Agric Res J **55** (2) : 282-286, *June* 2018
DOI No. 10.5958/2395-146X.2018.00051.0

COMPARISON OF TOMATO FRUIT QUALITY UNDER WICK AND DRIP SUBSTRATE HYDROPONIC SYSTEMS

Harsimran Kaur[1*], Seema Bedi[1], V P Sethi[2] and A S Dhatt[3]

[1]Department of Botany, [2]Department of Mechanical Engineering, [3]Department of Vegetable Science
Punjab Agricultural University, Ludhiana- 141004, Punjab

ABSTRACT

In the present study, the effect of wick and drip substrate hydroponic systems and composition of nutrient solutions on leaf assimilates and fruit quality of tomato crop raised in summer and winter seasons was compared. There was higher accumulation of total starch, total soluble proteins and free amino acids in leaves of winter crop. Leaf assimilates were more in crop supplied with nutrient solution containing higher doses of N and K irrespective of hydroponic systems used. Overall fruit quality in terms of ascorbic acid, total soluble sugars and firmness was more in crop supplied with nutrient solution containing higher levels of potassium. Winter crop raised under wick system gave higher yield and quality of the fruit.

Key words: Assimilates, Fruit quality, Hydroponics, Nutrient, Tomato

Tomato is a good source of vitamins and antioxidants like lycopene. Efforts are being made worldwide for production of high yield and quality in tomato. The concentration of dry matter (Bertin *et al.,* 2000), sugar and acid (Malundo *et al.,* 1995) in tomatoes has been studied to understand the processes contributing to fruit quality. Dry matter of fruit comes from the leaves as assimilates are accumulated during photosynthesis. These assimilates are then transported to the fruit as sucrose. The transformation of the sucrose and other sugars in the fruit into organic compounds determines the taste of fruit (Mitchell *et al.,* 1991).

Nitrogen and potassium play an important role in many aspects of plant growth and development and therefore directly affect the yield and quality of fruit (Zekri and Obreza, 2003). Tomato yields and quality are associated to the application of potassium (Chapagain and Wiesman, 2004). The proper growth of plant and fruit development is related to the nitrogen nutrition of the plant (Saure, 2001).

In open field, fruit yield and quality are poor due to prevailing low and high temperatures respectively during the winters and summers. The plants also face severe attack of insect pests resulting in the poor growth of crop. To overcome this problem, protected cultivation or greenhouse is the best alternative for the production of high yield and quality of fruits. The hydroponic or soilless cultivation under greenhouse is the most effective method of crop production. Hydroponics involves cultivation of crop on an inert substrate medium (gravel, sand, perlite, vermiculite, clay pebbles, etc.) with the supply of all essential nutrients in the form of nutrient solution (Winterborne, 2005).

The objective of the present study was to compare the effect of nutrient solution compositions, drip and wick type substrate hydroponic systems on leaf metabolites and quality of tomato during summer and winter seasons.

MATERIALS AND METHODS

The experiment was conducted on tomato (*Solanum lycopersicum* L.) var. Punjab Varkha Bahar 1, raised under two substrate hydroponic systems in summer and winter during 2014-15 and 2015-16, at the Punjab Agricultural University (PAU), Ludhiana, India. The nursery was raised as per recommended practices (Anonymous, 2015) in the field area of Department of Vegetable Science. For winter crop, the nursery was raised during 2nd week of July and transplanted to the respective substrate hydroponic systems during mid-August. Nursery was planted during last week of October for summer crop and seedlings were transplanted in first week of December in each season.

Substrate hydroponic systems

The two substrate hydroponic systems (wick and pumping) designed at the Department of Mechanical Engineering, Punjab Agricultural University, Ludhiana (Bhullar *et al.,* 2016) were used to raise the crop in the current study.

In wick type self-suction substrate hydroponic system, the crop was raised in plastic pots (diameter of approximately 30 cm and height 28 cm) containing cocopeat, vermiculite and perlite (3:1:1) medium. Four holes were drilled at the base of the pot through which cotton wicks of suitable thickness and length were inserted in the substrate medium and a sufficient length passed below the pot through holes. These pots were placed on the top of plastic buckets of 6 litre capacity containing 5 litres of nutrient solution. The nutrient solution was drawn into the substrate medium with the help of cotton wicks without using any energy.

*Corresponding author : simranpau171@gmail.com
Date of receipt : 29.01.2018, Date of acceptance : 30.04.2018

In drip substrate hydroponic system, the nutrient solution was contained in plastic drums and supplied to each pot by a plastic pipe to which small drippers were attached. The nutrient solution was circulated from drum to the pots and then back into the drum, using an electric pump.

Fertilizer treatment

The nutrient solutions comprising different ratios of nitrogen (N) and potassium (K) at vegetative and reproductive stages were evaluated under both the substrate hydroponic systems. A nutrient solution formulation (Resh, 1985) was modified and four different combinations of N and K were evaluated as treatments (Table 1). Macronutrients were supplied as magnesium nitrate, potassium nitrate, potassium dihydrogen orthophosphate, calcium nitrate, potassium sulfate and magnesium sulphate. Quantities of magnesium sulphate, magnesium nitrate, potassium sulphate and potassium nitrate were varied to obtain four combinations of N and K (treatments). A commercially available formulation of micronutrients was supplied to the plants. EC and TDS meters were used to monitor electrical conductivity, pH and total dissolved salts of the nutrient solution.

Inside the greenhouse, environmental data were recorded weekly for the full crop cycle. The temperature inside the polyhouse was maintained by using heaters in winters and coolers in summers. Additionally, the polyhouse was shaded using green net to block sun rays during months of August till end of September. In summer growing seasons, the average day temperatures were 29°C (maximum) and 23°C (minimum). In winter growing seasons, the average day temperatures were 27°C (maximum) and 21°C (minimum).

Sampling and analysis

Various assimilates (Total soluble sugars, total starch, total soluble proteins, free amino acids) were estimated from leaves. Total soluble sugars and total starch content were estimated as per Dubois *et al.* (1956) while total soluble proteins were estimated as per Lowry *et al.* (1951).Free amino acids (Lee and Takahashi, 1966), proline (Bates *et al.,* 1973), peroxidase (Shannon *et al.,* 1966), catalase (Chance and Maehly, 1955) and superoxide dismutase (Marklund and Marklund, 1974) were also determined. Three fully matured fruits were picked from each replicated treatment and then quality parameters were estimated. The ascorbic acid in tomato was determined as per Ranganna (1986). Fruit firmness was determined by hand penetrometer. Extraction and estimation of fruit total soluble sugars was as per Dubois *et al.* (1956).

Statistical design and data analysis

The experiment was conducted in a CRD factorial design with fertilizer treatments (N**:** K ratios) in the main plot, hydroponic systems in the sub-plot and growing seasons in the sub-sub plot. Data were evaluated by analysis of variance (ANOVA), which was applied to each substrate hydroponic system and season in order to evaluate the effects of different fertilizer levels. Mean values were compared using the Tukey test at a significance level of 0.05.

RESULTS AND DISCUSSION

In winter crop (summer sown) maximum fruit yield (8.15 kg/plant) was obtained from crop raised under wick system while in summer crop (winter sown) maximum fruit yield (7.53 kg/plant) was obtained from crop under drip system. With respect to nutrient solution, maximum fruit yield (16.88 kg/plant) was obtained with application of T4 (N**:** K= 1.4**:** 3 at vegetative stage; N**:** K= 1.7**:** 3.5 at reproductive stage) nutrient solution irrespective of hydroponic systems or seasons (Kaur *et al.,* 2017).

The overall mean values showed that there was higher accumulation of total starch, total soluble proteins and free amino acid contents in leaves in winter crop (Table 2). There was low level of irradiant light on summer crop (winter sown) during early phase of plant development (December and January). Therefore, there was less accumulation of total starch and total soluble proteins in the leaves. In *Lactuca sativa* (L.) exposure to high light intensity increased the concentration of total soluble proteins (Pérez-López *et al*., 2015) and a drop in concentration of total soluble sugars and amino acids in tomato crop treated with low irradiant light (Grozeff *et al.,* 2016).

Table 1. Fertilizer treatments (g/l of water) with different ratios of N and K*

Treatment (Growth stage)	$Ca(NO_3)_2.4H_2O$	$MgSO_4.7H_2O$	KH_2PO_4	$Mg(NO_3)_2.6H_2O$	K_2SO_4	KNO_3
T1(vegetative stage N:K= 1.2: 2)	0.884	0.369	0.22	0.143	0.308	0
Flowering stage (N:K= 1.5: 2.5)	0.884	0.299	0.22	0.217	0.283	0.155
T2 (vegetative stage N:K= 1.2: 3)	0.884	0.418	0.22	0.093	0.497	0.036
Flowering stage (N:K= 1.5: 3.5)	0.884	0.347	0.22	0.167	0.472	0.195
T3 (vegetative stage N:K= 1.4: 2)	0.884	0.306	0.22	0.209	0.228	0.089
Flowering stage (N:K= 1.7: 2.5)	0.884	0.235	0.22	0.283	0.203	0.247
T4 (vegetative stage N:K= 1.4: 3)	0.884	0.354	0.22	0.159	0.417	0.129
Flowering stage (N:K= 1.7: 3.5)	0.884	0.284	0.22	0.232	0.392	0.287

* Modified from Resh (1985).

Table 2. Leaf metabolites and quality traits (mean values) of tomato fruit under wick and drip substrate hydroponic systems in winter and summer crop

Parameter	Winter crop		Summer crop	
	Wick system	Drip system	Wick system	Drip system
Total starch (mg/g dry weight)	129.5$^{a\ 1}$	128.2$^{a\ 1}$	122.1$^{a\ 2}$	124.51$^{a\ 1,2}$
Total soluble sugars (mg/g dry weight)	163.4$^{a\ 1}$	162.4$^{a\ 1}$	159.7$^{a\ 1}$	160.3$^{a\ 1}$
Total soluble Proteins (mg/g dry weight)	124.4$^{a\ 1}$	124.2$^{a\ 1}$	120.3$^{a\ 1,2}$	119.1$^{a\ 2}$
Free amino acids (mg/g dry weight)	27.95$^{a\ 1}$	29.02$^{a\ 1}$	21.3$^{a\ 2}$	20.1$^{a\ 2}$
Proline (mg/g dry weight)	2.97$^{a\ 1}$	2.95$^{a\ 1}$	3.23$^{a\ 1}$	2.87$^{a\ 1}$
Peroxidase (units min^{-1} g^{-1} FW)	7.18$^{a\ 1,2}$	7.59$^{a\ 1,2}$	8.38$^{a\ 2}$	6.83$^{b\ 1}$
Catalase (μmoles of H_2O_2 hydrolyzed min^{-1} g^{-1} FW)	87.4$^{a\ 1}$	87.8$^{a\ 1}$	88.4$^{a\ 1}$	85.9$^{a\ 1}$
Superoxide dismutase (unit min^{-1} g^{-1} FW)	0.59$^{a\ 1}$	0.67$^{a\ 1}$	0.73$^{a\ 1}$	0.58$^{b\ 1}$
Ascorbic Acid (fruit) (mg/100g FW)	27.7$^{a\ 1}$	24.4$^{b\ 2}$	22.5$^{a\ 2}$	23.4$^{a\ 2}$
Total soluble sugars (fruit) (g/100g FW)	5.45$^{a\ 1}$	4.93$^{b\ 2,3}$	4.65$^{b\ 3}$	5.20$^{a\ 1,2}$
Fruit Firmness (Kgf)	5.27$^{a\ 1}$	4.85$^{b\ 2}$	4.58$^{b\ 3}$	5.05$^{a\ 1,2}$

For both the seasons, mean corresponded to four treatments combining different N:K ratios (n=3). Values followed by a same alphabetical superscript in each crop season in a row are not statistically different. Numerical superscripts represent the mean values of overall comparison of parameters among both seasons (Tukey test).

The application of T4 treatment resulted in maximum accumulation of total starch, total soluble sugars, total soluble proteins and free amino acids content in the leaves followed by T2 treatment (N: K= 1.2: 3 at vegetative stage; N: K= 1.5: 3.5 at reproductive stage) (Table 3). Among the treatments in this experiment, both the treatments T4 and T2 had higher levels of K and treatment T4 also had highest level of N and hence more accumulation of total starch, total soluble sugars, total soluble proteins. Similar results were reported by Urbanczyk-Wochniak and Fernie (2005) who reported that amino acids significantly decreased in leaves of tomato grown hydroponically, when N is limiting. Likewise, Sung *et al.* (2015) reported that N and K deficiency caused decrease in amino acid in leaves of tomato. There was no effect of substrate hydroponic systems on the accumulation of various leaf metabolites viz. total starch, total soluble sugars, total soluble proteins and free amino acids content in both summer and winter crops.

Accumulation of reactive oxygen species (ROS) as a result of nutritional stress is a major cause of loss of crop productivity. Stress-induced ROS accumulation is counteracted by enzymatic antioxidant systems that include a variety of scavengers, such as peroxidase (POX), catalase (CAT), superoxide dismutase (SOD) and proline (a non-enzymatic antioxidant). In winter crop, there was no effect of substrate hydroponic systems on proline content and the activity of antioxidant enzymes viz., POX, CAT and SOD in leaves (Table 2). The activity of POX and SOD was increased in leaves of plants raised under wick type substrate hydroponic system in winter sown crop. The proline content and the activity of CAT were same under both the hydroponic systems in summer crop. In the present study it was observed that proline content, POX, CAT, SOD enzymes activity in

Table 3. Overall treatment mean of various leaf metabolites under wick and drip substrate hydroponic systems in winter and summer crop

Treatments	Total starch (mg/g dry weight)	Total soluble sugars (mg/g dry weight)	Total soluble Proteins (mg/g dry weight)	Free amino acids (mg/g dry weight)	Proline (mg/g dry weight)	Peroxidase (units min^{-1} g^{-1} FW)	Catalase (μmoles of H_2O_2 hydrolyzed min^{-1} g^{-1} FW)	Superoxide dismutase (units min^{-1} g^{-1} FW)
T1 (N: K= 1.2: 2; N: K= 1.5: 2.5)	92.7	102.8	114.5	24.4	3.87	9.77	112.4	1.00
T2 (N: K= 1.2: 3; N: K= 1.5: 3.5)	145.12	178.56	123.30	24.0	2.96	6.83	72.7	0.43
T3 (N: K= 1.4: 2; N: K= 1.7: 2.5)	97.59	157.45	115.75	20.8	3.57	8.60	98.8	0.84
T4 (N: K= 1.4: 3; N: K= 1.7: 3.5)	168.96	207.08	134.56	29.0	1.62	4.79	65.6	0.30
CD (P=0.05)	4.4	4.0	3.6	2.9	0.59	1.06	3.35	0.12

Table 4. Overall treatment means of quality traits of tomato fruit under wick and drip substrate hydroponic systems in summer and winter crop

Treatment	Ascorbic acid (mg/100g FW)	Total soluble sugars (g/100g FW)	Firmness (Kgf)
T1 (N: K= 1.2: 2; N: K= 1.5: 2.5)	19.9 ^{b}	3.70 ^{c}	4.11 ^{d}
T2 (N: K= 1.2: 3; N: K= 1.5: 3.5)	26.8 ^{a}	6.18 ^{a}	5.54 ^{b}
T3 (N: K= 1.4: 2; N: K= 1.7: 2.5)	22.4 ^{b}	4.08 ^{b}	4.37 ^{c}
T4 (N: K= 1.4: 3; N: K= 1.7: 3.5)	28.9 ^{a}	6.28 ^{a}	5.74 ^{a}

Values followed by a same superscript in a column are not statistically different (**Tukey** test).

leaves decreased with the application of T4 treatment (N**:** K= 1.4**:** 3 at vegetative stage; N**:** K= 1.7**:** 3.5 at reproductive stage) followed by T2 treatment (N**:** K= 1.2**:** 3 at vegetative stage; N**:** K= 1.5**:** 3.5 at reproductive stage) (Table 3). In a study conducted on *Solanum lycopersicum* L. roots, total POX and SOD activities greatly increased with potassium starvation (Hernandez *et al.,* 2012). Zhang *et al.* (2016) reported that the activity of POX, SOD and CAT enzyme increased significantly under nitrogen deficiency in cucumber seedlings.

The ascorbic acid content and total soluble sugars in fruit was higher in fruits obtained from plants supplied with T4 treatment (N**:** K= 1.4**:** 3 at vegetative stage; N**:** K= 1.7**:** 3.5 at reproductive stage) and T2 treatment (N**:** K= 1.2**:** 3 at vegetative stage; N**:** K= 1.5**:** 3.5 at reproductive stage), while fruit firmness was significantly higher with T4 followed by T2 treatment (Table 4). An adequate supply of potassium has been reported to increase the concentration of ascorbic acid in tomato fruit (Balliu and Ibro, 2002), thereby considerably improving the sensory quality of tomato. Optimal application of N improves the flavor and firmness, while excess nitrogen can damage the fruit (Wang *et al.,* 2007). It was also found that K not only increased fruit yields of solanaceous crops, but also improved fruit quality by increasing dry matter and sugar content of tomato (Wuzhong, 2002). The overall result showed that there was higher accumulation of ascorbic acid content in fruits under wick system in winter crop (Table 2).

It was found that in winter crop, there was higher accumulation of total starch, total soluble proteins and free amino acids content in leaves. The translocation of these photosynthates from leaves to the fruits could be responsible for the better quality of fruits in terms of ascorbic acid content in this season. In winter crop, better fruit quality was obtained under wick system than under drip system, because there were more evapotranspiration losses during early stages of winter crop (August-September), water and nutrient uptake through wick system rapidly compensated for these losses. It is well known that high rates of K improve the quality of fruit, so with the application of T4 treatment (N: K= 1.4: 3 at vegetative stage; N: K= 1.7: 3.5 at reproductive stage) and T2 (N: K= 1.2: 3 at vegetative stage; N: K= 1.5: 3.5 at reproductive stage), the fruit quality was improved.

Authors' contribution:

Conceptualization of research work and designing of experiments (HK, SB, VPS); Execution of field/lab experiments and data collection (HK, VPS, ASD); Analysis of data and interpretation (HK); Preparation of manuscript (HK, SB).

LITERATURE CITED

Anonymous 2015. *Package of Practices for Cultivation of Vegetables*. Punjab Agricultural University, Ludhiana, pp. 30-36.

Balliu A and Ibro V 2002. Influence of different levels of potassium fertilizers on growth, yield and ascorbic acid content of tomato fruit Grown in non-heated greenhouse. *Acta Hort* **579**:385-88.

Bates L S, Waldren R and Pand-teare I D 1973. Rapid determination of free proline for water stress studies. *Plant Soil* **39**:205-07.

Bertin N, Guichard S, Leonardi C, Longuenesse J, Langlois Y and Navez B 2000. Seasonal evolution of quality of fresh glasshouse tomatoes under Mediterranean conditions, as affected by air vapour pressure deficit and plant fruit load. *Ann Bot* **85**: 741–50.

Bhullar J, Sethi V P, Sharma A and Lee C 2016. Design and evaluation of wick type and recirculation type substrate hydroponic systems for greenhouse tomatoes. *Agric Res J* **53**: 228-33.

Chance B and Maehly A C 1955. Assay of catalase and peroxidise. In *Methods of Enzymology*, Colowick S P (ed.). Kaplan N O, Academic Press, New York, pp. 764-75.

Chapagain B P and Wiesman Z 2004. Effect of Nutri-Vant-PeaK foliar spray on plant development, yield, and fruit quality in greenhouse tomatoes. *Sci Hort* ***102***: 177-88.

Dubois M, Giles K A, Hamilton J K, Reters P A and Smith F 1956. Calorimetric method for the determination of sugars and related substances. *Anal Chem* **28:**350-56.

Grozeff G EG, Senn M E, Alegre M L, Chaves A R and Bartoli C G 2016. Nocturnal low irradiance pulses improve fruit yield and lycopene concentration in tomato. *Sci Hort* **203**: 47-52.

Hernandez M, Fernandez-Garcia N, Garcia-Garma J, Rubio-Asensio J S, Rubio F, and Olmos E 2012. Potassium starvation induces oxidative stress in *Solanum lycopersicum* L. roots. *J Plant Physiol* **169**: 1366-74.

Ibrahim M 1996. *Research and development project on the use of muriate of potash, (MOP) in Pakistan*. Technical Progress Report of Rabi, PARC, Islamabad, Pakistan.

Kaur H, Bedi S, Sethi V P and Dhatt A S 2017. Effects of substrate hydroponic systems and different N and K ratios on yield and quality of tomato fruit. *J Plant Nutr (In Press)*.

Lee Y P and Takahashi T 1966. An improved calorimetric determination of amino-acids with the use of ninhydrin. *Annu Rev Biochem* **14**: 71-77.

Lowry O H, Rosenbrough N J, Farr A L and Randell R J 1951. Protein measurement with folin-phenol reagent. *J Biol Chem* **193**: 265-75.

Malundo T M, Shewfelt R L and Scott J W 1995. Flavor quality of fresh tomato (*Lycopersicon esculentum* Mill.) as affected by sugar and acid levels. *Postharvest Biol Technol* **6**: 103–10.

Marklund S and Marklund G 1974. Involvement of the superoxide anion radical in the autoxidation of pyrogallol and a convenient assay for superoxide dismutase. *Eur J Biochem* **47:** 469-74.

Mitchell J P, Shennan C and Grattan S R 1991. Developmental changes in tomato fruit composition in response to water deficit and salinity. *Physiol Plant* **83:** 177–85.

Pérez- López U, Miranda-Apodaca J, Muñoz-Rueda A and Mena-Petite A 2015. Interacting effects of high light and elevated CO_2 on the nutraceutical quality of two differently pigmented *Lactuca sativa* cultivars (Blonde of Paris Batavia and Oak Leaf). *Sci Hort* **191**: 38-48.

Ranganna S 1986. *Manual of Analysis of Fruit and Vegetable Products.* Tata McGraw-Hill publisher, New Delhi, 194 p.

Resh H M 1985. *Hydroponic food production.* Woodbridge press publishing company. Santa Barbara. California, pp 21-161.

Saure MC 2001. Blossom-end rot of tomato (*Lycopersicon esculentum* Mill.) a calcium or a stress-related disorder. *Sci Hort* **90**: 193–208.

Shannon L M, Kay E and Lew J Y 1966. Peroxidase isozymes from horse radish roots: Isolation and physical properties. *J Biol Chem* **241**: 2166-72.

Sung J, Lee S, Lee Y, Ha S, Song B, Kim T, Waters B N and Krishnan H B 2015. Metabolomic profiling from leaves and roots of tomato (*Solanum lycopersicum* L.) plants grown under nitrogen, phosphorus or potassium-deficient condition. *Plant Sci* **241**:55-64.

Urbanczyk-Wochniak E and Fernie A R 2005. Metabolic profiling reveals altered nitrogen nutrient regimes have diverse effects on the metabolism of hydroponically-grown tomato (*Solanum lycopersicum*) plants. *J Exp Bot* **56**:309-21.

Wang Y T, Huang S W, Liu R L and Jin J Y 2007. Effects of nitrogen application on flavour compounds of cherry tomato fruits. *J Plant Nutr Soil Sci* **170**: 461-68.

Winterborne J 2005. *Hydroponics: Indoor Horticulture.* Pukka Press. Guildford, pp 39-48.

Wuzhong N 2002. Yield and quality of fruits as of solanaceous crops as affected by potassium fertilization. *Better Crops* **16**: 6-9.

Zekri M and Obreza T A 2003. *Plant nutrients for citrus trees*. University of Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, EDIS, pp. 1-2.

Zhang X, Yu H J, Zhang X M, Yang X Y, Zhao W C, Li Q, and Jiang W J 2016. Effect of nitrogen deficiency on ascorbic acid biosynthesis and recycling pathway in cucumber seedlings. *Plant Physiol Biochem* **108**: 222-30.