoassimilates continue to be transported into the fruit [22]. This might have been a reason that the fruit weight was lower at I_1 (40% ETc). Tomato yields in I_2 (60% ETc) and I_3 (80% ETc), suggests that tomato plants of these treatments did not suffer from water stress. These results are in conformity with the findings of Ya-dan et al. [14] and Huimeng Zhang et al. [20].

Progressive yield increase observed in F_3 (100% RDF) (7.64 and 7.37% in first and second season, respectively) and F_2 (75% RDF) (7.29 and 6.66% in first and second season, respectively) as compared with F_1 (50% RDF)was probably due to incremental doses of NPK fertilizers might have created favorable effects of nutrients on dry matter production, yield components and uptake of nutrients. Because of higher dry matter production coupled with higher nutrient uptake, more assimilates got synthesized which might have translocated efficiently to fruits and increased the yields. Tomato yield in F_2 (75% RDF) and F_3 (100% RDF) was on par suggesting that 25 per cent of recommended dose of fertilizers (RDF) can be saved under drip fertigation treatments.

Progressive yield increase observed in fertigation treatments as compared to conventional soil application of fertilizers could be attributed to the fact that fertilizer application through fertigation device is restricted to the wetted volume of soil where the active roots were concentrated and hence, it was available to plants fully [23]. This enhanced the current photosynthesis for developing fruit leading to the development of fruit to marketable size and producing more number of fruits per plant and fruit weight in fertigation treatments compared to soil application treatments [24].

5. CONCLUSION

Drip irrigation at 40% ETc under greenhouse condition increased TSS, ascorbic acid content, titratable acidity, total phenol content andlycopene content in tomato fruits over 60 and 80% ETc irrigation regimes. However, the yield recorded by 60 and 80% ETc irrigation regimes were on par and significantly superior as compares to 40% ETc irrigation regimes. Adjusting crop coefficients to the actual needs of drip irrigated tomato crops under polyhouse condition may help to save water (approximately 40% less in our experiment) and diminish drainage during the growth period. Fertigation at

75 and 100% RDF improved quality and yield of tomato fruits over 50% RDF. Fertigation of fertilizer enhanced quality and yield of tomato over soil application of fertilizers.

ACKNOWLEDGEMENT

We are grateful to High-Tech Horticulture unit members, University of Agricultural Sciences, Dharwad, INDIA for the kind assistance in field experiments, constructive criticism and valuable suggestions, with due respect.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Franceschi S, Bidoli E, La-Vecchia C, Talamini R, D'Avanzo B, Negri E. Tomatoes and risk of digestive-tract cancers. Int. J. Cancer. 1994;59:181-184.
2. Gerster H. The potential role of lycopene for human health. J. American Coll. Nutr. 1997;16:109-126.
3. Oshima S, Ojima F, Sakamoto H, Ishiguro Y, Terao J. Supplementation with carotenoids inhibits singlet oxygen mediated oxidation of human plasma low-density lipoprotein. J. Agric. Food Chem. 1996;44:2306-2309.
4. Davies JN, Hobson GE. The constituents of tomato fruit-The influence of environment, nutrition and genotype. Crit. Rev. Food Sci. Nutr. 1981;15:205-279.
5. Velioglu YS, Mazza G, Gao L, Oomah BD. Antioxidant activity and total phenolics in selected fruits, vegetables, and grain products. J. Agric. Food Chem. 1998;46: 4113-4117.
6. Hart DJ, Scott KJ. Development and evaluation of an HPLC method for the analysis of carotenoids in foods, and the measurement of the carotenoid content of vegetables and fruits commonly consumed in the UK. Food Chem. 1995;54:101-111.
7. Luthria DL, Mukhopadhyay S, Krizek D. Content of total phenolics and phenolic acids in tomato (*Lycopersicon esculentum* Mill.) fruits as influenced by cultivar and solar UV radiation. J. Food Com. Anal. 2006;19:771-777.
8. Ozyurek M, Guclu K, Bektasoglu B, Apak R. Spectrophotometric determination of ascorbic acid by the modified CUPRAC method with extractive separation of flavonoids–La (III) complexes. Analytica Chimica Acta. 2007;588:88-95.
9. Kader AA. Effects of postharvest handling procedures on tomato quality. Acta Horti. 1986;190:209-221.
10. Baldwin EA, Scott JW, Einstein MA, Malundo TMM, Carr BT, Shewfelt RL, Tandon KS. Relationship between sensory and instrumental analysis for tomato flavor. J. American Soc. Horti. Sci. 1998;123: 906-915.
11. Kahlon MS, Josan AS, Khera KL, Choudhary OP. Effect of drip and furrow methods of irrigation on tomato under two irrigation levels. Indian J. Agric. Res. 2007;41(4):282-286.
12. Yuan B, Kang Y, Nishiyama S. Drip irrigation scheduling for tomatoes in unheated greenhouses. Irri. Sci. 2001;20: 149-154.
13. Nangare DD, Yogeshwar Singh, Suresh Kumar P, Minhas PS. Growth, fruit yield and quality of tomato (*Lycopersicon esculentum* Mill.) as affected by deficit irrigation regulated on phenological basis. Agric. Water Manage. 2016;171:73–79.
14. Ya-dan DU, Hong-xia CAO, Shi-quan LIU, Xiao-bo GU, Yu-xin CAO. Response of yield, quality, water and nitrogen use efficiency of tomato to different levels of water and nitrogen under drip irrigation in Northwestern China. J. Integrative Agric. 2017;16(5):1153-1161.
15. Matsuzoe N, Zushi K, Johjima T. Effect of soil water deficit on coloring and carotene formation in fruit of red, pink and yellow type cherry tomatoes. J. Japanese Soc. Horti. Sci. 1998;67(4):600-606.
16. Mahajan G, Singh KG. Response of greenhouse tomato to irrigation and fertigation. Agric. Water Manage. 2006; 84(1-2):202-206.
17. Hao L, Ai-wang D, Fu-sheng L, Jing-sheng S, Yan-cong W, Chi-tao S. Drip irrigation scheduling for tomato grown in solar greenhouse based on pan evaporation in north China plain. J. Integrative Agric. 2013;12(3):520-531.
18. Toor RK, Savage GP. Antioxidant activity in different fractions of tomatoes. Food Res. Int. 2005;38:487-494.
19. Liu K, Zhang TQ, Tan CS, Astatkie T. Responses of fruit yield and quality of

processing tomato to drip-irrigation and fertilizers phosphorus and potassium. Agron. J. 2011;103:1339-1345.
20. Huimeng Zhang, Yunwu Xiong, Guanhua Huang, Xu Xu, Quanzhong Huang. Effects of water stress on processing tomatoes yield, quality and water use efficiency with plastic mulched drip irrigation in sandy soil of the Hetao Irrigation District. Agric. Water Manage. 2017;179:205-214.
21. Rana RS, Devi K, Verma IM. Fertigation studies in hybrid tomato (*Lycopersicon esculentun* Mill). Ann. Agri-biosys. Res. 2005;10(1):87-90.
22. Ho LC. The physiological basis for improving tomato quality. Acta Horti. 1999;487:33-40.
23. Gupta AJ, Chattoo MA, Bhat FN. Techno-economic evaluation of drip irrigation and fertigation practices in capsicum under Kashmir conditions. Veg. Sci. 2009;36(3): 309-314.
24. Shedeed SI, Zaghloul SM, Yassen AA. Effect of method and rate of fertilizer application under drip application on yield and nutrient uptake by tomato. Ozean J. Appl. Sci. 2009;2:139–147.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20874