Effect of regulated deficit irrigation ~~and cluster position~~ on quality parameters, carotenoids and phenolics
of diverse tomato varieties (*Solanum lycopersicum* L.)

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Abstract

This study aims to evaluate the effects of regulated deficit irrigation (RDI) and of cluster position (CI: first and second cluster; CII: third and fourth cluster; CIII: fifth and sixth cluster) on fruit quality parameters, carotenoids and phenolics in tomatoes. Three common (‘Tigerella’, ‘Palamós’ and ‘Byelsa’) and two cherry varieties (‘Lazarino’ and ‘Summerbrix’) were studied. The results showed that the regulated deficit irrigation with reduction of 40 and 50% in the leaf water potential in common and cherry tomatoes did not affect greatly the organoleptic quality of common tomatoes and ‘Summerbrix’., while cherry varieties were significantly affected with the cluster position. In most case, significant changes in the levels of carotenoids were observed depending on the treatment and the cluster position in all varieties. Significant changes with the treatment and no change with the cluster position were observed in phenolic compounds. Thus, in general, increased total carotenoid levels and reduced the content of phenolic compounds were observed. Considering the significance of changes in the levels of these groups of compounds it was concluded that ‘Lazarino’ was more susceptible to water deficit, whereas ‘Summerbrix’ and ‘Palamós’ were more resistant. On the other hand, the organoleptic and functional quality changed with the variety.

Graphical abstract

[Highlights](#)

[Marked differences in some of the parameters studied were found across tomato varieties.](#)

[Regulated deficit irrigation \(RDI\) can enhance carotenoids and phenolics levels.](#)

[Overall RDI and cluster position had no major impact in the fruit commercial quality.](#)

Key words: functional foods, hydrosustainable foods, lycopene, phytoene, phytofluene, leaf water potential, water stress

1. INTRODUCTION

The tomato (*Solanum lycopersicum* L.) is one of the most important crops and widely consumed either fresh or processed as food. Tomato is a source of fibre, potassium, phosphorous, vitamin C, B and E, carotenoids and phenolic compounds (Ripoll J. , Urban, Brunel, & Bertin, 2016).

The functional quality of the tomato regarding carotenoids and phenolic compounds levels is affected by agronomical factors, such as maturation in the plant, post-harvest treatment (Centeno, et al., 2011), collection period, light intensity, temperature of cultivation (Dorais, 2007), CO₂, vapour pressure deficit, air quality and pollutants (Torres, Adrews, & Davies, 2006). Carotenoids of tomatoes are of great interest for different reasons, thus, these are in general the primary source of lycopene in the human diet (Rao & Rao, 2007). These are also one of the best dietary sources of the colourless carotenoids phytoene and phytofluene (Meléndez-Martínez, Mapelli, Benítez, & Stinco, 2015) whose study is attracting increasing interest very recently (Meléndez-Martínez, Paulino, Stinco, Mapelli-Brahm, & Xiang-Dong, 2014; Stinco, Heredia, Vicario, & Meléndez, 2016) as they may provide health benefits (Meléndez-Martínez, Mapelli, Benítez, & Stinco, 2015; Meléndez-Martínez, et al., 2013). On the other hand, phenolics have been shown to exhibit antioxidant properties *in vitro*, and are thought to provide health benefits (Shadini & Ambigaipalan, 2015).

The tomato quality is a sum of several factors. The market quality change with water and environmental stress, these can affect the fruit size and sugar content (Vinha, Alves, Barreira, Castro, & Costa, 2014) because they can

generate varied responses in the plant, such as the reduction of water potential, turgor, water content, growth and crop productivity (Shao, Chu, Abdul, & Zhao, 2008). Deficit irrigation can be used to save water. This is characterized by watering the root zone with less water and can be useful to improve the quality of some products by enhancing the characteristic sensory attributes, which leads to ~~and~~ a greater level of satisfaction among international consumers (Cano-Lamadrid, et al., 2015).

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On the other hand, the increase of the population has provoked greater agricultural demand, with decrease of the available water. Water stress can cause changes in the fruit quality and increase soluble solids content in late growing seasons. It is a usual agronomical techniques for improving quality in the fruit ripening phase crops, (Johnstone, Hartz, LeStrange, Nunez, & Miyao, 2005). However, high levels of water ~~stress~~ deficit irrigation in sensitive phenological phases (such as flowering) may reduce the sugar, acid and carotenoid content (Ripoll J. , Urban, Brunel, & Bertin, 2016). Plant measurements have been considered very efficient tools for irrigation scheduling (Turner, 1990). Deficit irrigation based on plant water status (especiallly leaf water potential) are increasingly used for scheduling deficit irrigation (Corell, y otros, 2016). However, there are few studies on deficit irrigation techniques based on plant water status and cluster position, and its effect on the ~~fruit quality and nutritional content~~ commercial and functional tomato quality. -

In this regard, the main aim of the study was to determine the effect of a regulated deficit irrigation treatment (based on crop water status, with physiological measurements, and compared with well-irrigated plants) and the cluster position (CI: first and second cluster; CII: third and fourth cluster; CIII: fifth and sixth cluster) on fruit quality parameters (diameter, weight, soluble solids and colour) as well as in carotenoids and phenolics levels. For this purpose 5 tomato genotypes (three common 'Daniella' type and two cherry varieties) were considered. The controlled deficit irrigation, consisted in reducing the water amount applied in the more resistant phases of the

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[crop, so as not to affect the production and yield. In this particular case, this technique is based on measures of water status to optimize production, increasing the efficiency of water use. Measures of water status, with thresholds of stress that in theory do not affect the production of the crop were used. This deficit irrigation schedule is devised so as not cause a water stress in the plant that affects negatively the production.](#)

2. MATERIALS AND METHODS

2.1 Reagents and standards

Methanol, trichloromethane and hydrochloric acid were of analytical grade and purchased from Labscan (Dublin, Ireland). HPLC-grade methanol, HPLC-grade acetonitrile ([PumChemCID: 6342](#)), HPLC-grade ethyl acetate ([PumChemCID: 8857](#)) and formic acid ([PumChemCID: 284](#)) were obtained from Panreac (Barcelona, Spain). Water was purified in a NANOpureDiamondTM system (Barnsted Inc., Dubuque, IO). β -carotene ([PumChem CID: 5280489](#)) was purchased from Sigma-Aldrich (Taufkirchen, Germany) and lutein, lycopene, phytoene and phytofluene were obtained from appropriate sources as described elsewhere (Meléndez-Martínez, Vicario, & Heredia, 2007; Meléndez-Martínez, Stinco, Liu, & Wang, 2013). Quercetin ([PumChem CID: 5280804](#)), ferulic acid, caffeic acid, p-coumaric acid ([PumChem CID: 637542](#)), were purchased from Sigma-Aldrich (Madrid, Spain).

2.2 Plant materials

Five tomato (*S. lycopersicum*) varieties with indeterminate growth were studied, specifically three ‘Daniella’ type varieties (Palamós, Tigerella and Byelsa) and two cherry varieties (Summerbrix and Lazarino) ([Figure 1](#)). These were provided by Fitó from Spain. All varieties have a red colour except ‘Tigerella’ that is a striped round medium to small variety. ‘Palamós’ is a round medium to big variety, ‘Byelsa’ is a pear type of tomato, ‘Summerbrix’ is a pear small variety and ‘Lazarino’ is a round variety. They were tested in a greenhouse production at Escuela Técnica Superior de Ingeniería Agronómica (E.T.S.I.A.) in the Universidad de Sevilla (Sevilla, South Spain, 37°21'09.71" Lat. N, 5°56'19.13" Long. W, 33 m a.s.l.). They were tested during spring 2015 (23rd February to 15th June). [The varieties studied were germinated in seedlings and, when they developed three or four true leaves, they were transplanted and secondary plant stems were pruned. Pest control was](#)

[performed with insecticides and acaricides specific for tomatoes.](#) The irrigation of the plants was done by dripping, with two daily cycles of irrigation that depended to crop evapotranspiration (ETc) of the plant. The irrigation treatments were: Regulated deficit irrigation (RDI), with a water stress threshold of -1MPa of leaf water potential (55.1 mm of applied water) from flowering , and a control treatment with irrigation requirements determined according to ETc calculated with the FAO [Penman-Monteith](#) method [Allen et al. \(2006\)](#) (Allen, Pereira, Raes, & Smith, 2006) (532.2 mm of applied water). [The RDI was applied fifteen days after transplantation.](#) Each parcel was made up of 3 rows; [tomatoes samples were collected at central rows plants.](#) ~~and the main aspects of tomatoes were estimated on the plants of the central row.~~ All the clusters were harvest at the same time. Fruit harvest for the analysis was performed at full red ripening on June 21th.

[Figure 1. Photograph of five tomato...](#)

Samples included fruits representative of the three different clusters. The first and second clusters corresponded to position I (CI), the third and fourth clusters corresponded to position II (CII), and the fifth and sixth clusters corresponded to position III (CIII). Three fruits of seven plants for cherry varieties and one fruit of seven plants for common varieties were collected at each position. These were selected from different parts of the cluster. In most cases, fruit in the CI position was selected from the distal part, CII from medium part and CIII proximal part of the cluster. Samples included a mix of fruits of each level previously characterised. This mix was divided into two samples for the quantification of functional quality. The seeds and inside locular tissues were removed, cut and quickly frozen at -80 °C, before being freeze-dried with a Cryodos system (Telstar, Japan). The water content was determined by weighing the sample before and after freeze-drying.

The dried samples were ground in a basic IKA A 11 mill, then stored in a dark glass bottle and hermetically sealed under nitrogen atmosphere. The samples were stored in a freezer at -21 °C until their analysis.

2.3 Measurements performed on the fruits

The measurements performed on the fresh tomato quantified equatorial and longitudinal diameter (cm), weight (g), soluble solids (°Brix) and colour. The soluble solids were measured using a Hand-refractometer RHC-200ATC (Huake, China), and the fruit colour was analysed using a CM-700d colorimeter (Minolta, Japan). For

this purpose the whole visible spectrum (380 – 770nm) was recorded with a bandwidth of 1nm. The colour parameters corresponding to the uniform colour space CIELAB were obtained directly from the apparatus. Illuminant D65 and 10° observer were considered as reference.

2.4 Carotenoid analysis

Sample preparation

Individual carotenoids were determined as described by Borghesi, *et al.* (2011) (~~Borghesi, et al., 2011~~) with slight modifications. Approximately 20 mg of homogenized freeze-dried powder were used for the extractions. The powder was mixed with 250 µL of methanol, 500 µL of trichloromethane and 250 µL of MiliQ-water and then vortexed, sonicated for 2 min and centrifuged to remove the aqueous phase at 14 000x g for 3 min. After recovering the coloured fraction, 500 µL of trichloromethane were added, and then the mixture was vortexed, sonicated and centrifuged again. These operations were repeated until the solids did not have colour. The organic coloured fractions were evaporated to dryness at a temperature below 30 °C in a vacuum concentrator and stored under N₂ at -20 °C until the analysis.

RRLC chromatography

The dry residue was re-dissolved in 40 µL of ethyl acetate prior to their injection in the RRLC system. The RRLC analysis was carried out using the method reported by Stinco *et al.* on an Agilent 1260 system equipped with a diode-array detector, C₁₈ Poroshell 120 column (2.7 µm, 5 cm x 4.6 mm) (Agilent, Palo Alto, CA), 2.5 µL of the injection volume at 30°C and 1 mL/min of the mobile phase (Stinco, Benítez, Hernanz, Vicario, & Meléndez, 2014). The mobile phase consisted of acetonitrile (solvent A), methanol (solvent B) and ethyl acetate (solvent C) with the linear gradient elution: 85% A +15% B, 0 min; 60%A +20%B, + 20%C, 5 min; 60%A+20%B+20%C, 7 min; 85% A+ 15% B , 9 min; 85% A + 15% B, 12 min. The chromatograms were monitored at 285, 350 and 450 nm with the open lab ChemStation software. Carotenoids were identified by comparison of their chromatographic and UV-vis spectroscopic characteristic with those of standard. The quantification of the carotenoids was performed by external calibration from the areas of the chromatographic peaks obtained by Uv detector at the following wavelengths: 285 nm for phytoene, 350 nm for phytofluene and 450 nm for lutein, lycopene and β-

[carotene](#). All dry residues re-dissolved were injected twice and the concentration expressed in µg/g dry weight (DW). Total carotenoids contents were calculated adding up all individual carotenoids.

2.5 Analysis of phenolic compounds

Sample preparation

Approximately 0.5 g of the freeze-dried was extracted with 15 mL of acidified methanol 0.1%. The mixture was vortexed and sonicated for 15 min, and centrifuged at 4190 g for 7 min at 4 °C; the supernatant was collected and the residue subjected to the same process twice, using only 5 mL of acidified methanol 0.1%. Finally, all the supernatants were combined. The extract was stored at -20 °C until analysis. All the samples were extracted in triplicate.

UHPLC analysis

One mL of the extract obtained was dissolved in 4 mL of 0.01% formic acid in water for injection in the UHPLC system. Chromatography analyses were carried out in an Agilent 1290 chromatograph equipped with a diode-array detector (Agilent Technologies, Palo Alto, CA. USA), an Eclipse Plus C18 column (1.8 µm , 2.1 x 5 mm), 5 µL of injection volume, 1 mL/min of the mobile phase at 30°C and peaks were monitored at 220-500 nm. The mobile phase consisted of 0.01% of formic acid in water (solvent A) and acetonitrile (solvent B) with the linear gradient elution: 100% A, 0 min; 95%A +5%B, + 20%C, 5 min; 50%A+50%B, 20 min; washing and re-balancing of the column, 22 min. The chromatograms were monitored at 280 ~~and~~, 320 ~~and 370~~ nm with the open lab ChemStation software. Phenolic compounds were identified by their retention time and UV-vis spectra by comparison with standards. The quantification of phenolic acids was achieved by comparison of their retention times and spectra with those of appropriate standards, their levels being determined by external calibration considering the following wavelengths: 280 nm for *p-hydroxibenzoic acid*, *p-coumaric acid*, caffeic acid, chlorogenic acid, ferúlico acid, naringin and crisin; and 320 nm for quercetrin and quercetin . All the extracts were injected twice and the concentration expressed in mg/100 g (DW). Total phenolic content was calculated adding up all individual phenolics.

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2.6 Statistical analysis

Statistical differences were determined by analysis of variance (simple and factorial ANOVA). The mean separation was made via a Tukey's test with 0.01 significant differences and correlations by Pearson with 95% confidence level were employed to estimate the possible significance of the effect. The STATGRAPHICS Centurion XVII software was used for statistical analyses.

3. RESULTS AND DISCUSSION

Regulated deficit irrigation affected plant water status significantly during the experiment. In the vegetative development of the plant, the leaf water potentials in RDI ranging from -0.8 to -1.2 MPa, while in the control ranging between -0.2 to -0.5 MPa, were observed. At harvest ([June 21th](#)) the leaf water potential was -1 MPa in the RDI treatment and -0.6 MPa in the control sample for 'Palamós' and 'Byelsa'; -1,2 MPa in the RDI treatment and -0.7 MPa in the control sample for 'Tigerella' and -1 MPa in the RDI treatment and -0.5 MPa in the control sample for 'Lazarino' and 'Summerbrix'. These data showed that during experimentation, the RDI in the plants of common and cherry tomatoes exhibited a reduction of 40 and 50%, respectively, of leaf water potential.

On the other hand, at harvest the plant height for 'Lazarino', 'Summerbrix' and 'Tigerella' was of 2.3 m, while 'Palamos' showed a height of 2 m and 'Byelsa' of 1.5 m. Thus, cherry varieties showed an average of 38 tomatoes per cluster, while 'Tigerella' 16 fruits per cluster, 'Palamós' 7 fruits per cluster and 'Byelsa' 5 fruits per cluster. However, in this study it was observed that the load was not affected with the application of RDI.

The tomato quality data (diameter, weight, soluble solids and colour) are summarized in Table 1.

3.1 Estimation of fruit quality

3.1.1 Size

Fruit size keeps similarity with the data reported in other studies for cocktail tomato with normal water regime. Thus, length values between 30 and 42 mm (Ripoll J. , Urban, Brunel, & Bertin, 2016; Choi S. , et al., 2014) have been reported elsewhere. In most cases, the diameter of tomatoes did not change significantly with the treatment,

except for 'Lazarino', variety in which size reductions were observed in the CI and CII clusters. These data obtained for common varieties were different from those of other authors which found that the lack of water decreased the size of the fruits (Ozbahce & Tari, 2010). With regard to the effect of cluster position, significant effects were observed in 'Summerbrix' in RDI and 'Lazarino' in RDI and control. Overall, the treatment only affected 'Lazarino', while cluster position affected the size of the fruit in the cherry varieties. On the other hand, the change in equatorial diameter was largely influenced by the variety and position of the cluster. Although longitudinal diameter changed with the regulated deficit irrigation, cluster position and variety, as shown by several studies (Choi S. , et al., 2014; Verheul, Slimestad, & Holta, 2015).

Table 1. Average values of parameters related to the commercial quality of tomatoes ^a

3.1.2. Weight

In this study, 'Palamós' and 'Byelsa' in normal water regime showed higher weight values (109 and 66 g respectively) compared with other studies, which reported values ranging from 58 to 73 g of fruit (Patané, Tringali, & Sortino, 2011; Saito, et al., 2008). Contrastingly, the values found in the present study for cherry varieties (ranging from 10 to 16 g) were similar and low compared with 'Lazarino' and 'Summerbrix' respectively, to those found in other studies which studied 12 greenhouse-grown commercial cherry tomato varieties (ranging from 13 to 27) (Choi S. , et al., 2014) . The low values of fruit weights can be due to the difference in variety under study and growth and environmental conditions, as suggested by others authors (Vinha, Alves, Barreira, Castro, & Costa, 2014). The weights of 'Lazarino' in all clusters, as well as of 'Summerbrix' and 'Byelsa' in the CI cluster exhibited differences as a result of the treatment. Thus, the weight decreased in 'Lazarino' and 'Byelsa' but increased in 'Summerbrix'. In this sense, there are previous studies reporting changes both in cherry and common tomatoes, which were dependent on the variety under study (Patané, Tringali, & Sortino, 2011). No significant changes in the fruit weight as a result of the cluster position were observed in 'Palamós', although in other varieties significant changes were observed both in RDI or control samples, specifically decreases with respect the CI cluster. The effect of RDI on the weight of cherry and common varieties showed no significant change in the most case; however it is accepted that water stress causes a decrease

in the weight of the fruit (Ozbahce & Tari, 2010; Patané, Tringali, & Sortino, 2011; Favati, et al., 2009). On the other hand, the cluster position exhibited change only 'Summerbrix'. Overall, the weight showed greater influence with the treatment and variety.

3.3.4 Soluble solids

The soluble solids (SS) values range in cherry control samples (ranging from 7.1 to 8.3 °Brix) was similar to that reported by Figás, et al. (2015) (7.6 to 7.7 °Brix) (Figás, y otros, 2015). That of common tomatoes (ranging from 3.8 to 5.0 °Brix) agreed well with those reported elsewhere (3.5 and 5.4 °Brix) (Patané, Tringali, & Sortino, 2011; Vinha, Alves, Barreira, Castro, & Costa, 2014; Gómez, Segura, & Fernández, 2010).

In the present study, in some cases, the treatment led to statistically significant differences in the SS values. This applies to 'Tigerella' and 'Byelsa', where increases were observed. Increases in common tomatoes as a result of the treatment have also been described by other authors (Patané, Tringali, & Sortino, 2011; Favati, et al., 2009). However, whereas no significant differences in SS values with reduced irrigation were observed in the present study for cherry tomatoes, increases have been reported in others (Pernice R., et al., Antioxidants profile of small tomato fruits: Effect of irrigation and industrial process, 2010). Thus, it has been suggested that water stress can be useful to increase the soluble solids in tomato (Beckles D., Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit, 2012). With regards to the effect of cluster position, cherry varieties showed significant differences in RDI and control samples, which were not observed in common tomatoes. In the case of 'Lazarino', the SS decreased from CI to CIII in RDI, but the contrary is observed in the case of 'Summerbrix'. These and other observations throughout the text exemplify the fact that the parameters studied are dependent on factors of different nature (like agronomic, climatic, developmental or genotype factors, among others); hence the difficulty of finding uniform behaviours within and across studies. Overall, the RDI and cluster position presented change in all varieties except in 'Lazarino' and 'Palamós', respectively. On the other hand, the SS exhibit greater influence of change with the cluster position and variety, as suggested by other authors (Beckles D., 2012).

3.3.5 Colour

Concerning the colour parameters in normal water regime samples, the L^* , a^* , b^* , C_{ab}^* and h_{ab} values for red tomato found in the present study (ranging from L^* 35.1 to 47.4, a^* 14.0 to 31.1, b^* 21.4 to 38.5, C_{ab}^* 31.8 to 47.9 and h_{ab} 39.4 to 70.0) were similar in some cases to values found in other studies which reported ranges of L^* 28.0 to 44.6, a^* 17.0 to 31.2, b^* 15.0 to 29.4, C_{ab}^* 22.0 to 42.8 and h_{ab} 40.7 to 60.1 (Gómez, Segura, & Fernández, 2010; Vinha, Alves, Barreira, Castro, & Costa, 2014; Stinco, Benítez, Hernanz, Vicario, & Meléndez, 2014). Some significant effects were observed for colour parameters with the treatment in some clusters in all varieties. ‘Palamós’ in CII, ‘Sumerbrix’ in CII and CIII did not show changes in the colour parameters with treatment. On the other hand, in ‘Lazarino’ and ‘Byelsa’ decreases in the values of the colour parameters were observed with the treatment, while increases were observed in ‘Tigerella’. Regarding the effect of the cluster position, statistically significant differences in some colour parameters in RDI and control were observed in all varieties. As an example, increases in the value of L^* , b^* , C_{ab}^* and h_{ab} from CI to CIII were observed in ‘Lazarino’.

Overall, it was concluded that ‘Summerbrix’ with the treatment showed change in all colour parameters, while the cluster position changed in all colour parameters in cherry varieties. . In addition, a^* and C_{ab}^* values, exhibited greater influence of change with the cluster position and variety, while the other colour parameters changed with the treatment, cluster position and variety. This adds support to previous evidence indicating that water deficit has an impact on tomato quality parameters depending on fruit developmental stage and genotype (Ripoll J. , Urban, Brunel, & Bertin, 2016; Beckles D. , 2012).

3.2 Carotenoid analysis

3.2.1 Total carotenoids

Quantitative data on total carotenoids (TC) for cherry and common tomatoes are presented in Figure 21 and on the individual compounds in Table 2.

Statistically significant differences in the TC as a function of the treatments were found in all varieties. In cherry varieties and ‘Byelsa’ the deficit irrigation led to increases in the levels of TCs while in ‘Tigerella’ the situation

was the contrary. With respect to the cluster position, in general, statistically significant differences were found in RDI and control, except for 'Summerbrix' in the case of the control. In all the cultivars studied, the highest TC values were found in the CI cluster in RDI and control samples, with the exception of 'Tigerella' in the case of the control. The changes in the TC values as a function of cluster position for 'Summerbrix' and 'Tigerella' showed some analogies. For example 'Summerbrix' in RDI had high values of TC in CI, it decreases in CII and in CIII it increases again. On the other hand, in 'Lazarino' TC decreased in RDI and control in the CIII cluster. This may be due to the fact that in May and June the average ambient temperature in 2015 was 30°C. Thus inside the greenhouse temperature were higher than 36°C, temperature at which the generation of lycopene can be slowed, as suggested other authors (Camejo & Torres, 2001).

The TC in 'Palamós' did not change with the treatment, although all varieties showed changes with the cluster position. Overall the TC values were noticeably influenced by the variety and the cluster position, 'Tigerella' and 'Byelsa' being the ones with the highest values among the common tomatoes and 'Summerbrix' in the case of cherry varieties. The total carotenoid levels observed in cherry varieties in control samples (ranging from 36.1 to 96.2 mg/100 g DW) were lower compared with the data reported by other authors. For example Ripoll et al. (2016) reported values between 1297 and 1374 mg/Kg DW (Ripoll J. , Urban, Brunel, & Bertin, 2016). However, the values in cherry varieties subjected to the treatment were higher than the values reported by Pernice *et al.* (2010) for normal and reduced irrigation (Pernice R. , et al., 2010). 'Summerbrix' and 'Lazarino', despite being cherry cultivars with small dimensions, can be more important sources of carotenoids than other common cultivars (Shadini & Ambigaipalan, 2015). In any case it is important to bear in mind that the levels of carotenoids and other secondary metabolites are dependent on factors of different nature (like agronomic, seasonal, climatic or genotypal, among others) (Poiroux-Gonord, et al., 2010; Borghesi, et al., 2011). In this sense important quantitative differences have been reported even in samples from the same variety grown in greenhouses under the same conditions. There are examples in an investigation by Meléndez-Martínez *et al.* (2010) (~~Meléndez-Martínez, Fraser, & Bramley, 2010~~) in which the accumulation of carotenoids and phenolics along development and ripening were studied in different tomatoes and wild relatives. Specifically, the highest and lowest levels of

some carotenoids (lycopene, phytoene and phytofluene) and tocopherols at the ripe stage were found in two different accessions of *S. lycopersicum* var. *cerasiforme* (Meléndez-Martínez, Fraser, & Bramley, 2010).

Figure 21. Total carotenoids (mg/100 g DW)...

3.2.2 Individual carotenoids

The major carotenoids identified in this study were phytoene ([retention times \(\$t_R\$ \) 8.4 min](#)), phytofluene ([\(\$t_R\$ 7.7 min\)](#)), lutein ([\(\$t_R\$ 1.4 min\)](#)), lycopene ([\(\$t_R\$ 5.3 min\)](#)) and β -carotene ([\(\$t_R\$ 7.7 min\)](#)) (Figure 2), which are the typical predominant carotenoids in red tomato genotypes (Stinco, Heredia, Vicario, & Meléndez, 2016; Meléndez-Martínez, Fraser, & Bramley, 2010; Perveen, et al., 2015). Lycopene was the major carotenoid followed by either phytoene or β -carotene in the five varieties studied.

The levels of phytoene in normal water regime samples, ranging from 1.8 to 16.8 mg/100 g DW, were similar compared with those reported in others studies (Meléndez-Martínez, Fraser, & Bramley, 2010; Perveen, et al., 2015) and higher relative to other, which reported values ranging from 0.6 to 0.7 mg/100 g FW for cherry varieties (Pernice R. , et al., 2010). The amount of this carotenoid increased in 'Lazarino' with the treatment in the three clusters, while in the other varieties did not show a particular pattern. This agrees well with the observations reported elsewhere, in the sense that water deficit or stress can either increase or decrease the concentration of phytoene depending on the variety (Pernice R. , et al., 2010). With respect to the cluster position, significant differences between RDI and control were observed in all varieties. The levels of phytoene increased from CI to CII in 'Lazarino' and 'Palamós' both in RDI and control samples. In the CI cluster, 'Lazarino', 'Summerbrix' and 'Palamós' presented high levels of phytoene in RDI, while 'Lazarino' and common varieties in control. In addition, phytoene with the treatment did not change significantly in 'Tigerella', while all varieties changed with cluster position. Overall, phytoene exhibited greater influence with the treatment, cluster position and variety.

The levels of phytofluene in control samples (ranging from 0.6 to 1.8 mg/100 g DW) were lower compared with those reported in other studies (Meléndez-Martínez, Fraser, & Bramley, 2010; Perveen, et al., 2015) and similar to those reported by other authors (0.39-0.43 mg/100 g FW) in cherry varieties (Pernice R. , et al., Antioxidants profile of small tomato fruits: Effect of irrigation and industrial process, 2010). The cherry varieties showed

higher levels of phytofluene than the common tomatoes. The levels of this carotenoid increased significantly in all clusters with the treatment. This contrasted with the results obtained by other authors in cherry varieties, which indicated that reduced irrigation led to decreases in the concentration (Pernice R. , et al., 2010). With respect to the cluster position, the concentration of phytofluene increased in 'Lazarino' in RDI and control samples and in 'Tigerella' in RDI samples, while in 'Summerbrix' the higher levels were detected in the CII cluster. Thus, phytofluene exhibited change with the treatment and cluster position. Interestingly, phytofluene was not detected in common tomatoes in the control samples, but it was in the RDI ones. Overall, the treatment and variety influenced the phytofluene values.

The levels of lutein in common varieties for normal water regime (ranging from 0.7 to 4.2 mg/100 g DW) were higher compared with those reported elsewhere (Zhang, Liu, Zhang, Zhang, & Wang, 2014) and similar to those found in other studies (Meléndez-Martínez, Fraser, & Bramley, 2010). Such levels changed with the treatment in all varieties and all clusters, except in CI in 'Summerbrix' and 'Palamós'. The levels of lutein in 'Tigerella' decreased with the treatment in all clusters. On the other hand, the concentration of this compound changed significantly with the cluster position in cherry varieties in RDI and control and in 'Palamós' in RDI. In the case of 'Lazarino', the concentration of lutein increased with cluster position in RDI. In control samples, higher levels were observed in the highest cluster in most cases. In addition, lutein did not change with the treatment in cherry varieties, although changes depending on the cluster position were observed in common varieties. Overall, the treatment, cluster position and variety influenced the lutein values.

The levels of lycopene in cherry and common varieties subjected to normal water regimen (ranging from 25.2 to 151.3 mg/100 g DW) were higher compared to other studies, which reported values ranging between 100.0 and 370.0 µg/g DW (Verheul, Slimestad, & Holta, 2015; Choi S. , et al., 2014). They also agreed well with those found in other studies (Meléndez-Martínez, Fraser, & Bramley, 2010; Cortés-Olmos, Leiva-Brondo, Roselló, Raigón, & Cebolla-Cornejo, 2014). The treatment led to statically significant differences in the concentration of this compound in all varieties and clusters. The treatment increased the levels of lycopene in cherry varieties while 'Tigerella' decreased. These data agree well with those reported by other authors in cherry varieties,

indicating that reduced irrigation and water stress can heighten the levels of lycopene (Wang, Kang, Du, Li, & Qiu, 2011; Pernice R. , et al., 2010). However other authors reported that the behaviour of lycopene with respect to the treatment was dependent on the variety in cherry tomatoes. Thus, in some cases the treatment led to increases and in some others to decreases (Sánchez-Rodríguez R. , Leyva, Constán-Aguilar, Romero, & Ruiz, 2012). In the case of common varieties, increased levels of lycopene with the treatment have been reported by other authors (Gahler, Otto, & Bphm, 2003). The cluster position led to statically significant differences in all varieties in both RDI and control samples. In the case of 'Lazarino' (RDI samples) and 'Summerbrix' (control samples), the levels of lycopene decreased with cluster position. Such levels were higher in the CI cluster in RDI samples in cherry and common varieties. Hence, the lycopene values changed with the treatment in all varieties, except in 'Palamós', while the cluster position changed in all varieties. Overall, the treatment, cluster position and variety influenced the lycopene values in this study.

The levels of β -carotene in cherry and common varieties in normal water regime samples (ranging from 5.9 to 16.9 mg/100 g DW) were similar to those found in some studies (Meléndez-Martínez, Fraser, & Bramley, 2010; Cortés-Olmos, Leiva-Brondo, Roselló, Raigón, & Cebolla-Cornejo, 2014) and higher compared to those reported in others, which ranged from 10.0 to 25.1 μ g/g DW (Verheul, Slimestad, & Holta, 2015; Choi S. , et al., 2014). The treatment led to significant differences in some clusters in cherry and common varieties, with decreases in 'Tigerella' in all clusters. The results obtained in RDI samples agree well with those reported by other authors in cherry varieties and common varieties, indicating that in the cherry varieties the amount of β -carotene increase or decrease depending on the variety (Sánchez-Rodríguez R. , Leyva, Constán-Aguilar, Romero, & Ruiz, 2012; Pernice R. , et al., 2010), while common varieties only decreased (Favati, et al., 2009). With respect to the cluster position, cherry varieties showed statically significant differences in RDI and control samples and 'Tigerella' only in RDI. The β -carotene values increased with cluster position in 'Lazarino' in RDI. In addition, β -carotene exhibited changes with the treatment in common varieties, although the cluster position did not change in 'Lazarino' and 'Tigerella'. Overall, β -carotene was largely influenced by the treatment and variety.

Table 2. Average values of carotenoids (mg /100 g DW) in cherry and common tomatoes studied^a

Significant changes in the levels of all the studied carotenoids were observed in the five tomato varieties depending on the treatment and the cluster position. Cherry varieties increased phytofluene and lycopene concentrations with treatment and 'Tigerella' decreased lutein, lycopene and β -carotene levels. Concerning the cluster position, individual carotenoids in common and cherry varieties exhibited significant difference for RDI and control treatments. This is another example that the carotenoid content is not only affected by the lack of water, but also by varietal, agronomic and environmental factors, as noted in other studies (Pernice R. , et al., 2010). The results of this study showed that the treatment, the variety and the cluster position significantly affect the individual carotenoid content, causing an increase in most tomatoes under study.

3.3. Phenolic analysis

3.3.1. Total phenolic content

Quantitative data about total phenolic content (TPC) are presented in Figure 3 and those for the individual compounds in Table 3.

In some cases, the TPC in cherry varieties (ranging from 209 to 350 mg/100 g DW) were higher and in others similar to those reported in common tomatoes (ranging from 210 to 286 mg/100 g DW). These data agree well with those of other authors, for example Vinha et al. (2014) (Vinha, Alves, Barreira, Castro, & Costa, 2014), who studied four tomato cultivars and reported TPC values between 54 to 67 mg gallic acid equivalent (GAE)/100 g FW and Cortés-Olmos et al. (2014) (Cortés-Olmos, Leiva-Brondo, Roselló, Raigón, & Cebolla-Cornejo, 2014) , who surveyed a collection of 126 populations of 16 traditional varieties and reported values between 30 to 79 mg caffeic acid equivalent (CAE)/100 g FW.

On the other hand, TPC in common varieties in this study were higher compared with those found in others, which reported variations of concentration from 18 to 31 mg GAE/100 g FW (Gahler, Otto, & Bphm, 2003) or from 26 to 42 mg/100 g FW (Minutolo, Amalfitano, Evidente, Frusciante, & Errico, 2013). This may be due, at least in part, to the fact that in this study acidified methanol was used and this favors the extraction of phenolics according to the findings of some authors (Ju & Howard, 2003; Arranz, 2010). On the other hand, the freeze-dried

increase between 2.6 to 5.9% the amounts of TPC according to other authors which study the effects of different drying processes (Ching-Hi, Hsing-Yu, Chi-Yue, & Yung-Chuan, 2006). The data corresponding to cherry and common varieties agree well with those found by other authors, who reported phenolic concentration ranges of 65 to 440 mg/100 g DW of 12 cherry varieties and 51 to 54 mg/100 g FW for three common tomatoes (Choi S. , et al., 2014; Raiola, et al., 2015) .

Some significant differences in the TPC values were observed as a result of the treatment in all varieties and some clusters. In cherry varieties, the treatment caused an overall reduction in the total phenolic content, although in 'Byelsa' it increased. Phenolic compounds are thought to have a strong link to the cultivar and water content of the fruit (Minutolo, Amalfitano, Evidente, Frusciante, & Errico, 2013; Sánchez-Rodríguez, Ruiz, Ferreres, & Moreno, 2012), which could explain in part these results. On the other hand, these data agree well with those of other authors. For example Pernice et al. (2010) studied two tomato cherry varieties in normal, reduced and lack of irrigation and concluded that the varieties had higher contents of phenolics in reduced irrigation, while a non consistent behaviour was observed for the non irrigated samples (Pernice R. , et al., 2010); this behavior was also noticed in other studies (Sánchez-Rodríguez R. , Leyva, Constán-Aguilar, Romero, & Ruiz, 2012; Sánchez-Rodríguez, Ruiz, Ferreres, & Moreno, 2012). Again, the data demonstrate that the genotype has an important effect on the levels of the compounds (Minutolo, Amalfitano, Evidente, Frusciante, & Errico, 2013).

As far as the cluster position was concerned, significant differences were observed in RDI and control samples in all varieties. The concentration of total phenolic compounds was highest in CIII for cherry varieties and 'Tigerella'. However, the highest values were found in samples of the Byelsa variety in CI. The TPC values in cherry varieties and 'Tigerella' increased from CI to CIII. This could be due to some extent to the fact that phenolics are components of plant tissues, and their distribution is influenced by light and environmental conditions. As an example, some studies suggest that leaves growing under shade have a low concentration of phenolics (Minutolo, Amalfitano, Evidente, Frusciante, & Errico, 2013; Rugna, Ricco, Gurni, & Wagner, 2008), which may help explain, at least in part, the high TPC in the CIII cluster.

Hence, the treatment showed only change in 'Lazarino' and the cluster position changed in all varieties. Overall, the variety and cluster position influenced the TPC values.

Figure 3. Total phenolic content (mg/100 g DW)..

3.3.2. Phenolics

In the five varieties studied, hydroxybenzoic acid derivatives (p-hydroxybenzoic acid, [t_R 0.5 min](#)), hydroxycinnamic acid derivatives (p-coumaric, [t_R 6.2 min](#); caffeic, [t_R 4.5 min](#); chlorogenic, [t_R 5.38 min](#); ferulic, [t_R 7.4 min](#)), flavanones (naringin, [t_R 9.48 min](#)), flavones (crisin, [t_R 16.5 min](#)), flavonols (quercetrin, [t_R 8.9 min](#) and quercetin, [t_R 10.5 min](#)) were quantified (Table 3 and Figure 4). The levels in control samples (ranging from 209 to 350 mg/100 g DW) were similar to those reported by other authors. For example Choi et al. (2014) studied 12 samples of cherry tomato and reported sums of individual phenolic compounds of 65 to 440 mg/100 g DW (Choi S. , et al., 2014).

The results of the present study showed that p-hydroxybenzoic acid, p-coumaric acid, chlorogenic acid, and quercetin were the predominant acids in common and cherry varieties. As it can be readily observed in Table 3, there were statistically significant differences with treatment in some clusters.

p-Hydroxybenzoic acid levels changed significantly with the treatment in all varieties and all clusters with decreases in 'Summerbrix' and increases in 'Tigerella'. Regarding the cluster position, all varieties exhibited statically significant differences in RDI and control samples, with decreases from CI to CIII in 'Lazarino', 'Summerbrix' and 'Palamós' varieties. In addition, p-hydroxybenzoic did not change with the treatment in some varieties, while the cluster position exhibited changes in all the varieties.

p-Coumaric acid levels varied significantly with treatment in all varieties and all clusters except in the case of CI in 'Lazarino'. In 'Summerbrix', 'Tigerella' and 'Palamós' the treatment increased the concentration, while the contrary was observed in 'Byelsa'. On the other hand, all the varieties showed significant difference in RDI and control samples with higher values in CIII of RDI samples in 'Lazarino', 'Summerbrix' and 'Tigerella'. In

'Tigerella' RDI samples, p-coumaric acid values increased from CI to CIII. Hence, p-coumaric acid with the treatment and cluster position changed in all varieties.

Raiola et al. (2015) reported in normally irrigated common varieties ranges between 0.92 and 1.80 mg/100 g FW for caffeic acid, 15.63 and 23.16 mg/100 g FW for chlorogenic acid, 0.25 and 1.17 mg/100 g FW for quercetin and 0.22 and 0.51 mg/100 g FW for naringenin. These values were similar (chlorogenic acid) or low (caffeic acid, quercetin, naringenin) to the ones found in the present study (Raiola, et al., 2015). Caffeic acid concentrations changed significantly with the treatment in all varieties and clusters, except in CIII for 'Lazarino'. The treatment decreased the levels in 'Summerbrix', 'Tigerella' and 'Byelsa' and increased them in 'Palamós'. With respect to the cluster position, all varieties except 'Summerbrix' in RDI showed statically significant difference. 'Summerbrix', 'Lazarino' and 'Palamós' decreased with cluster position in control. These data agree well with those of other authors, indicating no clear behaviour of caffeic acid with respect cluster position because this changed depending of tomato variety (Arranz, 2010). In addition, the caffeic acid changed with the treatment in all varieties, while the cluster position did not change in 'Tigerella'.

The levels of chlorogenic acid changed significantly with the treatment in all varieties and clusters, except in the case of CII samples in the variety 'Palamós'. In this study, the concentration of this compound decreased with the treatment in 'Tigerella' and increased in 'Palamós' and 'Byelsa'. These data agreed well with those reported by Sánchez-Rodríguez (2012), which showed both increases and decreases of chlorogenic acid with water stress in the two tomato varieties studied (Sánchez-Rodríguez, Ruiz, Ferreres, & Moreno, 2012). Regarding the cluster position, all the varieties exhibited significant differences and increases from CI to CIII. These observations contrasted with those of other authors. For example Minutolo et al. (2013) reported that chlorogenic acid levels decreased at the top of the plant (Minutolo, Amalfitano, Evidente, Frusciante, & Errico, 2013). Again these differences could also be related with changes in the environmental conditions and harvest. In addition, 'Lazarino' did not change the chlorogenic acid values with the treatment, while the cluster position changed in all varieties.

The levels of ferulic acid changed significantly with the treatment in some clusters without presenting a defined trend. 'Summerbrix', 'Tigerella' and 'Palamós' control samples showed the highest value in the CII cluster. These

findings agree well with those of other authors, suggesting that there is not a consistent behaviour of ferulic acid with respect to cluster position as this changed depending on the tomato variety (Minutolo, Amalfitano, Evidente, Frusciante, & Errico, 2013). Overall, the ferulic acid showed change with the treatment and this did not change with the cluster position only in 'Summerbrix'.

The concentration of naringin varied significantly with treatment in all the varieties except 'Palamós' in CII and 'Lazarino' in the CI and CIII clusters. The treatment increased its concentration in 'Tigerella'. These data are in agreement with those of other authors. For example Pernice, et al. (2010) reported that reduced irrigation increased naringin levels but stress decreased them (Pernice R. , et al., 2010). These authors reported naringin levels ranging between 3.76 and 6.30 mg/100 g FW in normal irrigated samples, these values being higher than those found in this study (ranging from 8.6 to 35.3 mg/100 g DW). Naringin values in RDI varied significant with the cluster position in all varieties. 'Summerbrix' and 'Tigerella' showed high levels of naringin in the CIII cluster. In addition, only 'Summerbrix' did not change in the naringin values with the treatment, while 'Lazarino' and 'Palamós' with the cluster position.

The treatment led to significant changes in the levels of crisin in CIII in the case of 'Summerbrix' in CI, CII and CIII in the case of 'Tigerella', CII in the case of 'Palamós' and CI in the case of 'Byelsa'. The treatment led to decreases in 'Tigerella' and 'Byelsa'. Regarding the effect of the cluster position, 'Summerbrix' and 'Palamós' in control showed statically significant difference and high crisin value in CII, while 'Tigerella' in RDI presented statically significant difference and high value in the CIII cluster. Overall, 'Palamós' and 'Byelsa' exhibited change in the crisin values with the treatment, while cherry varieties did not change with the cluster position.

The treatment led to statically significant differences in the levels of quercetrin in all the varieties and some clusters. Decreases in 'Tigerella' and increases in 'Palamós' were observed. With respect to the cluster position, quercetrin showed statically significant difference in RDI and control in all varieties and the quercetrin value increased from CI to CIII. In addition, only 'Byelsa' did not change with the treatment, while all varieties changed with the cluster position.

Regarding quercetin, the treatment caused significant differences in its concentration in all the varieties except in the case of CII and CIII in the 'Summerbrix' variety. Decreases in all the varieties were observed, except in the case of 'Byelsa' variety which the levels increased. These data contrast with those found by other authors. Thus, Pernice, et al. (2010) concluded that both reduced irrigation (1.1 for normal irrigation and 2.1 mg/100 g FW for reduced irrigation in the biotype PC01) and stress water (1.7 normal irrigation and 2.2 mg/100 g FW for none irrigation in the biotype PC05) increased quercetin concentrations (Pernice R. , et al., 2010). They reported levels of quercetin ranging between 1.07 and 1.71 mg/100 g FW in samples subjected to normal irrigations. These values keep relationship with those found in this study (ranging from 37.6 to 99.0 mg/100 g DW). This disagreement in the results of both studies can be due to a great extent to the fact that different varieties were surveyed. The cluster position had a significant effect in both RDI and control samples in all varieties. The levels increased from CI to CIII in all cases but 'Tigerella' control samples, where the highest concentration was found in CII. In addition, the treatment and the cluster position led to changes in the quercetin values.

Noticeable differences as a function of the variety were also observed. Thus for sample, the major phenolics in 'Lazarino' were quercetin and p-hydroxybenzoic acids, in this order. Their highest levels were found in CI and CII independent of the treatment (Table 3). Overall, p-hydroxybenzoic acid, p-coumaric acid, ferulic acid, naringin and crisin were largely influenced by the treatment and variety, while caffeic acid, quercetin and quercetrin only by the variety and finally chlorogenic acid by the cluster position and variety.

Interestingly, the treatment led to noticeable decreases in the levels of quercetin in all clusters. These increases were particularly noteworthy (> 3-fold) in CIII and contributed to that the highest levels of phenolics were detected in the samples corresponding to cluster position and treatment (Figure 32). On the other hand, several studies indicate that the soluble solids values may be influenced by phenolics, in special flavonols, that can inhibit glycolysis and improve gluconeogenesis (Stakhova, Ladygin, & Stakhov, 2001). Considering the treatment, this relationship was found in all the varieties studied, especially in 'Lazarino' in CI and CIII between SS and quercetrin, 'Summerbrix' in all clusters between SS and quercetrin and 'Tigerella' in all clusters between SS with quercetrin and quercetin. In 'Tigerella' it was observed that, while SS increased, quercetrin and quercetin

decreased. With respect to the cluster position, cherry varieties RDI samples showed a relationship between SS and flavonols. Thus, in 'Lazarino' SS decreased and flavonols increased while in 'Summerbrix' both SS and flavonols increased.

Table 3. Average values of phenolic compounds (mg /100 g DW) ..

In summary, the present study supports the idea that regulated deficit irrigation did not change the fruit organoleptic quality and enhance the levels of some secondary metabolites like certain carotenoids and phenolics. In general, it can be concluded that regulated deficit irrigation with reduction of 40 and 50% in the leaf water potential in common and cherry tomatoes and the cluster position had no major impact in the fruit quality except in 'Lazarino' but this did have a noticeable impact in functional quality.. The treatment did not allow: 1) significant changes on equatorial diameter, SS, a^* and C^*_{ab} values; 2) lycopene and hence total carotenoids; 3) caffeic acid, chlorogenic acid, quercetrin, quercetin and hence total phenolics. Thus, strong varieties to treatment were observed. For example in most cases, 'Summerbrix' did not change the organoleptic parameters; 'Palamós' in total carotenoid while 'Summerbrix', 'Tigerella' and 'Palamós' in total phenolic compounds. It was also observed that cluster position did not lead to changes in the weight, phytoene, β -carotene and all individual phenolics except chlorogenic acid. The organoleptic and functional quality exhibited greater influence with the variety.

Overall, it can be concluded that the treatment and cluster position affected the organoleptic quality parameters to the greatest extent in 'Lazarino', the carotenoids levels in cherry varieties and 'Tigerella' and phenolics in all varieties.

ABBREVIATIONS USED

E.T.S.I.A., Escuela Técnica Superior de Ingeniería Agronómica; a.s.l., above sea level; RDI, regulated deficit irrigation; ETc, crop evapotranspiration; FAO, Food and Agriculture Organization of the United Nations; CIELAB, the Commission International of IEclairage (CIE), defined colour spaces that includes CIE $L^*a^*b^*$; UV-vis, ultraviolet-visible; RRLC, rapid

resolution liquid chromatography; UHPLC, ultra performance liquid chromatography; SS, soluble solids; TC, total carotenoids; TPC, total phenolic content; FW, fresh weight; DW dry weight;

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Código de campo cambiado

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Notes

The authors declare that there are no competing financial interests

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699

Table 1. Average values of parameters related to the commercial quality of tomatoes ^a

'Lazarino'		CI			CII			CIII			$A_{CI, CII, CIII}^b$	
		RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
Diameter (cm)	Equa.	4.6 ± 0.4	4.9 ± 0.4	**	4.4 ± 0.4	4.7 ± 0.2	**	4.7 ± 0.3	4.5 ± 0.4	n.s.	*	***
	Long.	4.6 ± 0.4	4.9 ± 0.4	**	4.1 ± 0.6	4.7 ± 0.2	***	4.7 ± 0.4	4.5 ± 0.4	n.s.	***	**
Weight (g)		13.1 ± 2.9	16.4 ± 3.5	**	12.7 ± 4.0	14.4 ± 1.6	*	14.3 ± 2.8	12.6 ± 2.6	*	n.s.	***
Soluble solids		7.7 ± 0.5	7.7 ± 0.3	n.s.	7.6 ± 0.6	7.9 ± 0.7	n.s.	6.9 ± 0.4	7.1 ± 0.8	n.s.	***	***
Colour	L*	34.1 ± 2.8	36.9 ± 1.4	***	37.3 ± 1.9	38.1 ± 1.3	n.s.	43.9 ± 2.3	47.4 ± 3.3	n.s.	***	***
	a*	23.2 ± 2.1	23.8 ± 1.8	n.s.	23.7 ± 2.8	25.4 ± 1.8	*	17.4 ± 5.2	14.0 ± 8.0	n.s.	***	***
	b*	21.4 ± 2.0	23.9 ± 2.2	***	24.8 ± 3.1	26.0 ± 2.0	n.s.	34.9 ± 3.3	37.6 ± 3.0	*	***	***
	C* _{ab}	31.6 ± 2.4	33.7 ± 2.5	**	34.5 ± 1.9	36.4 ± 2.1	**	39.4 ± 3.1	38.9 ± 9.4	n.s.	***	***
	h _{ab}	42.8 ± 2.9	45.1 ± 2.4	**	46.3 ± 6.0	45.7 ± 2.8	n.s.	63.7 ± 7.8	70.0 ± 11.6	*	***	***

'Summerbrix'		CI			CII			CIII			$A_{CI, CII, CIII}^b$	
		RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
Diameter (cm)	Equa.	4.0 ± 0.3	3.9 ± 0.4	n.s.	3.8 ± 0.3	3.8 ± 0.3	n.s.	3.8 ± 0.4	3.8 ± 0.5	n.s.	*	n.s.
	Long.	4.9 ± 0.4	4.6 ± 0.6	*	4.4 ± 0.4	4.6 ± 0.5	*	4.7 ± 0.4	4.7 ± 0.5	n.s.	***	n.s.
Weight (g)		12.7 ± 2.5	10.5 ± 3.2	*	9.3 ± 2.0	10.2 ± 2.5	n.s.	10.3 ± 2.4	10.5 ± 3.7	n.s.	***	n.s.
Soluble solids		6.9 ± 0.6	7.2 ± 0.7	n.s.	7.7 ± 1.0	8.3 ± 0.6	*	7.9 ± 0.7	8.1 ± 0.7	n.s.	**	***
Colour	L*	35.3 ± 1.5	35.1 ± 1.3	n.s.	35.3 ± 0.9	35.2 ± 1.0	n.s.	37.9 ± 2.0	38.0 ± 3.0	n.s.	***	***
	a*	25.0 ± 1.3	26.1 ± 2.2	*	25.7 ± 1.6	26.4 ± 1.7	n.s.	28.7 ± 2.0	28.5 ± 3.3	n.s.	***	**
	b*	21.8 ± 2.2	21.4 ± 2.3	n.s.	21.5 ± 1.2	21.7 ± 1.7	n.s.	25.5 ± 3.3	25.8 ± 4.6	n.s.	***	***
	C* _{ab}	33.2 ± 2.2	33.7 ± 2.9	n.s.	33.6 ± 1.8	34.1 ± 2.2	n.s.	38.4 ± 3.2	38.6 ± 4.2	n.s.	***	***
	h _{ab}	41.0 ± 2.4	39.4 ± 2.1	*	40.0 ± 1.6	39.4 ± 1.3	n.s.	41.6 ± 3.0	42.0 ± 5.6	n.s.	n.s.	*

'Tigerella'		CI			CII			CIII			$A_{CI, CII, CIII}^b$	
		RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
Diameter (cm)	Equa.	7.4 ± 0.6	7.2 ± 0.5	n.s.	7.2 ± 0.5	6.7 ± 0.7	n.s.	7.5 ± 0.3	7.6 ± 0.9	n.s.	n.s.	*
	Long.	7.0 ± 0.5	6.7 ± 0.6	n.s.	6.5 ± 0.2	6.4 ± 0.7	n.s.	6.6 ± 0.8	7.0 ± 0.9	n.s.	n.s.	n.s.
Weight (g)		47.7 ± 5.0	45.0 ± 2.7	n.s.	41.9 ± 3.7	44.2 ± 8.2	n.s.	45.8 ± 4.2	47.8 ± 10.0	n.s.	n.s.	n.s.
Soluble solids		5.2 ± 0.5	3.8 ± 0.2	***	6.1 ± 0.3	3.9 ± 0.0	***	5.4 ± 0.2	3.9 ± 0.0	***	**	n.s.
Colour	L*	33.4 ± 1.0	36.7 ± 2.3	**	37.1 ± 2.5	38.7 ± 4.2	n.s.	35.4 ± 1.7	38.6 ± 4.4	n.s.	*	n.s.
	a*	23.0 ± 1.6	20.9 ± 2.2	*	26.8 ± 3.7	24.1 ± 3.4	n.s.	28.4 ± 2.3	24.5 ± 2.2	*	**	*
	b*	24.1 ± 2.4	23.9 ± 3.5	n.s.	29.8 ± 3.9	22.6 ± 2.6	**	28.4 ± 2.5	24.2 ± 1.8	**	*	n.s.
	C* _{ab}	33.3 ± 2.6	31.8 ± 3.6	n.s.	40.1 ± 4.9	33.1 ± 3.9	*	40.2 ± 3.3	34.4 ± 2.7	**	**	n.s.
	h _{ab}	46.3 ± 2.0	48.7 ± 3.7	n.s.	48.1 ± 2.8	43.2 ± 2.8	*	45.0 ± 1.1	44.6 ± 1.9	n.s.	*	**

'Palamós'		CI			CII			CIII			$A_{CI, CII, CIII}^b$	
		RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
Diameter (cm)	Equa.	9.3 ± 1.1	9.8 ± 0.3	n.s.	9.6 ± 0.7	10.0 ± 0.5	n.s.				n.s.	n.s.
	Long.	8.8 ± 0.9	9.1 ± 0.3	n.s.	8.8 ± 0.6	9.2 ± 0.3	n.s.				n.s.	n.s.
Weight (g)		96.3 ± 30.3	106.8 ± 10.1	n.s.	98.9 ± 20.7	109.1 ± 10.5	n.s.				n.s.	n.s.
Soluble solids		4.7 ± 0.5	4.4 ± 0.3	n.s.	4.8 ± 0.6	4.5 ± 4.5	n.s.				n.s.	n.s.
Colour	L*	41.0 ± 1.9	42.4 ± 2.0	n.s.	43.9 ± 3.6	46.0 ± 3.6	n.s.				*	*
	a*	31.1 ± 1.7	27.6 ± 1.3	***	26.1 ± 5.2	24.1 ± 4.8	n.s.				*	*
	b*	34.7 ± 2.8	35.0 ± 3.1	n.s.	37.8 ± 3.7	38.5 ± 3.3	n.s.				n.s.	*
	C* _{ab}	46.7 ± 1.7	44.6 ± 2.0	*	46.3 ± 1.7	45.7 ± 1.4	n.s.				n.s.	n.s.
	h _{ab}	48.1 ± 3.5	51.7 ± 3.5	*	55.3 ± 7.7	58.0 ± 7.3	n.s.				*	*

'Byelsa'		CI			CII			CIII			$A_{CI, CII, CIII}^b$	
		RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
Diameter (cm)	Equa.	6.7 ± 0.9	7.0 ± 0.6	n.s.								
	Long.	8.2 ± 1.5	8.7 ± 0.6	n.s.								
Weight (g)		43.3 ± 13.8	65.6 ± 9.6	*								
Soluble solids		6.5 ± 0.8	5.0 ± 0.6	**								
Colour	L*	35.5 ± 0.6	42.3 ± 3.3	***								
	a*	32.3 ± 2.2	31.1 ± 2.4	n.s.								
	b*	25.6 ± 1.9	36.2 ± 6.0	**								
	C* _{ab}	41.2 ± 2.8	47.9 ± 4.4	**								
	h _{ab}	38.4 ± 1.1	49.0 ± 5.7	**								

^aMean values ± SD (n=14 common and n=42 cherry tomatoes). ^bSignificance of differences between RDI and control samples (A_{RC}), and cluster position ($A_{CI, CII, CIII}$) is given: n.s., not significant; *, $P < 0.1$; **, $P < 0.01$; ***, $P < 0.001$.

Table 2. Average values of carotenoids (mg /100 g DW) in the cherry and common tomatoes studied^a

'Lazarino'										
	CI			CII			CIII			$A_{CI, CII, CIII}^b$
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	
Phytoene	7.4 ± 0.0	5.4 ± 0.1	***	5.9 ± 0.1	4.1 ± 0.3	***	1.9 ± 0.0	1.8 ± 0.2	n.s.	***
Phytofluene	1.3 ± 0.1	0.7 ± 0.0	***	0.9 ± 0.0	0.8 ± 0.0	**	1.0 ± 0.0	0.6 ± 0.0	***	***
Lutein	1.5 ± 0.0	1.7 ± 0.1	*	1.7 ± 0.1	2.9 ± 0.6	*	2.9 ± 0.0	2.0 ± 0.3	***	*
Lycopene	64.0 ± 1.8	46.6 ± 1.0	***	55.4 ± 0.5	49.2 ± 1.4	**	34.2 ± 0.8	25.2 ± 0.7	***	***
β-carotene	7.0 ± 0.1	8.5 ± 0.6	**	9.2 ± 0.6	8.3 ± 0.2	*	9.1 ± 0.0	6.6 ± 0.1	***	**
Total carot	81.2 ± 0.5	62.8 ± 0.3	***	73.0 ± 0.2	65.3 ± 0.4	**	49.0 ± 0.2	36.1 ± 0.3	***	***
'Summerbrix'										
	CI			CII			CIII			$A_{CI, CII, CIII}^b$
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	
Phytoene	13.9 ± 0.2	11.0 ± 0.3	***	13.6 ± 0.1	12.1 ± 0.2	***	7.3 ± 0.1	7.8 ± 0.0	*	***
Phytofluene	1.7 ± 0.1	1.4 ± 0.0	*	1.9 ± 0.1	1.8 ± 0.1	n.s.	1.7 ± 0.0	1.5 ± 0.1	*	*
Lutein	1.3 ± 0.0	1.3 ± 0.0	n.s.	1.0 ± 0.1	0.7 ± 0.1	*	1.3 ± 0.0	2.7 ± 0.2	***	***
Lycopene	119.4 ± 2.4	74.8 ± 3.5	***	83.6 ± 0.7	73.8 ± 4.9	*	104.8 ± 6.9	70.1 ± 5.1	**	***
β-carotene	7.9 ± 0.4	7.9 ± 0.2	n.s.	7.2 ± 0.1	5.9 ± 0.5	*	8.0 ± 0.6	12.2 ± 0.2	***	*
Total carot	144.2 ± 0.7	96.2 ± 1.0	***	107.2 ± 0.3	94.2 ± 1.3	*	123.0 ± 1.9	94.1 ± 1.4	**	***
'Tigerella'										
	CI			CII			CIII			$A_{CI, CII, CIII}^b$
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	
Phytoene	13.5 ± 0.8	16.8 ± 0.6	**	12.3 ± 0.1	10.7 ± 0.7	*	16.7 ± 0.4	10.2 ± 0.5	***	***
Phytofluene	2.2 ± 0.1	nd	nd	2.0 ± 0.1	nd	nd	2.5 ± 0.2	nd.	nd.	**
Lutein	2.7 ± 0.1	3.9 ± 0.1	*	3.0 ± 0.3	3.9 ± 0.2	*	2.6 ± 0.0	4.2 ± 1.0	*	n.s.
Lycopene	118.8 ± 0.0	127.6 ± 5.4	*	53.1 ± 4.6	89.4 ± 1.5	***	75.8 ± 3.9	151.3 ± 8.2	***	***
β-carotene	10.9 ± 0.5	15.6 ± 0.4	***	8.9 ± 0.9	15.8 ± 0.1	***	9.5 ± 0.5	16.9 ± 1.7	**	*
Total carot	147.8 ± 0.3	163.8 ± 1.6	**	79.3 ± 1.2	119.8 ± 0.6	***	107.0 ± 1.2	182.6 ± 2.3	***	***
'Palamós'										
	CI			CII			CIII			$A_{CI, CII, CIII}^b$
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	
Phytoene	3.5 ± 0.2	5.0 ± 0.1	***	2.7 ± 0.2	3.3 ± 0.1	**	nd	nd	nd	**
Phytofluene	0.9 ± 0.0	nd	nd	nd	nd	nd	nd	nd	nd	***
Lutein	1.5 ± 0.1	1.5 ± 0.1	n.s.	1.3 ± 0.0	1.6 ± 0.1	**	nd	nd	nd	*
Lycopene	60.8 ± 0.4	77.5 ± 5.8	**	58.4 ± 0.6	40.2 ± 0.4	***	nd	nd	nd	n.s.
β-carotene	5.2 ± 0.4	6.2 ± 0.2	*	6.5 ± 0.3	6.5 ± 0.5	n.s.	nd	nd	nd	**
Total carot	71.9 ± 0.2	90.3 ± 1.5	**	68.9 ± 0.2	51.6 ± 0.1	***	nd	nd	nd	***
'Byelsa'										
	CI			CII			CIII			$A_{CI, CII, CIII}^b$
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	
Phytoene	9.9 ± 0.8	5.9 ± 0.2	***	nd	nd	nd	nd	nd	nd	***
Phytofluene	nd	nd	nd	nd	nd	nd	nd	nd	nd	***
Lutein	2.3 ± 0.2	3.4 ± 0.3	**	nd	nd	nd	nd	nd	nd	*
Lycopene	124.8 ± 9.3	90.5 ± 0.6	**	nd	nd	nd	nd	nd	nd	n.s.
β-carotene	7.7 ± 0.1	6.4 ± 0.1	***	nd	nd	nd	nd	nd	nd	***
Total carot	144.7 ± 2.6	106.1 ± 0.3	**	nd	nd	nd	nd	nd	nd	***

^aMean values dry weight (DW) ± Standard deviation (SD) (n=12). ^bSignificance of differences between the RDI and control samples (A_{RC}) and cluster position ($A_{CI, CII, CIII}$) is given: n.s., not significant; *, P<0.1; **, P<0.01; ***, P<0.001. nd: not detected

Table 3. Average values of phenolic compounds (mg /100 g DW) in the cherry and common tomatoes studied^a

'Lazarino'	CI			CII			CIII			$A_{CI, CII, CIII}^b$	
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
p- Hydrox. acid	47.9 $\pm$ 4.1	54.0 $\pm$ 0.7	*	46.0 $\pm$ 1.0	41.4 $\pm$ 0.3	**	36.2 $\pm$ 0.4	31.3 $\pm$ 0.6	***	***	***
p- Coumaric acid	17.3 $\pm$ 0.3	17.4 $\pm$ 0.3	n.s.	16.8 $\pm$ 0.0	15.6 $\pm$ 0.2	***	18.4 $\pm$ 0.0	16.9 $\pm$ 0.1	***	***	***
Caffeic acid	13.4 $\pm$ 0.5	16.6 $\pm$ 0.1	***	14.4 $\pm$ 0.0	16.2 $\pm$ 0.1	***	11.2 $\pm$ 1.7	10.5 $\pm$ 0.1	n.s.	*	***
Chlorogenic acid	30.9 $\pm$ 1.0	22.6 $\pm$ 1.5	*	31.3 $\pm$ 0.3	30.5 $\pm$ 0.5	*	91.4 $\pm$ 0.4	111.8 $\pm$ 1.5	***	***	***
Ferulic acid	12.6 $\pm$ 3.3	9.1 $\pm$ 0.1	n.s.	9.2 $\pm$ 0.2	8.8 $\pm$ 0.2	*	11.2 $\pm$ 0.1	12.6 $\pm$ 1.3	n.s.	n.s.	**
Naringin	36.6 $\pm$ 3.6	35.3 $\pm$ 2.2	n.s.	42.5 $\pm$ 1.0	34.0 $\pm$ 1.9	**	35.5 $\pm$ 1.9	35.1 $\pm$ 0.4	n.s.	*	n.s.
Crisin	31.4 $\pm$ 0.7	30.5 $\pm$ 1.8	n.s.	31.4 $\pm$ 1.1	30.9 $\pm$ 0.1	n.s.	30.5 $\pm$ 0.3	31.2 $\pm$ 0.6	n.s.	n.s.	n.s.
Quercetrin	21.0 $\pm$ 0.3	25.6 $\pm$ 1.8	*	25.3 $\pm$ 1.5	26.3 $\pm$ 0.2	n.s.	27.3 $\pm$ 0.7	29.4 $\pm$ 1.6	n.s.	***	*
Quercetin	55.6 $\pm$ 0.1	74.8 $\pm$ 2.9	***	66.7 $\pm$ 0.6	80.4 $\pm$ 2.3	***	83.9 $\pm$ 5.5	99.0 $\pm$ 2.9	**	***	***
Total phenolics	266.7 $\pm$ 17.8	285.9 $\pm$ 2.8	*	283.6 $\pm$ 0.6	284.1 $\pm$ 3.8	n.s.	345.6 $\pm$ 5.1	377.8 $\pm$ 7.4	**	***	***

'Summerbrix'	CI			CII			CIII			$A_{CI, CII, CIII}^b$	
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
p- Hydroxybe. acid	39.1 $\pm$ 0.3	55.9 $\pm$ 2.0	***	37.8 $\pm$ 4.3	49.8 $\pm$ 1.5	**	29.6 $\pm$ 0.5	30.4 $\pm$ 0.0	**	***	***
p- Coumaric acid	16.7 $\pm$ 0.1	14.9 $\pm$ 0.3	***	14.7 $\pm$ 0.1	14.0 $\pm$ 0.2	**	16.7 $\pm$ 0.1	15.9 $\pm$ 0.0	***	***	***
Caffeic acid	15.9 $\pm$ 0.1	17.8 $\pm$ 1.0	*	15.4 $\pm$ 2.4	16.4 $\pm$ 0.9	n.s.	13.7 $\pm$ 0.1	15.3 $\pm$ 0.7	*	n.s.	*
Chlorogenic acid	27.8 $\pm$ 0.6	34.3 $\pm$ 3.1	*	36.8 $\pm$ 0.1	35.2 $\pm$ 1.1	*	48.4 $\pm$ 0.1	49.6 $\pm$ 0.5	*	***	***
Ferulic acid	9.4 $\pm$ 0.3	10.3 $\pm$ 0.1	**	9.7 $\pm$ 0.0	10.5 $\pm$ 0.4	*	9.7 $\pm$ 0.0	9.6 $\pm$ 0.6	n.s.	*	*
Naringin	23.8 $\pm$ 0.7	31.7 $\pm$ 2.5	**	32.2 $\pm$ 0.7	28.8 $\pm$ 1.8	*	36.4 $\pm$ 0.2	31.6 $\pm$ 0.0	***	***	n.s.
Crisin	31.3 $\pm$ 0.2	31.3 $\pm$ 0.4	n.s.	30.8 $\pm$ 0.7	31.6 $\pm$ 0.1	n.s.	31.5 $\pm$ 0.0	30.7 $\pm$ 0.4	*	n.s.	*
Quercetrin	23.0 $\pm$ 1.2	21.6 $\pm$ 0.9	n.s.	24.6 $\pm$ 1.3	21.0 $\pm$ 0.6	*	27.7 $\pm$ 0.8	27.7 $\pm$ 1.7	n.s.	**	***
Quercetin	38.0 $\pm$ 0.8	44.7 $\pm$ 1.9	**	46.2 $\pm$ 0.7	46.1 $\pm$ 2.1	n.s.	65.8 $\pm$ 2.3	67.8 $\pm$ 0.4	n.s.	***	***
Total phenolics	225.0 $\pm$ 1.3	266.5 $\pm$ 5.6	**	248.2 $\pm$ 2.1	253.4 $\pm$ 3.5	*	279.5 $\pm$ 3.0	278.6 $\pm$ 2.5	n.s.	***	***

'Tigerella'	CI			CII			CIII			$A_{CI, CII, CIII}^b$	
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
p- Hydroxybe. acid	99.2 $\pm$ 2.9	85.6 $\pm$ 0.5	**	99.8 $\pm$ 1.5	84.8 $\pm$ 0.2	***	123.0 $\pm$ 1.8	80.6 $\pm$ 0.4	***	***	***
p- Coumaric acid	45.7 $\pm$ 0.9	32.9 $\pm$ 0.3	***	83.2 $\pm$ 3.3	30.4 $\pm$ 0.3	***	95.8 $\pm$ 1.6	31.6 $\pm$ 0.4	***	***	***
Caffeic acid	12.0 $\pm$ 0.0	17.5 $\pm$ 0.0	***	10.8 $\pm$ 0.4	17.3 $\pm$ 0.0	***	14.9 $\pm$ 0.7	16.2 $\pm$ 0.1	*	***	***
Chlorogenic acid	29.9 $\pm$ 0.6	53.1 $\pm$ 0.2	***	50.5 $\pm$ 1.4	76.6 $\pm$ 0.5	***	57.4 $\pm$ 0.5	77.1 $\pm$ 0.6	***	***	***
Ferulic acid	12.8 $\pm$ 0.8	12.0 $\pm$ 0.8	n.s.	12.2 $\pm$ 0.0	13.4 $\pm$ 0.2	***	15.3 $\pm$ 1.0	13.1 $\pm$ 0.5	*	**	*
Naringin	13.4 $\pm$ 3.6	8.6 $\pm$ 0.0	*	23.8 $\pm$ 1.2	10.3 $\pm$ 0.0	***	30.4 $\pm$ 1.3	9.5 $\pm$ 1.0	***	***	*
Crisin	30.3 $\pm$ 0.8	31.5 $\pm$ 0.4	*	30.3 $\pm$ 0.2	32.0 $\pm$ 0.1	***	34.7 $\pm$ 0.4	31.2 $\pm$ 0.7	**	***	n.s.
Quercetrin	18.6 $\pm$ 1.0	24.7 $\pm$ 0.4	***	15.3 $\pm$ 0.3	28.0 $\pm$ 0.0	***	23.1 $\pm$ 0.4	30.3 $\pm$ 0.3	***	***	***
Quercetin	28.6 $\pm$ 0.2	56.0 $\pm$ 0.2	***	29.2 $\pm$ 2.0	69.8 $\pm$ 1.1	***	34.4 $\pm$ 0.9	60.4 $\pm$ 0.5	***	**	***
Total phenolics	290.5 $\pm$ 5.1	321.9 $\pm$ 0.8	***	355.1 $\pm$ 2.0	362.6 $\pm$ 1.5	***	429.0 $\pm$ 6.9	350.0 $\pm$ 1.5	***	***	***

'Palamós'	CI			CII			CIII			$A_{CI, CII, CIII}^b$	
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
p- Hydroxybe. acid	73.1 $\pm$ 0.4	69.6 $\pm$ 1.6	*	65.0 $\pm$ 1.3	66.7 $\pm$ 0.6	*				***	*
p- Coumaric acid	29.1 $\pm$ 0.7	25.7 $\pm$ 0.4	**	25.9 $\pm$ 0.1	22.4 $\pm$ 1.2	**				**	*
Caffeic acid	10.6 $\pm$ 0.4	9.8 $\pm$ 0.2	*	12.6 $\pm$ 0.5	11.5 $\pm$ 0.2	*				**	***
Chlorogenic acid	44.5 $\pm$ 0.3	51.5 $\pm$ 0.9	**	77.0 $\pm$ 0.2	80.5 $\pm$ 2.0	n.s.				***	***
Ferulic acid	9.3 $\pm$ 0.2	9.9 $\pm$ 0.2	*	10.4 $\pm$ 0.4	10.2 $\pm$ 0.5	n.s.				*	n.s.
Naringin	18.2 $\pm$ 1.8	13.7 $\pm$ 0.6	*	14.5 $\pm$ 0.7	14.0 $\pm$ 1.6	n.s.				*	n.s.
Crisin	31.7 $\pm$ 0.0	31.4 $\pm$ 0.7	n.s.	32.0 $\pm$ 0.9	33.8 $\pm$ 0.3	**				n.s.	**
Quercetrin	25.1 $\pm$ 0.6	22.9 $\pm$ 0.1	**	31.7 $\pm$ 0.4	29.3 $\pm$ 0.3	**				***	***
Quercetin	35.1 $\pm$ 1.2	37.6 $\pm$ 0.5	*	40.9 $\pm$ 1.3	46.9 $\pm$ 0.8	**				**	***
Total phenolics	276.7 $\pm$ 2.8	272.1 $\pm$ 1.4	n.s.	310.0 $\pm$ 0.5	315.3 $\pm$ 6.5	n.s.				***	***

'Byelsa'	CI			CII			CIII			$A_{CI, CII, CIII}^b$	
	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control	A_{RC}^b	RDI	Control
p- Hydroxybe. acid	31.5 $\pm$ 0.5	67.0 $\pm$ 0.8	***								
p- Coumaric acid	17.0 $\pm$ 0.1	22.4 $\pm$ 1.3	**								
Caffeic acid	10.6 $\pm$ 0.1	11.5 $\pm$ 0.2	**								
Chlorogenic acid	112.5 $\pm$ 1.1	79.1 $\pm$ 4.2	***								
Ferulic acid	12.7 $\pm$ 1.2	10.3 $\pm$ 0.5	*								
Naringin	35.3 $\pm$ 0.2	14.1 $\pm$ 1.7	***								
Crisin	31.4 $\pm$ 0.7	33.9 $\pm$ 0.4	**								
Quercetrin	29.6 $\pm$ 1.5	29.4 $\pm$ 0.4	n.s.								
Quercetin	99.6 $\pm$ 2.6	47.1 $\pm$ 0.9	***								
Total phenolics	380.2 $\pm$ 6.1	314.8 $\pm$ 9.7	**								

^aMean values dry weight (DW) $\pm$ Standard deviation (SD) (n=6). ^bSignificance of differences between RDI and control (A_{RC}) and cluster height ($A_{CI, CII, CIII}$) is given: n.s., not significant; *, P<0.1; **, P<0.01; ***, P<0.001.

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Figure1. Photographs of the tomato varieties studied. A) 'Lazarino', B) 'Summerbrix', C) 'Tigerella', D) 'Byelsa' and E) 'Palamós'

Figure 21. Total carotenoids (mg/100 g DW) in the common and cherry tomatoes studied. Mean values in the same cluster for RDI and control columns followed by the same letter do not differ significantly at confidence level 95% and significance of differences between cluster height is given: n.s., not significant; *, $P < 0.1$; **, $P < 0.01$; ***, $P < 0.001$. The values are means $\pm$ SE ($n = 4$)

Figure 2. Cromatogram of tomato carotenoids at 285 , 350 and 450 nm of the variety *Tigerella*. 1. Phytoene; 2. Phytofluene; 3. Lutein; 4. Lycopene; 5. β-carotene

Figure 3. Total phenolic content (mg/100 g DW) in the common tomato and cherry tomatoes studied. Mean values in the same cluster of RDI and control column followed by the same letter do not differ significantly at confidence level 95% and significance of differences between cluster height is given: n.s., not significant; *, $P < 0.1$; **, $P < 0.01$; ***, $P < 0.001$. The values are means $\pm$ SE (n = 6)

[Figure 4. Cromatogram of tomato phenolics at 280 and 320 nm of the variety Tigerella.](#)
[1. p-Hydroxybenzoic acid; 2.Caffeic acid; 3. Chlorogenic acid; 4. p-Coumaric acid; 5.](#)
[Ferulic acid; 6. Naringin; 7. Crisin; 8. Quercetrin; 9. Quercetin](#)