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The Simultaneous Effect of Water Supply and Genotype on Yield Quantity, Antioxidants Content and Composition of Processing Tomatoes

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Abstract

An open field experiment was carried out two years, in order to study the simultaneous effect of water supply and examined varieties on the yield parameters (marketable yield, °Brix and °Brix yield) and main antioxidant components (carotenoids, mainly lycopene, phenolic compounds and tocopherols) in two different type of processing tomatoes. It was conducted in the Experimental Farms of the Institute of Horticulture at Szent István University, Gödöllő, Hungary. 'Brixsol' F_1 (normal average fruit weight) and 'Strombolino' F_1 (cherry type) varieties were used. Climatic conditions were significantly different in the two seasons. Increasing the water supply increased fruit yield but reduced antioxidants of individual fruits, by inducing more and larger fruits, and by its dilution effects. We have measured significantly higher carotenoids and polyphenols content by processing cherry type hybrid 'Strombolino' F_1. In general, we can state that irrigation decreased (most cases significantly) carotenoids, polyphenol and tocopherol concentrations in tomato fruits.

Keywords: carotenoid, polyphenol, processing tomato, tocophenol

Introduction

Phytonutrients (also referred to as phytochemicals) are certain natural components of plants. Vegetables (tomato, sweet pepper, eggplant, broccoli, carrot, onion, etc.) are rich sources of phytonutrients. WHO places low fruit and vegetable intake sixth on its list of 20 risk factors for mortality worldwide (WHO, 1990). The importance of tomato cultivation has been growing rapidly in the last decades in the world. Beside the fresh market tomatoes, the processing tomato has a great importance in the food industry, basically because of its health promoting features (Clinton *et al*., 1996). Bioactive composition of tomatoes is complex and very difficult to assess. Levels of plant metabolites are strongly affected by genetic and environmental factors as well as transportation and storage conditions (Hanson *et al*., 2004). The growth factors such as light, temperature, humidity, type of soil, application of fertilizers, damage caused by microorganisms and insects, stress induced by UV radiation, heavy metals, and pesticides all alter metabolite composition of plants (Orcutt and Nilsen, 2000; Helyes and Lugasi, 2006; Helyes *et al*., 2006; Pék *et al*., 2010).

There are several reports on the effect of irrigation on tomato yield, dry matter and fruit soluble solids content. Pernice *et al.* (2010) found, that tomatoes produced an average yield of almost 100 t ha^{-1}. Yield was greatly influenced by the water regime; when comparing no irrigation to the reduced irrigation condition a considerable increase was observed in average yield (+45.7%). Similarly Liu *et al.* (2011) reported that drip irrigation compared to nonirrigation, increased tomato fruit size by 32%. Others (Patanè and Cosentino, 2010) also reported this marked influence of irrigation on tomato fruit size. Liu *et al.* (2011) found that irrigation also increased marketable fruit yield by 127% and total fruit yield by 66%, while it decreased soluble solids content by 19% which was also reported by Favati *et al.* (2009). In summary the greatest effect of increasing soil water deficit is the rise in soluble solids, total solids and fruit firmness, and a decrease in fruit size and yield (Patanè and Cosentino, 2010).

More than 700 carotenoids have been isolated from different plant sources. Lycopene is the most important carotenoid in tomato fruit (Rao, 2006). Chlorophyll breaks down and carotenoids, mostly lycopene, accumulate during ripening (Biacs and Daood, 2000). García-Valverde *et al.* (2013) reported from 83.2 to 97.6 mg kg^{-1} fw. total lycopene and from 3.0 to 6.1 mg kg^{-1} fw. β-carotene in the fruits of five processing tomato cultivars. Liu *et al.* (2011) reported that lycopene content decreased by 8% in irrigated compared to nonirrigated conditions. While Riggi *et al.* (2008) found that in the well watered treatment higher amounts of lycopene were measured, regardless of the ripening stage. They also found that β-carotene content was positively affected by water stress. Particularly in the first 2 ripening stages β-carotene/lycopene ratio was also influenced by water stress and suggested that, the carotenoid biosynthetic pathway is more 'β-carotene accumulation' oriented under soil water deficit conditions. Favati *et al.* (2009) also found that compared to well irrigated the lycopene and β-carotene concentration was higher in less irrigated tomatoes.

The term phenolic antioxidant refers to both simple phenolic acids and flavonoids. Tomato fruits are also rich in polyphenols that amount to the largest part of the antioxidant capacity of the soluble phase (Inert *et al.*, 2009).

In the case of tomatoes, several studies point to high levels of vitamin E in the processed product (Abushita *et al.*, 2000; Seybold *et al.*, 2004). Tomatoes at the ripening stage contain α-tocopherol and γ-tocopherol at the average concentration of 3.5 and 1.2 g/g, respectively (Abushita *et al.*, 1997).

The aim of the present study was to evaluate the influence of genetic and environmental factors (temperature and water supply) on yield quantity and quality, especially on the content of carotenoids (lycopene and its isomers, β-carotene), phenolic compounds (flavonoids and phenolic acids and total phenolics) and tocopherols in a cherry tomato, compared with a normal fruit weight variety.

Materials and methods

Plant material

This experiment was conducted at the Experimental Farm of the Institute of Horticultural, Szent István University, in Gödöllő, Hungary. The experimental field is on brown forest soil, with mechanical composition of sand, sandy-clay and the subsoil water is below 5 m, therefore it cannot influence the water turnover. 'Brixsol' F_1 (normal average fruit weight) 'Strombolino' F_1 (cherry type) seeds were sown on the 2nd of April in 2010 and 7th of April in 2011 in greenhouse and transplanted on the 14th of May 2010 and 12th of May in 2011. The experimental design was randomized block, number of replications were four for each treatment. Tomato plants were arranged in double (twin) rows with a distance of 1.2 and 0.4 m between the rows and 0.3 m between the plants. Crop density was 4.2 plant/m^2. Regularly irrigated and control (with no irrigation) were the two different water supply treatments applied in the present work. The amount of irrigation supply was calculated from weather forecasting data of the Hungarian Meteorological Service (2011). The amount of daily irrigation demand was estimated from expected daily potential evapotranspiration according to a previous study (Helyes and Varga, 1994).

In drip irrigation the water was given in accordance with air temperature (daily irrigation water (mm) = average daily temperature×0.2). National Meteorological Institute forecasts were used to calculate the probable air temperature. It is important to note that precipitation of 2010 was very extreme, because the highest rainfall in the last hundred years was measured that year in Hungary. Water amounts of 558 and 410 mm in 2010 and 524 and 159 mm in 2011 were usable for plants in irrigation treatment and unirrigated control respectively during the vegetation period (Fig. 1). Fruits were measured at harvesting on the 6th of August in 2010 and 26th of July and 26th of August in 2011.

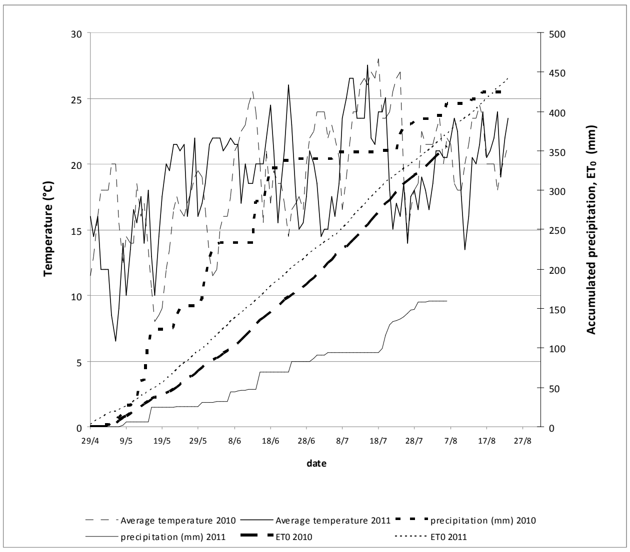

Fig. 1. Meteorological data during tomato vegetation period in 2010 and 2011

Measurement of environmental parameters

Changes of the environmental factors were monitored via measuring three parameters. During the experiment we defined the air temperature (°C), relative humidity (RH %) and incoming light intensity (μmol $m^{-2}s^{-1}$). Temperature, relative humidity and photosynthetically active radiation (not shown) were measured six times per hour using a SKYE DataHog micrometeorological instrument, placed at two meters height (Skye Instruments Ltd, Llandrindrod Wells, UK).

Analysis of quality components

Extraction of carotenoids, tocopherols. Lipids and fat-soluble pigments and tocopherols from raw tomato were extracted according to a previously described procedure with slight modification (Abushita *et al.*, 1997). Five-gram samples from tomato fruits were taken in triplicate (at least) and disintegrated in a crucible mortar in the presence of quartz sand. The water was removed by adding 25 mL of methanol with further disintegration of the aggregating bulk. The mixture was then transferred quantitatively to a 100 mL conical flask, and 70 mL of a 6:1 dichloroethane-methanol solution was added. The mixture was shaken for 15 min by a mechanical shaker. A few drops of distilled water were added when the dichloroethane phase was not clearly separated from the polar phase (water + methanol). A separatory funnel separated the two phases, and the lower layer containing lipids in dichloroethane was dried over anhydrous sodium sulfate. Finally, the organic solvent was evaporated under vacuum by rotary evaporator (IKA® RV

10, Sigma-Aldrich Ltd., Budapest, Hungary) at not higher than 40 °C. The residues were either redissolved in the HPLC eluent for analysis of carotenoids or saponified for analysis of tocopherols.

HPLC equipments and conditions. To analyse carotenoid and flavonoid type compounds, a Waters Alliance liquid chromatographic instrument consisting of a Model 2696 Separation Module (Gradient pump, autosampler and column heater) and a Model 2695 photodiode array detector was used. Operation and data processing were performed by Empower software.

The separation of carotenoids was performed on Cross-linked-C18 (240 _ 4.6 mm i.d.) 3μm ISIS column using gradients elution starting with 20% water in acetone and ending with 5% water in acetone with a flow rate of 0.7 mL/min according to Daood *et al.* (2013). The column effluents were detected at their maximum absorption wavelength lycopene, β-carotene and zeaxanthin were identified and quantified using standard materials purchased from Sigma-Aldrich Ltd. (Budapest, Hungary). Identification of other compounds was based on their retention time, spectral characteristics and mass spectrum data array). They were quantified as either lycopene- or β-carotene-equivalent according to their spectral characteristics (Fig. 2).

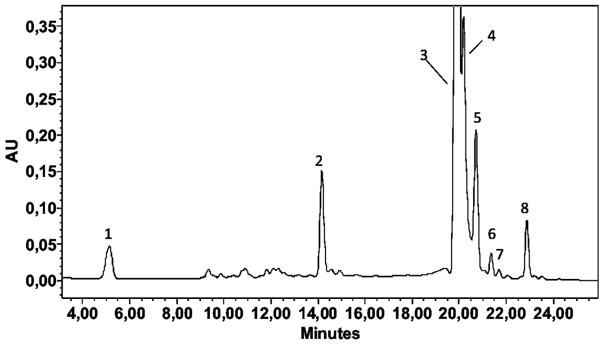

Fig. 2. HPLC profile of tomato carotenoids separated on cross-linked C18 column with gradient elution of water in acetone (for more details see text). Peak identification as: 1: zeaxanthin, 2: lycoxanthin, 3: lycopene, 4 and 5: cis-lycopene, 6: unidentified, 7 gamma-caotene, 8: beta-carotene

For tocopherol analysis, a combination of a Beckman 114M isocratic pump, a model RF-535 Shimadzu fluorometric detector, and a Waters-740 Data Module integrator was used. The separation was performed on Lichosorb 5μm (250 _ 4.6 mm i.d.) with a mobile phase consisting of 99.5:0.5 n-hexane-ethanol. The fluorometric detector was set at 295 and 320 nm as the excitation and emission wavelength, respectively (Abushita *et al.*, 1997) (Fig. 3).

The phenolic compounds were determined by RP-HPLC. Sample preparation and extraction: Tomato sample was homogenised by a warring blender, 10 g was weighed into an Erlenmeyer flask, 10 ml distilled water was added to the sample and placed in ultrasonic bath for 30 sec., 15 ml of 2% acetic acid in methanol was added to the mixture. Mechanical shaker shook the mixture for 15 minutes. The flask was kept at 4 °C for overnight. Next day, the filtrate

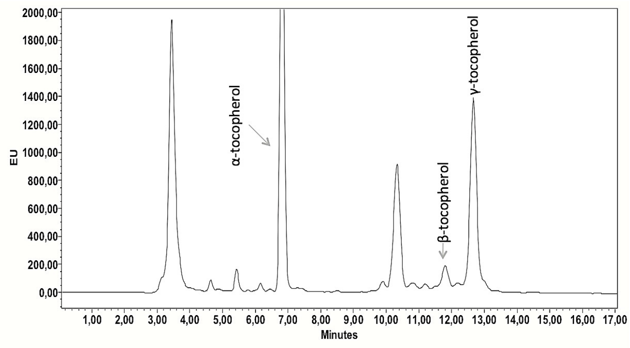

Fig. 3. Separation of tocopherol analogues from tomato by normal-phase HPLC using n-hexane-ethanol, 99.5:0.5, as the mobile phase and fluorescence detection (excitation 295 nm, emission 320 nm)

was cleaned further by passing through 0.45 μm HPLC syringe filter before injection onto HPLC column for analysis of phenolic compounds. The analytical column was EC NUCLEODUR Sphinx RP (Symetron Ltd. Budapest, Hungary), 3μm, 150 x 4.6. The mobile phase was [B] 1% formic acid in water, [C] acetonitril and a flow rate of 0.6 ml/min. Injected volume was 20 μl. Phenols having absorption maxima around 280 nm were quantified as gallic acid- equivalent, while flavonoids were quantified as rutin-equivalent at 320 nm and 355 nm. Peaks of phenol components were identified by comparing their spectral characteristics and retention with those of available standards (apigenin, caffeic acid glucoside, chlorogenic acid, sinapic acid glucoside, and ferulic acid; Sigma-Aldrich Ltd. Budapest, Hungary) (Pék *et al.*, 2013) (Fig. 4).

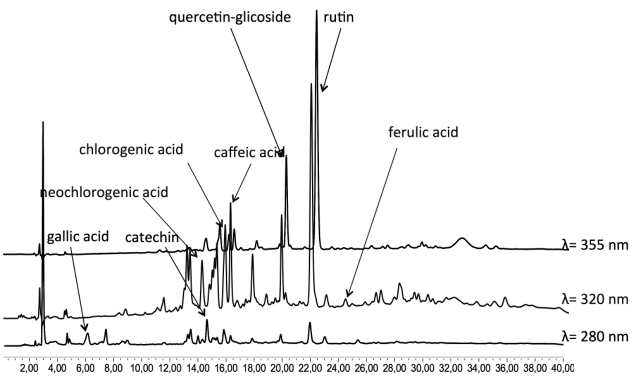

Fig. 4. HPLC profile of tomato phenols separated EC NUCLEODUR Sphinx RP with gradient elution of water in formic acid and acetonitril

Statistical analysis

The data were analysed by two-factor analysis of variance (ANOVA) with repetitions and the means separated using the Student's test at p=0.05.

Results and discussion

The effect of irrigation on tomato yield parameters depends on the actual weather conditions, basically the air temperature and precipitation (quantity and distribution).

Fig. 1 shows daily average temperature and precipitations during the vegetation period in these two years. It is also important to note that precipitation of 2010 was very extreme, because the highest rainfall in the last hundred years was measured that year in Hungary.

Average daily precipitation was almost three times more (4.1 mm) in 2010, than in 2011 (1.4 mm) during the crop season.

The two cultivars differ basically in average fruit weight, so normal processing type 'Brixsol' F1 produced higher yield than cherry type 'Strombolino' F1, but it was significant only in 2011. The irrigated plants gave significantly higher yield quantity in both years, while unirrigated plants showed yield loss particularly in 2011 (Tab. 1), which is in agreement with previous studies of processing tomatoes (Barbagallo *et al.*, 2013; Helyes *et al.*, 2012).

The effect of irrigation on processing tomato is complex; through the number of flowers and the percentage of fruit set it first increases the number of fruits per plant, and then enlarges the size of fruits (Wudiri and Henderson, 1985).

Better water supply caused lower °Brix, than control. The soluble solid content of fruits was often very high without irrigation. In spite of this, the level of Brix yield per hectare remarkably increased as a result of significantly higher yield quantity (Tab. 2). Greatest effect of increasing soil water deficit was the rise in fruit firmness, soluble solids and a decrease in fruit size and yield, which is in agreement with Patanè and Cosentino (2010).

In this study we evaluated total carotenoid, polyphenol and tocopherol contents and their composition depending on tested cultivars and water supplement in 2010 and 2011. During the two-year experiment, we found that the total carotenoid concentration of the tomato fruits ranged from 52.5 to 109.2 mg kg^{-1}. This is nearly a twofold difference. Cherry type tomatoes contain significantly higher lycopene concentration than large fruited cultivars (Helyes and Lugasi, 2006; Kuti and Konuru, 2005). StC gave the highest total carotenoid content (109.2 mg kg^{-1}) in July 2011, because of the cooler weather conditions (Dumas *et al.*, 2003) (Tab. 3). During the ten days preceding the 26th of July harvest, the average maximum temperature was 25.2 °C, the average minimum temperature was 14.5 °C and every day was a little rainy and cloudy. On the contrary, the ten days preceding the 26th of August harvest was much warmer. The average daily minimum temperature was 14.2 °C, the average maximum temperature was 29.3 °C and the maximum temperature reached or was above 30 °C five times. It is important to note that the average *cis*-lycopene ratio was significantly higher in case of 'Strombolino' F_1 in 2011, particularly in the second harvest (Tab. 3). Since irrigation also decreased lycopene concentration, thus to

Tab. 2. Soluble solid content (°Brix) and Brix yield (t ha^{-1}) of tomatoes under different water supply in 2010 and 2011 (n=4; ±SD)

Cultivars and treatments	2010		2011	
	°Brix	Brix yield	°Brix	Brix yield
BI	4.58 ± 0.12^{a}	1.80 ± 0.42^{a}	5.33 ± 0.17^{a}	5.44 ± 0.55^{c}
BC	5.03 ± 0.21^{a}	1.35 ± 0.16^{a}	7.25 ± 0.65^{bc}	3.54 ± 0.84^{b}
STI	5.44 ± 0.08^{b}	1.52 ± 0.15^{a}	6.63 ± 0.19^{b}	3.59 ± 0.62^{b}
STC	5.98 ± 0.12^{c}	1.44 ± 0.34^{a}	7.48 ± 0.49^{c}	1.97 ± 0.48^{a}

BI: 'Brixsol' irrigated, BC: 'Brixsol' control, StI: 'Strombolino' irrigated, StC: 'Strombolino' control.
Values are reported as the mean ± standard deviation. Means in a column with different letters are significantly different at p=0.05.

Tab. 1. Quantitative yield parameters (t ha^{-1}) of tomatoes under different water supply in 2010 and 2011 (n=4; ±SD)

Cultivars and treatments	2010			2011		
	Red yield	Green yield	Marketable yield	Red yield	Green yield	Marketable yield
BI	39.2 ± 8.1^{b}	10.2 ± 2.2^{b}	49.4 ± 5.1^{b}	102.1 ± 7.0^{c}	18.7 ± 3.4^{c}	120.8 ± 5.5^{c}
BC	26.8 ± 2.1^{a}	4.2 ± 0.6^{a}	31.0 ± 1.6^{a}	48.8 ± 7.2^{a}	14.4 ± 1.7^{b}	63.2 ± 3.8^{b}
StI	27.9 ± 7.1^{ab}	14.5 ± 3.9^{b}	42.4 ± 5.5^{b}	54.1 ± 7.8^{b}	5.6 ± 3.7^{a}	59.7 ± 5.7^{b}
StC	24.0 ± 1.6^{a}	6.0 ± 2.1^{a}	30.0 ± 1.8^{a}	26.4 ± 4.7^{a}	7.1 ± 2.8^{a}	33.5 ± 3.7^{a}

BI: 'Brixsol' irrigated, BC: 'Brixsol' control, StI: 'Strombolino' irrigated, StC: 'Strombolino' control.

Tab. 3. Carotenoid components (mg kg^{-1} FW) of tomatoes under different water supply in 2010 and 2011 (n=4; ±SD)

Harvesting date	Cultivars and treatments	Zeaxanthin	Lycoxanthin	Lycopene	9Z+13Z Lycopene	β-carotene	γ-carotene	Phytoene
06.8.2010	BI	0.33 ± 0.06^{c}	0.83 ± 0.09^{ab}	43.6 ± 3.12^{a}	3.40 ± 0.98^{a}	2.85 ± 0.25^{bc}	0.19 ± 0.03^{a}	1.27 ± 0.19^{a}
	BC	0.35 ± 0.04^{c}	0.52 ± 0.04^{a}	41.7 ± 4.10^{a}	6.81 ± 1.38^{b}	2.47 ± 0.34^{b}	0.23 ± 0.03^{ab}	1.72 ± 0.08^{a}
	StI	0.47 ± 0.07^{c}	1.05 ± 0.07^{ab}	48.3 ± 4.78^{a}	4.55 ± 0.74^{a}	3.63 ± 0.50^{c}	0.32 ± 0.04^{c}	2.02 ± 0.21^{b}
	StC	0.57 ± 0.01^{c}	1.49 ± 0.06^{b}	62.6 ± 2.77^{b}	2.98 ± 1.21^{a}	3.27 ± 0.17^{c}	0.28 ± 0.02^{c}	1.69 ± 0.13^{a}
26.7.2011	StI	0.28 ± 0.10^{b}	0.86 ± 0.20^{a}	73.5 ± 15.8^{bc}	8.30 ± 1.66^{bc}	2.77 ± 0.23^{b}	0.24 ± 0.01^{b}	1.61 ± 0.19^{a}
	StC	0.18 ± 0.03^{a}	1.55 ± 0.23^{b}	95.8 ± 10.2^{c}	7.51 ± 1.93^{b}	2.40 ± 0.31^{b}	0.21 ± 0.03^{a}	1.51 ± 0.07^{a}
26.8.2011	BI	0.21 ± 0.02^{a}	0.69 ± 0.15^{a}	39.3 ± 11.7^{a}	9.95 ± 0.57^{c}	1.16 ± 0.14^{a}	0.31 ± 0.01^{c}	1.95 ± 0.21^{ab}
	BC	0.37 ± 0.14^{bc}	1.32 ± 0.35^{b}	48.9 ± 6.4^{a}	15.11 ± 1.01^{e}	1.12 ± 0.11^{a}	0.29 ± 0.05^{c}	2.33 ± 0.50^{abc}
	StI	0.24 ± 0.01^{ab}	0.78 ± 0.28^{a}	57.3 ± 19.4^{ab}	13.60 ± 0.32^{d}	3.45 ± 0.26^{c}	0.25 ± 0.04^{ab}	2.76 ± 0.32^{c}
	StC	0.41 ± 0.07^{c}	1.53 ± 0.42^{b}	72.1 ± 24.5^{abc}	19.57 ± 1.85^{f}	3.70 ± 0.79^{c}	0.48 ± 0.11^{d}	2.55 ± 0.57^{bc}

BI: 'Brixsol' irrigated, BC: 'Brixsol' control, StI: 'Strombolino' irrigated, StC: 'Strombolino' control.
Values are reported as the mean ± standard deviation. Data in the same column bearing the same superscript letter are not significant at p=0.05.

improve fruit yield and lycopene concentration of tomatoes, Sánchez-Rodríguez *et al.* (2012) suggest moderate water stress. Irrigation probably indirectly affected lycopene concentration by inducing more and larger fruits, and thus had a dilution effect on ingredients. By the higher lycopene production per unit area the higher yield could account for the concentration loss of individual fruits (Helyes *et al.*, 2012).

The all-*trans* form of lycopene of tomato fruits was higher, while *cis*-isomers of lycopene were lower in all of the cultivars and harvests. The average *cis*-lycopene concentration was significantly higher in 2011 than in 2010, and it was nearly two-fold higher in case of 'Strombolino' at the second harvest date in 2011. It seems probable that the warmer temperatures and a better light supply activated the biosynthesis of *cis*-isomers of lycopene in 2011, which is in agreement with Kuti and Konuru (2005).

Tab. 4 shows the effect of water supply and examined varieties on the concentration of polyphenol groups (flavonoids and phenolic acids). We have measured significantly lower flavonoids and phenolic acids concentration in irrigated samples, which is contradictory to the findings of Sánchez-Rodríguez *et al.* (2012), in tomato grown in a growth chamber near optimal environmental conditions. Phenolic acids results showed the same pattern as flavonoids and ranged between 30.7-154.1 mg kg^{-1}. Irrigated samples gave lower values, in agreement with Sánchez-Rodríguez *et al.* (2012), who reported lower phenolic acids concentration of cherry tomato fruits under moderate water stress conditions.

In the examined tomato samples we could identify nine components of polyphenols. These are the following: neochlorogenic acid, chlorogenic acid, caffeic acid, ferulic acid, gallic acid, quercetin, rutin, catechin, naringin (Tab. 5.). In our experiment the average rutin content ranged from 41.7 to 98.8 mg kg^{-1}. This is more than a double difference, and in all samples, the rutin concentration showed significant decrease with irrigation. The second largest concentration was found to be of chlorogenic acid. We could not measured detectable amount of naringin in 'Brixsol' F1. Riga *et al.* (2008) found strong negative correlation between cumulative temperature during the 45 days before harvest and total phenolic concentration. Also lower phenolics content of fresh tomato fruit was reported at higher temperatures (Incerti *et al.*, 2009), and our results could confirm this temperature effect. Probably seasonal

Tab. 4. Concentration of polyphenols (mg kg^{-1} FW) of tomatoes under different water supply in 2010 and 2011 (n=4, ±SD)

Harvesting date	Cultivars and treatments	Flavonoids (mg kg^{-1})	Phenolic acids (mg kg^{-1})
06.8.2010	BI	25.7±2.5 a	30.7±3.6 a
	BC	69.9±8.7 cd	39.9±4.9 b
	StI	81.5±16.2 d	65.9±8.2 c
	StC	106.9±5.3 e	78.3±3.7d
26.7.2011	StI	69.0±6.4 d	109.0±15.5 e
	StC	58.6±4.3 c	154.1±19.4 f
26.8.2011	BI	22.6±3.8 a	31.7±4.0 a
	BC	37.7±6.9 b	42.2±5.6 b
	StI	81.0±11.0 d	101.1±12.7 e
	StC	120.1±20.4 e	112.5±20.2 e

BI: 'Brixsol' irrigated, BC: 'Brixsol' control, StI: 'Strombolino' irrigated, StC: 'Strombolino' control.
Values are reported as the mean ± standard deviation. Data in the same column bearing the same superscript letter are not significant at p=0.05.

Tab. 5. Concentration of main polyphenols (mg kg^{-1} FW) of cherry tomato under different water supply (n=4, ±SD)

Harvesting date	Cultivars and treatments	Quercetin-glucoside	Rutin	Catechin	Naringin	Neoclorogenic acid	Clorogenic acid	Caffeic acid	Ferulic acid	Gallic acid
06.8. 2010	BI	7.2 ± 0.3^{a}	14.3 ± 1.6^{a}	4.3 ± 0.5^{c}	nd	4.8 ± 0.6^{a}	12.4 ± 1.2^{b}	7.7 ± 0.2^{b}	2.9 ± 0.4^{b}	2.9 ± 1.1^{c}
	BC	15.3 ± 1.2^{cd}	45.8 ± 5.9^{cd}	8.8 ± 1.6^{d}	nd	9.0 ± 0.9^{b}	10.7 ± 1.0^{b}	8.7 ± 1.0^{b}	3.7 ± 1.0^{b}	7.7 ± 0.9^{f}
	StI	13.6 ± 2.2^{bc}	46.6 ± 10.0^{cd}	6.0 ± 2.1^{cd}	15.3 ± 1.6^{c}	11.9 ± 1.4^{c}	26.6 ± 3.2^{c}	19.7 ± 2.5^{e}	3.1 ± 0.3^{b}	4.7 ± 0.7^{de}
	StC	12.8 ± 0.5^{b}	68.1 ± 2.5^{e}	10.4 ± 1.4^{d}	15.5 ± 0.8^{c}	20.5 ± 0.8^{e}	30.2 ± 0.9^{d}	19.4 ± 1.1^{e}	3.6 ± 0.3^{b}	4.5 ± 0.4^{d}
26.7. 2011	StI	13.2 ± 0.9^{bc}	41.7 ± 1.9^{c}	3.3 ± 0.4^{b}	0.3 ± 0.03^{a}	13.3 ± 1.8^{cd}	45.8 ± 6.9^{e}	6.3 ± 0.6^{a}	5.8 ± 0.6^{c}	3.0 ± 0.4^{c}
	StC	13.4 ± 1.8^{bc}	52.2 ± 4.9^{d}	3.0 ± 0.4^{b}	0.4 ± 0.05^{b}	12.0 ± 1.4^{c}	84.3 ± 12.4^{f}	8.0 ± 0.7^{b}	7.1 ± 0.5^{d}	1.2 ± 0.1^{a}
26.8. 2011	BI	7.8 ± 1.8^{a}	11.7 ± 1.2^{a}	3.2 ± 0.8^{bc}	nd	4.8 ± 0.6^{a}	10.9 ± 1.5^{b}	5.0 ± 0.8^{a}	0.3 ± 0.1^{a}	1.5 ± 0.1^{b}
	BC	13.1 ± 3.4^{bc}	19.1 ± 2.4^{b}	5.6 ± 1.10^{c}	nd	9.2 ± 1.10^{b}	7.4 ± 1.02^{a}	6.2 ± 0.8^{a}	2.0 ± 0.6^{b}	1.4 ± 0.2^{ab}
	StI	13.2 ± 1.2^{bc}	65.5 ± 9.2^{de}	2.0 ± 0.3^{a}	0.4 ± 0.06^{b}	15.0 ± 1.4^{d}	22.6 ± 2.9^{c}	11.4 ± 1.8^{d}	9.5 ± 1.8^{e}	6.5 ± 0.7^{ef}
	StC	18.1 ± 3.4^{d}	98.8 ± 16.2^{f}	2.7 ± 0.4^{ab}	0.4 ± 0.05^{b}	28.9 ± 4.2^{f}	31.5 ± 3.0^{d}	13.1 ± 2.9^{d}	12.6 ± 4.5^{e}	6.5 ± 1.2^{def}

BI: 'Brixsol' irrigated, BC: 'Brixsol' control, StI: 'Strombolino' irrigated, StC: 'Strombolino' control, nd: not detected.
Values are reported as the mean ± standard deviation. Data in the same column bearing the same superscript letter are not significant at p=0.05.

Tab. 6. Effect of season and water supply on concentration of tocopherol in tomato fruits (μg g^{-1} FW) (n=4) (±SD)

Harvesting date	Cultivars and treatments	α-tocopherol	β-tocopherol	γ-tocopherol	γ-tocotrienol
06. 8. 2010	BI	7.07±0.24 ^{d}	0.71±0.01 ^{c}	2.04±0.05 ^{b}	0.19±0.01 ^{a}
	BC	4.85±0.30 ^{b}	0.53±0.07 ^{ab}	2.02±0.03 ^{b}	0.20±0.01 ^{a}
	StI	6.19±0.49 ^{c}	0.65±0.05 ^{bc}	2.25±0.09 ^{c}	0.26±0.01 ^{b}
	StC	7.14±0.22 ^{d}	0.57±0.04 ^{b}	2.26±0.01 ^{c}	0.24±0.01 ^{b}
26. 7. 2011	StI	6.85±0.68 ^{cd}	0.41±0.11 ^{a}	2.87±0.59 ^{c}	0.63±0.07 ^{d}
	StC	7.69±0.72 ^{d}	0.36±0.12 ^{a}	3.43±0.66 ^{cd}	0.45±0.11 ^{c}
26. 8. 2011	BI	3.93±0.65 ^{a}	0.88±0.10 ^{d}	1.21±0.28 ^{a}	0.33±0.07 ^{bc}
	BC	6.78±1.37 ^{cd}	0.91±0.04 ^{e}	1.55±0.24 a	0.26±0.04 ^{b}
	StI	4.29±0.60 ^{a}	0.86±0.15 ^{de}	3.35±0.31 ^{d}	0.39±0.07 ^{c}
	StC	9.49±1.67 ^{e}	0.83±0.14 ^{cde}	3.77±1.05 ^{cd}	0.56±0.04 ^{cd}

BI: 'Brixsol' irrigated,BC: 'Brixsol' control, StI: 'Strombolino' irrigated, StC: 'Strombolino' control.
Values are reported as the mean ± standard deviation. Data in the same column bearing the same superscript letter are not significant at p=0.05.

variation of phenolic compounds is also closely correlated with the temperature regime during the fruit development period of tomato.

We have also measured tocopherol content and composition. Four components of tocopherols were identified in the examined tomato samples. There were determined α-tocopherol, γ-tocopherol, β-tocopherol and γ-tocotrienol were determined in decreasing percentage respectively α-tocopherol represented 48-70% of total tocopherols and γ-tocopherol had the second largest concentration (between 22-38%) depending on treatment, while the remaining two were lower than 10% (Tab. 6). Control plants gave higher average α-tocopherol concentration (except BI sample, in the first harvest in 2010), which is in agreement with Hwang *et al.* (2012).

Conclusions

The climatic conditions, particularly the precipitation was significantly different in the two investigated seasons, because 2010 was the rainiest year, but during 2011 there was drought. Increasing the water supply increased fruit yield but reduced °Brix significantly. On the other hand it is very important to mention that Brix yield increased significantly. Many studies have demonstrated that the ingredient content is fundamentally determined by the genetic nature of varieties, but it does not exclude the fact that environmental factors also strongly affect it. Irrigation decreased ingredients contents of individual fruits, by inducing more and larger fruits, and by its dilution effects, but the higher yield could compensate for the concentration loss of individual fruits by higher ingredients production per unit area. We have measured significantly higher carotenoids and polyphenols content in processing cherry type hybrid 'Strombolino' F_1. Cherry type shows significantly higher carotenoid contents, mainly lycopene, than large fruited cultivars. α-tocopherol is the most abundant tocopherol in tomato fruits. In general, we can state that irrigation decreased (in most cases significantly) carotenoids, polyphenol and tocopherol concentration in tomato fruits.

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