Annals of Agricultural Sciences 62 (2017) 139–143

HOSTED BY

Contents lists available at ScienceDirect

Annals of Agricultural Sciences

journal homepage: www.elsevier.com/locate/aoas

Morphological and physico-biochemical characterization of various tomato cultivars in a simplified soilless media

Mahboob Ahmad Khan[a], Shahid Javed Butt[b], Khurshied Ahmed khan[e], Faisal Nadeem[f], Balal Yousaf[d], Hafiz Umer Javed[c,*]

[a] Grower Hydroponic, Saudi Advance Agriculture Company, Riyadh, Saudi Arabia
[b] Director Academics, University of Management and Technology, Sialkot Campus, Sialkot, Pakistan
[c] Center for Viticulture and Enology, College of Food Science and Nutritional Engineering, China Agricultural University, Beijing 100083, China
[d] CAS-Key Laboratory of Crust-Mantle Materials and the Environment, School of Earth and Space Science, University of Science and Technology of China, Hefei 230026, China
[e] Key Lab of Agricultural Engineering in Structure and Environment, Ministry of Agriculture, College of Water Conservancy and Civil Engineering, China Agricultural University, Beijing 100083, China
[f] Department of Plant Nutrition, College of Resources and Environmental Sciences, China Agricultural University, Beijing 100083, China

ARTICLE INFO

Keywords:
Tomato varietal response
Morphological attributes
Physico-biochemical characteristics
Hydroponic system

ABSTRACT

This study aimed to investigate nine commercial cultivars of tomato, in order to identify the most suitable cultivar in terms of morphological (plant height, fruit size, fruit weight and total yield) and physico-biochemical (color, firmness, total soluble solid, titratable acidity, ascorbic acid, total sugar, reducing and non-reducing sugar, β-carotene and lycopene) attributes. Plants were cultured hydroponically in the greenhouse. Results revealed that the morphological attributes of Beefsteak Group (BG) of tomatoes was significantly better than that of Cherry Group (CG). In addition, CG has higher concentration of biochemical attributes, mainly β-carotene, sugars, total soluble solids (TSS) and ascorbic acid contents. Within CG, cv. Aria was found to be the best for higher sugar contents, β-carotene and ascorbic acid contents; while, TSS was higher in the cv. Claree. Similarly in BG, cv. Sahel had the highest value of lycopene, β-carotene, TSS; whereas, lowest sugar contents were found in cv. Dirk. As far as firmness is concerned, cv. Naram (BG) was found to be more firm, than cv. Aria (CG). The highest total yield was recorded for cv. Vernal; in BG and in cv. Claree for CG, depicting that BG had significantly higher total yield, compared with CG.

Introduction

Tomato (*Solanum lycopersicon* L.) is one of the most consumed vegetables, not only in Pakistan but also in the world, and having a unique aspect of diet. Its fruit is widely used in vegetable mixes, salads, processed goods and as an integrative part of cuisines. The processed tomatoes are available as tomato ketchup, pastes, sauces and purees. The popularity of the tomato is obvious from the fact that it is rich in phosphorus, calcium, carbohydrates, and vitamin A and C (Taylor, 1986). The diversity and standardized classification evaluation system is based on several morphological attributes (fruit weight, fruit shape and color) (Paran and Van Der Knaap, 2007), physico-chemical and sensory quality (taste, flavor) (Georgelis et al., 2004), nutritional values (Di-Mascio et al., 1989), content of vitamin C, texture, hardness, pH and acidity (Madhavi and Salunkhe, 1998).

In tomato industry, the overall production has increased due to its high demand among the consumers (Tahir et al., 2012). All over the world, the rise of the fast food industry is also having a significant impact on the demand for tomato products. It is expected, that this trend will continue in the near future and the consumption of tomato is expected to increase further (AVRDC, 1996). In the recent years, a significant increase in area and production of the tomato crop has been reported in Pakistan. In the year of 2010–11, the area was increased to 52,300 hectares and production was about 529.6 thousand tons (GOP, 2015).

The production of horticultural crops is extremely difficult in summer season due to a higher rate of infestation by pathogenic organisms. The cultivated tomato varieties in Pakistan are highly susceptible to hot climatic conditions. Moreover, due to seasonal variations (particularly in the start of summer), their production and supply

Peer review under responsibility of Faculty of Agriculture, Ain-Shams University.
* Corresponding author.
E-mail address: qaziumerjaved@cau.edu.cn (H.U. Javed).

https://doi.org/10.1016/j.aoas.2017.10.001
Received 12 October 2016; Received in revised form 25 October 2017; Accepted 29 October 2017
Available online 24 November 2017

remains far less than demand. The high temperature (above 32 °C) has adverse effects on flower formation, fruit setting, vegetative growth, development and subsequent yield (Moore and Thomas, 1952; Berry and Rafique-Ud-Din, 1988). In Pakistan, the tomato is marketed mostly during the end of winter and fruit production gradually decreases with increasing temperature. Therefore, the shortfall in demand supply chain occurs during the summer season (Hussain et al., 2001; Singh et al., 2007). Commercial scale production of tomato and other solanaceous vegetables is significantly hindered by attacks of soil-borne diseases and sudden temperature fluctuation under the open field conditions. To cope with these challenges, the hydroponic technique is considered a promising tool for commercial vegetable productions (Mavromatis et al., 2013). However, utilization capacity of the soilless system in Pakistan has not yet expanded on a commercial scale due to higher capital investment. The hydroponic culture of tomato and other susceptible vegetable crops can facilitate their successful and profitable production. Therefore, a precise detection and management of biotic and abiotic stresses should be taking into consideration for immense production.

Hydroponics is the most intensive method for crop production in the agricultural industry (Jensen, 1991). It is highly productive, as it conserves water and land, and protects the environment. Hydroponics provides optimal conditions for plant growth compared to open field production. Therefore, higher yields can be obtained through it. It also offers a means of controlling pest and soil-borne diseases, which are especially desirable in the tropics, where the life cycle and infestation of these organisms continues in un-interrupted ways (Jensen, 1991). This enables the plants to achieve higher growth of the shoot system with more vegetation, larger fruits, flowers and other edible parts. Plants in hydroponics grow up to two times faster with higher yields than with conventional soil farming methods due to higher oxygen levels around the root system, optimum pH along with increased nutrient and water uptake (Ghazvini et al., 2006).

Keeping in view the importance of tomato, it was imperative to carry out an experiment on different varieties of tomatoes (*Solanum lycopersicon*) under greenhouse conditions by using hydroponics in Pakistan. The research evaluation was based on morphological, qualitative and analytical parameters, which are imperative for the development of rapid screening techniques and proper selection method of different tomato varieties. Therefore, the objective of this study was to explore the best variety under a hydroponic system and to evaluate its performance in terms of growth/yield and fruit quality.

Materials and methods

The experimental study was carried out at Farmers Market Private Limited owned by PMAS-Arid Agriculture University of Rawalpindi, during 2012–2013. The nine tomato cultivars of two major groups, Beefsteak (cvs. Grandy, Naram, Dirk, Sahel and Vernal) and Cherry (cvs. Cheramy, Aria, Nactar and Claree) were selected, and their seeds were purchased from “EnzaZaden and Rijkzwaan” Holland. These seeds were germinated in sowing trays (240 cell/holes filled with rockwool) and kept in an automatically controlled biological condition. Hydroponic sowing media consisted of rockwool plug and vermiculite. The seedlings were ready within a month and transplanted to another hydroponic growing media, referred to as coir (coconut fiber 100 × 20 × 7 cm/four plants/slabs). All of the tomato cultivars were kept under identicalclimatic conditions (25–30 °C, humidity 65–80%, high air circulation and level of carbon dioxide 1300 ppm) controlled through a computer (computational data), in the automated greenhouse.

Morphological parameters

Morphological parameters, such as plant height (cm), fruit diameter (cm), fruit weight (g) and total yield (g/plant) were recorded according to Shah et al. (2011).

Physico-biochemical parameters

The physico-biochemical analyses of nine different cultivars of tomatoes were performed after harvesting.

Firmness

The trait fruit firmness was checked by Penetrometer (FT-327). The tomato pulp was gently removed and placed over the plunger tip. The values were taken in kgf.

Total soluble solids (TSS)

TSS of selected cultivars were determined by Atago RX 500 digital refractometer (Barrett et al., 1998). The drop of tomato juice was placed on the prism of the refractometer and then the reading was recorded in °Brix (AOAC, 1990).

Titratable acidity (TA)

Acidity was determined by titrating 10 g of a homogenized sample of tomato juice, after dilution with 50 mL distilled water, 0.1% NaOH solution at a pH of 8.17 (Thakur et al., 1996), and the result was reported as g/L.

Ascorbic acid (AA)

Ascorbic acid concentration for selected tomatoes was measured following the method of Tareen et al. (2012). The procedure involved making a homogenized mixture of fruit pulp (5 g), 5 mL of 0.1% HCl (w/v) and then the mixture was centrifuged for 10 min at 10,000 rpm and the supernatant was collected. Then the absorbance of the supernatant solution was measured by a spectrophotometer (SP 3000 plus) at 243 nm.

Total sugar contents

Estimation of total sugar contents was calculated by following the method of (Hortwitz, 1960). An aliquot of 25 mL was prepared for reducing sugars into a flask. 20 mL of distilled water and 5 mL of HCl was poured into it to convert the non-reducing sugars into reducing sugars. This reaction mixture was kept at room temperature for overnight so that complete hydrolysis could take place. Then, 1 N NaOH was poured into the reaction mixture to neutralize the solution using phenolphthalein as an indicator. Titration was performed against Fehling's solution by slow boiling up to brick red color appearance then, again few drops of methyl blue were added. This titration method was repeated until the appearance of brick red color. The values of sugars were taken by the giving formula:

$$\text{Total Sugar (\%)} = 25 \times (X/Y)$$

where:

x = mL of standard sugar solution used against 10 mL Fehling’s solution.

Y = mL of sample aliquot used against 10 mL Fehling’s solution.

Analytical parameters

Lycopene & β-carotene

The lycopene and β-carotene (mg/100 mL) were evaluated in hydroponically grown tomatoes (Nagata and Yamashita, 1992). One gram of tomato sample was taken in a test tube; poured acetone: hexane (4:6) in the test tube and then the mixture was homogenized. The optical density of the homogenized mixture was measured at 663, 645, 505 and 453 nm. The values of lycopene and β-carotene were calculated by following formula:

$$\text{Lycopene(mg/100mL)} = -0.0458A_{663} + 0.204A_{645} + 0.372A_{505} - 0.0806A_{453}$$

$$\beta\text{-carotene(mg/100mL)} = 0.216A_{663} - 1.22A_{645} - 0.304A_{505} + 0.452A_{453}$$

where: A is the absorbance at 663, 645, 505 and 453 nm.

Color index

The color measurements of the nine tomato cultivars were performed at 10 points around the equatorial region on the tomato surface by Arias et al. (2000), using a Minolta CR-200 Chroma meter (Minolta Camera Co., Osaka, Japan).

Statistical analysis

The experiment was carried out in a Randomized Complete Block Design (RCBD). The data were statically analyzed and subjected to Software Statistix 8.1. Analysis of variance was applied at the level of significance $P \leq 0.05$, which was used to compare the differences among the collected data.

Results and discussion

Morphological attributes

The description of tomato fruits (color, shape, diameter, weight and yield potential) and plant growth of the cultivars Beefsteak & Cherry is shown in Table 1. In general, all tomato cultivars are indeterminate in growth habit, they attain an optimum height and then terminal bud of the primary shoot is transformed into a cluster. These cultivars were specially grown in hydroponic systems without any physiological disorders. Data analysis regarding plant height of Beefsteak (cvs. Dirk, Grandy, Naram, Vernal, and Sahel) and Cherry (cvs. Nactar, Cheramy, Aria, and Claree) tomatoes indicated a significant difference at $P \leq 0.05$. Significantly higher plant height was recorded in Cherry cv. Claree (193.24 cm) and Beefsteak cv. Naram (182.70 cm) while Cherry cv. Cheramy (151.81 cm) and Beefsteak cv. Dirk (144.39 cm) were shorter. These results did not coincide with the findings of Kaushik et al. (2011), who reported that the average plant height of indeterminate variety was 9–12 cm. Plant height varies with the genotype and also depends on the recipe that is given in hydroponic production (Shah et al., 2011). The plant height of cv. Vernal was significantly shorter as compared to other, but their yield was higher. Mehta and Asati (2008) reported the plant height is an important factor and because they have the highest positive effect on fruit yield.

Regarding fruit size and fruit weight, the data showed a statistically significant difference in both groups (Beefsteak & Cherry) of cultivars (Table 1). The fruit size and fruit weight of the Beefsteak group were significantly greater to the Cherry group. Among the Beefsteak cv. Vernal had significantly more fruit size (7.30 cm) and fruit weight (195.33 g) as compared to other cultivars. In the case of the Cherry cultivar, the fruit size and fruit weight remained non-significant. These findings were similar regarding the range of fruit size from 5 to 7 cm (Mavromatis et al., 2013), and range of fruit weight from 91 to 200 g (Shah et al., 2011). We observed that the fruit size plays an important role to increase the yield. The fruit size and fruit weight of the Beefsteak cultivars were greater than the Cherry, which showed the direct relationship regarding the yield. 'Vernal' showed a significantly more yield among the Beefsteak and Cherry cultivars. The plant yield depends on the weight and number of fruit. Therefore, the fruit weight was directly proportional to the yield of a plant (Dar and Sharma, 2011).

Physico-biochemical properties

The obtained results exhibited significant differences regarding firmness between cultivars and it ranged from 3.01 to 4.83 kgf (Table 2). Beefsteak cv. Naram (4.83 kgf) was significantly more firm as compared to other Beefsteak and Cherry cultivars, while more softness was observed in the Cherry cv. Arial (3.01 kgf), but it was not significantly softer than cv. Claree, Nactar and Sahel. However, these values were higher than the ones reported by Arias et al. (2000) for fresh consumption tomatoes grown under the hydroponic system (ca. 2 kgf). The difference could be attributed to the higher solids and pectin contents in processing tomatoes.

Data about total soluble solids of the Beefsteak and Cherry tomato cultivars were significantly different among all genotypes. Data presented in Table 2 illustrated the similar trend of TSS among Cherry cultivar, but it was significantly higher than the group of Beefsteak tomatoes. In comparison between Beefsteak and the Cherry tomato comparatively higher total soluble solid was found in cv. Aria (Cherry; 7.58) while the minimum in cv. Grandy (Beefsteak; 2.88). Mavromatis et al. (2013) reported that the values of the total soluble solid of different varieties fall in the range 2–4%, but the concentrations of total soluble solid (salts, sugar, proteins) vary with the variety and ripening stages due to the breakdown of polysaccharides (Dumville and Fry, 2003).

Titratable acidity was statically analyzed ($P \leq 0.05$) and it showed significant variation among the nine cultivars of tomato and its values ranged from 2.45 and 3.97 g/L. These results are consistent with the data reported by Romero-Rodriguez et al. (1994), within the range of 2.9–4.4 g/L. Significantly more concentration of TA was calculated in Cherry cv. Cheramy (3.97 g/L) which was similar to cv. Nactar (3.95 g/L) and Beefsteak cv. Grandy (3.65 g/L).

Ascorbic acid plays an important role in the human diet because it cures the chronic disease, stress and scurvy. Ascorbic Acid of Beefsteak and Cherry tomatoes showed significant differences at $P \leq 0.05$ with a range of 15.48–23.24 mg/100 g (Table 2). These values were supported to the outcome of Mavromatis et al. (2013) and Chattopadhyay et al. (2013). Data presented in Table 2 illustrated that the maximum AA concentration was found in the Cherry cv. Claree (23.24 mg/100 g) followed by cv. Aria (21.92 mg/100 g), Nactar (20.93 mg/100 g), Cheramy (20.56 mg/100 g) and the minimum in Beefsteak cv. Dirk (15.48 mg/100 g). The overall comparison between Cherry and Beefsteak, maximum AA concentration was recorded in cv. Claree (Cherry) and the minimum in cv. Dirk (Beefsteak). A possible reason for the differences obtained in AA content for the same variety can be

Table 1
Varietal description and morphological attributes of tomato varieties grown under hydroponic system.

Variety	Fruit shape	Fruit color	Plant height at 90 days (cm)	Fruit diameter (cm)	Fruit weight (g)	No. of fruits/plant	Total yield (g/plant)
Dirk	Round	Red	144.39 ± 6.75c	5.78 ± 0.35d	126.33 ± 2.54b	127.63 ± 4.24 fg	16131 ± 275c
Grandy	Round	Red	172.84 ± 5.82b	6.02 ± 0.25 cd	132.17 ± 4.25b	136.62 ± 7.65f	18292 ± 180bc
Naram	Round	Red	182.70 ± 8.79ab	6.39 ± 0.43bc	127.50 ± 2.57b	150.50 ± 5.25e	19199 ± 195b
Vernal	Oval	Red	137.47 ± 5.65 cd	7.30 ± 0.21a	195.33 ± 2.88a	118.25 ± 4.86 g	23092 ± 350a
Sahel	Oval	Red	168.38 ± 8.61c	6.63 ± 0.25b	136.50 ± 5.35b	124.93 ± 5.55 g	17052 ± 195bc
Nactar	Round	Red	185.93 ± 9.73ab	2.61 ± 0.18e	13.17 ± 1.25c	369.27 ± 9.24b	4857 ± 79de
Cheramy	Round	Red	151.81 ± 5.88c	2.82 ± 0.27e	11.33 ± 1.15c	338.33 ± 8.50c	3837 ± 115de
Aria	Oval	Yellow	115.45 ± 6.53d	2.52 ± 0.51e	10.33 ± 0.85c	284.83 ± 7.35d	2943 ± 124e
Claree	Round	Red	193.24 ± 9.15a	2.88 ± 0.36e	13.33 ± 1.23c	417.83 ± 9.87a	5569 ± 135d

n = 3; different letter indicate significance difference at $P \leq .05$.

Table 2
Physico-biochemical parameter of tomato varieties grown under hydroponic system.

Variety	Firmness (kgf)	TSS (Brix)	TA (g/L)	Vitamin C (mg/100 g)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
Dirk	4.28 ± 0.25 abc	3.57 ± 0.18 bcd	2.45 ± 0.15 d	15.48 ± 0.42 d	3.75 ± 0.11 c	0.75 ± 0.01 de	2.60 ± 0.12 d
Grandy	4.42 ± 0.19 abc	2.88 ± 0.10 d	3.65 ± 0.19 ab	18.38 ± 0.28 c	3.82 ± 0.09 c	0.82 ± 0.02 de	3.00 ± 0.09 d
Naram	4.83 ± 0.27 a	4.07 ± 0.35 bc	2.42 ± 0.13 d	17.81 ± 0.35 c	3.49 ± 0.15 c	0.66 ± 0.02 e	2.67 ± 0.08 d
Vernal	4.64 ± 0.35 ab	3.07 ± 0.26 cd	3.15 ± 0.11 c	17.47 ± 0.75 cd	3.30 ± 0.08 c	0.70 ± 0.03 de	2.30 ± 0.12 d
Sahel	3.40 ± 0.18 abcd	4.18 ± 0.51 b	2.63 ± 0.14 d	18.40 ± 0.55 c	3.74 ± 0.09 c	0.90 ± 0.05 cd	3.01 ± 0.09 d
Nactar	3.60 ± 0.21 bcd	6.62 ± 0.49 a	3.95 ± 0.13 ab	20.93 ± 0.82 ab	5.91 ± 0.13 b	1.61 ± 0.04 b	4.11 ± 0.24 bc
Cheramy	4.67 ± 0.38 ab	6.97 ± 0.55 a	3.97 ± 0.21 a	20.56 ± 0.38 ab	6.67 ± 0.18 ab	1.82 ± 0.10 ab	4.85 ± 0.18 b
Aria	3.01 ± 0.26 d	7.58 ± 0.63 a	3.60 ± 0.19 b	21.92 ± 0.52 b	7.73 ± 0.26 a	1.89 ± 0.09 a	5.86 ± 0.22 a
Claree	3.38 ± 0.35 cd	6.67 ± 0.39 a	2.52 ± 0.09 d	23.24 ± 0.75 a	4.43 ± 0.15 c	1.11 ± 0.09 c	3.32 ± 0.17 d

n = 3; different letter indicate significance difference at $P \leq .05$.
TSS: Total soluble solids.
TA: Titratable acidity.

explained for the incidence of light in tomato at the end of harvest, temperature conditions during pre-harvest, harvest time and post-harvest (Somers et al., 1951). The level of AA is higher at the time of maturity and then went down (Subbiah and Perumal, 1990).

The biochemical parameter (total sugar, reducing and non-reducing sugar) of the Beefsteak and the Cherry tomatoes revealed significant differences among all cultivars. 'Aria' of the Cherry group showed the significantly higher amount of total sugar (7.73%), reducing (1.86%) and non-reducing sugar (5.86%). The cultivars including Beefsteak group were shown the statistically lower concentration of total sugar, reducing and non-reducing sugar than that of the Cherry group (Table 2).

The indexes are used to evaluate the quality of the fruits and it showed relatively significant variation among the cultivar. The parameters of interest are L^*; which positive values indicate more lightness while negative readings signify darkness and its value varying from 41.67–47.97 in Beefsteak Group and 50.62–89.54 in Cherry Group. 'Aria' was one of the darkest in color as compared to other varieties. In the case of a^* which indicates the tomato redness and their values range 31.74–33.06 among in the Beefsteak Group and 12.84–55.91 in the Cherry Group. Result relating to b^* showed the yellowness and its value varies from 26.58–29.1 in the Beefsteak Group and 84.21–132.03 among the Cherry Group. The color indexes (darkness, redness and yellowness) were statistically similar in the Beefsteak cvs. Dirk, Grandy, Naram, Vernal and Sahel but lower than the Cherry group (Fig. 1). Significantly more darkness and yellowness were seen in cv. Aria while redness observed in cv. Claree.

Regarding lycopene content, the significant differences were observed among all tomato cultivars, and the Beefsteak group had

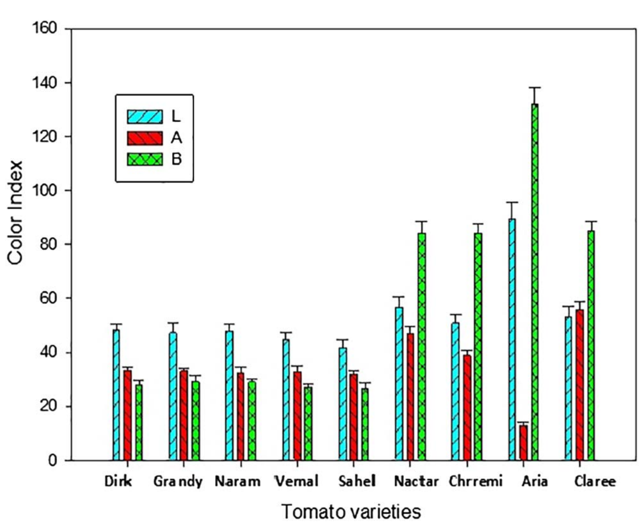

Fig. 1. Color index of nine tomato varieties grown under the hydroponic system.

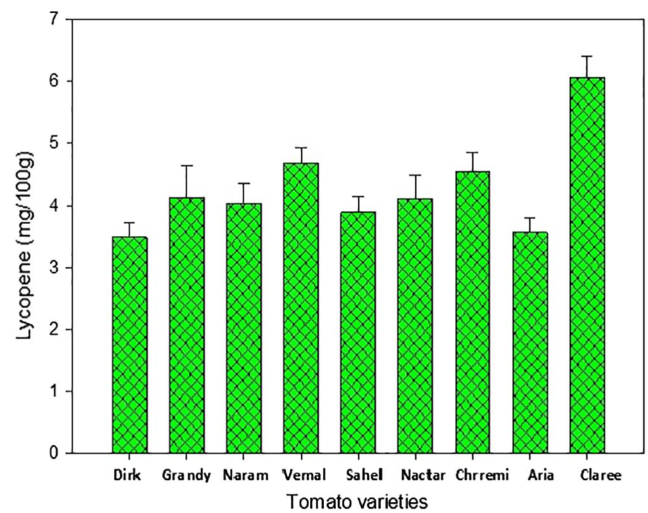

Fig. 2. Lycopene content of nine tomato varieties grown under the hydroponic system.

significantly more lycopene content (Fig. 2). The quantity of lycopene was significantly higher in the Cherry cv. Claree (6.06 mg/100 g) followed by Vernal (4.68 mg/100 g), Cheramy (4.54 mg/100 g), Grandy (4.12 mg/100 g), Nactar (4.11 mg/100 g), Naram (4.02 mg/100 g), Sahel (3.89 mg/100 g), Dirk (3.48 mg/100 g) and Aria (295 mg/100 g). The lycopene (mg/100 g) values were recorded from nine cultivars of Beefsteak and Cherry, which advocated already measured values range from 1.25 to 4.91 mg/100 g. The lycopene content showed red colored tomato (Baranska et al., 2006; Chattopadhyay et al., 2013; Hyman et al., 2004), and the degree of redness is directly proportional to the concentration of lycopene, while orange or yellow color shows less concentration of lycopene and it is inhibited on lower temperature < 12 °C while its production is prohibited > 32 °C (Cox et al., 2003).

Regarding β-carotene in Beefsteak and the Cherry cultivars, they revealed significant differences among all cultivars at the level of significance ($P \leq 0.05$). Except for cv. Nactar, the cultivars of Cherry group had a higher content of β-carotene as compared to the Beefsteak. Data presented in Fig. 3 demonstrated, the β-carotene contents significantly higher in cv. Aria (6.71 mg/100 g) than that of cv. Cheramy (4.68 mg/100 g), Vernal (4.00 mg/100 g), Sahel (3.84 mg/100 g), Claree (3.55 mg/100 g), Naram (3.47 mg/100 g), Nactar (2.96 mg/100 g), Grandy (2.87 mg/100 g) and minimum in Dirk (2.74 mg/100 g). The results are in the range of the findings of Baranska et al. (2006); Chattopadhyay et al. (2013); Hyman et al. (2004) recorded 0.23–4.00 mg/100 g of β-carotene in tomatoes. 'Aria' is yellow color variety, so it's yellow color due to the higher content of β-carotene (Dewanto et al., 2002). The β-carotene was degraded when fresh tomatoes are exposed to a higher temperature (88 °C) and after processing its concentration was decreased.

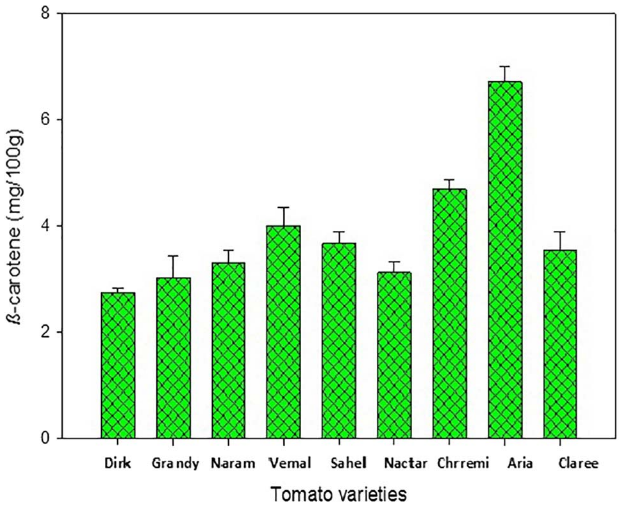

Fig. 3. β-carotene contents of nine tomato varieties grown under the hydroponic system.

Conclusion

The qualities of fruits with higher production are an important factor for both producers and consumers. The ultimate goal of this study to evaluating the best performing tomato cultivars in terms of growth/yield, fruit quality and physico-biochemical characteristics. The overall conclusion of this work is that the morphological attributes of Beefsteak tomato cultivars was significantly better than Cherry tomato. Regarding biochemical attributes, the CG has significantly higher concentration with respect to BG tomatoes. In the case of the Beefsteak cultivar, the performance of cv. Nactar regarding growth parameter (plant height, fruit size, fruit weight and yield) and cv. Sehal in term of biochemical attributes were significantly higher than other cultivars. Within Cherry group, cvs. Vernal and Aria showed better quality in growth and biochemical analysis respectively. Among 9 cultivars, Vernal had significantly higher yield production, fruit size and yield while cv. Aria in TSS, TA, ascorbic acid, total sugar, reducing and a non-reducing sugar, color index and β-carotene but the lycopene content was lower because cv. Aria is yellow color variety.

References

AOAC, 1990. Official methods of analysis. Association of analytical chemists, 15th ed. Virginia, Arlington, USA.

Arias, R., Lee, T.C., Specca, D., Janes, H., 2000. Quality comparison of hydroponic tomatoes (*Lycopersicon esculentum*) ripened on and off vine. J. Food Sci. 65, 545–548.

AVRDC, 1996. Vegetable research networking in South Asia: Savernet Phase I final report; Asian Vegetable Research and Development Center (AVRDC). Shanhua, Tainan, Taiwan 741, ROC. p.76.

Baranska, M., Schütze, W., Schulz, H., 2006. Determination of lycopene and β-carotene content in tomato fruits and related products: Comparison of FT-raman, ATR-IR, and NIR spectroscopy. Anal. Chem. 78, 8456–8461.

Barrett, D.M., Garcia, E., Wayne, J.E., 1998. Textural modification of processing tomatoes. Crit. Rev. Food Sci. Nutr. 38, 173–258.

Berry, S., Rafique-Ud-Din, M., 1988. Effect of high temperature on fruit set in tomato cultivars and selected germplasm. Hort. Sci. 23, 606–608.

Chattopadhyay, A., Chakraborty, I., Siddique, W., 2013. Characterization of determinate tomato hybrids: Search for better processing qualities. J. Food Process. Technol. 4, 1–6.

Cox, S.E., Stushnoff, C., Sampson, D.A., 2003. Relationship of fruit color and light exposure to lycopene content and antioxidant properties of tomato. Can. J. Plant Sci. 83, 913–919.

Dar, R.A., Sharma, J.P., 2011. Genetic variability studies of yield and quality traits in tomato (*Solanum Lycopersicum* L.). Int. J. Plant Breed. Genet. 5, 168–174.

Dewanto, V., Xianzhong, W., Adom, K.K., Liu, R.H., 2002. Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. J. Agric. Food Chem. 50, 3010–3014.

Di-Mascio, P., Kaiser, S., Sies, H., 1989. Lycopene as the most efficient biological carotenoid singlet oxygen quencher. Arch. Biochem. Biophys. 274, 532–538.

Dumville, J.C., Fry, S.C., 2003. Solubilisation of tomato fruit pectins by ascorbate: a possible non-enzymic mechanism of fruit softening. Planta 217, 951–961.

Georgelis, N., Scott, J.W., Baldwin, E.A., 2004. Relationship of tomato fruit sugar concentration with physical and chemical traits and linkage of RAPD markers. J. Am. Soc. Hortic. Sci. 129, 839–845.

Ghazvini, R.F., Payvast, G., Azarian, H., 2006. Effect of clinoptilolitic-zeolite and perlite mixtures on the yield and quality of strawberry in soil-less culture. J. Agric. Soc. Sci. 2, 51–53.

GOP, 2015. Agricultural Statistics of Pakistan 2010–11. Economic Wing, Ministry of Food Agriculture and Livestock, Islamabad.

Hortwitz, W., 1960. Official and tentative methods of analysis: Association of the Official Agriculture Chemist. Washington, D.C.

Hussain, S.I., Khokhar, K.M., Mahmood, T.M., M., M.H.L., Mahmud, M.M., 2001. Yield potential of some exotic and local tomato cultivars grown for summer production. Pakistan J. Biol. Sci. 4, 1215–1216.

Hyman, J.R., Gaus, J., Foolad, M.R., 2004. A rapid and accurate method for estimating tomato lycopene content by measuring chromaticity values of fruit purée. J. Am. Soc. Hortic. Sci. 129, 717–723.

Jensen, M.H., 1991. In: Hydroponic Culture for the Tropics: Opportunities and Alternatives. Depart. of Plant Sciences, University of Arizona Tucson, Arizona, U.S.A, pp. 1–12.

Kaushik, S.K., Tomar, D.S., Dixit, A.K., 2011. Genetics of fruit yield and it's contributing characters in tomato (*Solanum lycopersicum*). J. Agric. Biotechnol. Sustain. Dev. 3, 209–213.

Madhavi, D., Salunkhe, D.K., 1998. Tomato. In: Salunkhe, D.K., Kadam, S.S. (Eds.), Handbook of Vegetable Science and Technology, Production, composition, storage and processing. Marcel Dekker, New York, U.S.A, pp. 171–201.

Mavromatis, A.G., Athanasouli, V., Vellios, E., Khah, E., Georgiadou, E.C., Pavli, O.I., Arvanitoyannis, I.S., 2013. Characterization of tomato landraces grown under organic conditions based on molecular marker analysis and determination of fruit quality parameters. J. Agric. Sci. 5, 239–252.

Mehta, N., Asati, B.S., 2008. Genetic relationship of growth and development traits with fruit yield in tomato (*Lycopersicon esculentum* Mill). Karnataka J. Agric. Sci. 21, 92–96.

Moore, E., Thomas, W., 1952. Some effects of shading and paracolorphenoxy acetic acid on fruitfulness of tomatoes. Am. Soc. Hort. Sci. Proc. 60, 289–294.

Nagata, M., Yamashita, I., 1992. Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruit. J. Japan. Soc. Food Sci. Technol. 39, 925–928.

Paran, I., Van Der Knaap, E., 2007. Genetic and molecular regulation of fruit and plant domestication traits in tomato and pepper. J. Exp. Bot. 58, 3841–3852.

Romero-Rodriguez, M.A., Vazquez-Oderiz, M.L., Lopez-Hernandez, J., Simal-Lozano, J., 1994. Composition of babaco, feijoa, passionfruit and tamarillo produced in Galicia (North-west Spain). Food Chem. 49, 23–27.

Shah, A.H., Munir, S.U., Noor-Ul-Amin, Shah, S.H., 2011. Evaluation of two nutrient solutions for growing tomatoes in a non-circulating hydroponics system. Sarhad J. Agric. 27, 557–567.

Singh, R.P., Prasad, P.V.V., Sunita, K., Giri, S.N., Reddy, K.R., 2007. Influence of high temperature and breeding for heat tolerance in cotton: A Review. Adv. Agron. 93, 313–385.

Somers, G.F., Kelly, W.C., Hamner, K.C., Somers, G.F., Kelly, W.C., Hamner, K.C., 1951. Influence of nitrate supply upon the ascorbic acid content of tomatoes. Am. J. Bot. 38, 472–475.

Subbiah, K., Perumal, R., 1990. Effect of calcium sources, concentration, stages and number of sprays on physicochemical properties of tomato fruits. South Indian Horti. 38, 20–27.

Tahir, A., Shah, H., Sharif, M., Akhtar, W., Akmal, N., 2012. An overview of tomato economy of Pakistan: comparative analysis. Pakistan J. Agric. Res. 25, 123–126.

Tareen, M.J., Abbasi, N.A., Hafiz, I.A., 2012. Effect of oxalic acid treatments on storage life of peach fruit Cv. " *Flordaking*". Pak. J. Bot. 44, 207–310.

Taylor, I.B., 1986. Biosystematics of the tomato. In: Atherton, J., Rudich, J. (Eds.), The Tomato Crop. Chapman and Hall Ltd, New York, pp. 7–10.

Thakur, B.R., Singh, R.K., Nelson, P.E., 1996. Quality attributes of processed tomato products: A review. Food Rev. Int. 12, 375–401.