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Health and taste related compounds in strawberries under various irrigation regimes and bio-stimulant application

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ABSTRACT

Strawberry has a unique status within the fruit species in terms of health and taste related compounds. This experimental study concerned the application of a bio-stimulant at various drip irrigation levels (IR125, IR100, IR75 and IR50). The effects of the bio-stimulant (seaweed extract) on the eating quality, i.e., the taste-related (TSS, fructose, glucose, sucrose and citric, malic, L-ascorbic acid), and health-related (antioxidant activity, total phenol, myricetin and quercetin) compounds were studied in two strawberry cultivars. The 'Rubygem' with its higher sugar and lower acid content has been more preferable than the 'Kabarla' cultivar. The bio-stimulant contributes to taste by improving the TSS, fructose, sucrose and also to health by increasing the quercetin content of the fruit which is associated to the cardiovascular properties and cancer reducing agents. The experiment conducted revealed significant increases only in the TSS contents and antioxidant activity under the IR50 and IR75 deficit irrigation treatments.

1. Introduction

Berries are highly consumed for their attractive colour, delicate texture, and unique flavor and known as rich sources of natural antioxidants (Manganaris, Goulas, Vicente, & Terry, 2014). Their consumption has been associated to various cardiovascular, anti-proliferative and neurologic benefits. Berry fruits have vitamins, minerals, folate and fiber which are the main dietary components and also contain phytochemical compounds mostly represented by polyphenols (Giampieri et al., 2012). Enhancement of strawberry production needs the availability of high water sources due to their large leaf area, shallow root system, and fruits with high water contents (Chandler & Ferre, 1990). According to a UNESCO report, one-third of the world's population lives under the water scarcity condition, and it is predicted that this will reach over two-thirds in 2025 (UNESCO, 2009). Increasing world population demands increased land and water use. In this context, although farmers of the old world are knowledgeable and experienced in traditional crop production, they are in need of the contemporary clues obtained via the field experiments conducted for Sustainable land and water management. Farmers generally use their past experience to determine the optimal amount of irrigation water by observing the weather conditions and the visual plant indicators of stress. However, they tend to use excessively or inadequately supplied water, which can have a negative impact on the vegetative part of the crop and its fruit size (Ghaderi, Normohammadi, & Javadi, 2015; Liu et al., 2007). The amount of water applied not only affects yield and the vegetative part of the plant (Adak, Gubbuk, & Tetik, 2018; Yuan, Sun, & Nishiyama, 2004) but also influences the fruit quality parameters of taste and health related compounds (Giné-Bordonaba & Terry, 2010; Giné-Bordonaba and Terry, 2016; Weber et al., 2017). Deficit irrigation is applied not only to decrease water consumption but also to improve the quality parameters of taste and health via related compounds (Adak, et al., 2018; Giné-Bordonaba & Terry, 2010; Weber et al., 2017). Quality parameters of fruit such as color, firmness and chemical composition influence the consumer preference (Ornelas-Paz et al., 2013). Fruit flavor is mainly determined by the contents of total soluble solids, total acids and their ratios (Krüger et al., 2012). The content of taste and health-related compounds in strawberry could vary depending on the genotype (Kosar, Kafkas, Paydaş, & Baser, 2004), agricultural practice, environment, and maturity (Tulipani et al., 2011). However, the genotypic properties of strawberries were found to be more influential than cultivation practices for quality parameters (Capocasa, Scalzo, Mezzetti, & Battino, 2008). Some pre-harvest practices were applied together with irrigation levels for increasing health-related compounds (Giné-Bordonaba & Terry, 2016). Bio-stimulants have been gaining attention especially in sustainable agriculture, because their application enhances several physiological processes, that increase nutrient use efficiency, encouraging plant development and reducing

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fertilizer consumption (Bulgari, Cocetta, Trivellini, Vernieri, & Ferrante, 2015; Kunicki, Grabowska, Sekara, & Wojciechowska, 2010).

To the best of our knowledge, there has been no research conducted to investigate the combined effects of irrigation regimes with bio-stimulant application on health and taste-related compounds under farmers field conditions in the Mediterranean region of Turkey. Accordingly, the aim of this study is to determine the influence of the different irrigation levels (IR125, IR100, IR75, and IR50), bio-stimulant applications and their combined effects on health (total antioxidant, total phenol, quercetin and myrcetin) and taste-related (TSS, individual sugars and acids) compounds for two strawberry cultivars (Rubygem cv. and Kabarla cv.).

2. Materials and methods

The experiment was conducted in a high tunnel at the experimental farm of the Horticulture Department of the University of Çukurova (latitude: 36°59′9N, longitude 35°27′7E and altitude 20 m above sea level). Strawberries (*Fragaria* x *ananassa* Duch. Rubygem, Kabarla cv.) were planted on November 10 in 2015 and harvesting continued until June 8 in 2016.

The berries were planted in trapezoidal raised beds measuring 0.70 m from the base, 0.50 m at the top, with a height of 0.30 m. The distance between the beds was 0.4 m and the beds were covered by 0.05 mm-thick two-sided polyethylene mulch cover with a grey upper side and black under side suitable to the conventional cultural practices in the area. After planting, equal amounts of water was applied to all treatments until the plants were 3 trifoliate (28 January). Fertilizer was applied uniformly to all treatments during the trial through drip irrigation and foliar spraying. Plant protection was carried out by the timely spraying of the agricultural pesticides. This production system was described previously by Saridas, Paydas Kargı, Kapur, and Celiktopuz (2017).

The trail was implemented as a 2 × 4 × 2 factorial scheme in split split plot design at 3 replicates at totally 48 plots. The strawberry plant was subjected to four irrigation water levels as IR50, IR75, IR100, IR125 in which the water quantities applied were 0.5, 0.75, 1.00 and 1.25 times the pan evaporation measured by the US Weather Service Class A pan with a standard 120.7 cm diameter and 25 cm depth placed over the crop canopy in the center of the high tunnel.

The commercial bio-stimulant applied in this experimental study is natural, non-toxic and a new generation product obtained from seaweed extraction with organic certification. Bio-stimulant applications started approximately 2 months after planting with foliar application (Table 1).

The content of the bio-stimulant was certified by the BCS Öko-Garantie GMBH, Nurnberg, Germany as seaweed extract containing 67% organic matter, 1.5% K2O , 18% alginic acid and 250 ppm gibberellic acid.

Irrigation water (salinity 0.18 dS/m) was applied using drip tubes with emitters spaced every 0.3 m, with a flow rate of 2.7 L h^{-1} and the amount of irrigation water was calculated by using Eq (1).

$$t = \frac{A \times Ep \times pc \times kcp}{q \times n} \quad (1)$$

where, t is the irrigation time (hour), A is the area of the plot (m^2), Ep is the cumulative free surface water evaporation at irrigation interval (mm), pc is the plant cover (%), kcp is the crop-pan coefficients of 0.5, 0.75, 1.00, 1.25 for various irrigation regimes throughout the trial, q is the flow rate of emitters and n is the number of emitters in the plot.

Table 1
Application times and dose of bio-stimulant.

Application No	Application time	Dose of application
1	12.01.2016	20 g/15 l water
2	02.02.2016	20 g/15 l water
3	22.02.2016	20 g/15 l water
4	14.03.2016	20 g/15 l water

All results given here were obtained from the fruits harvested on 10 May 2016 for which the yield was maximum. The effect of different irrigation regimes can be seen clearly from the results. From the initiation of the treatment to the end of the trial, a total of 417, 345, 274 and 203 mm of water were applied to treatments IR125, IR100, IR75 and IR50 respectively.

As a pomological analysis, total soluble solids in fruit juice of each plot were determined by a hand-type refractometer (ATAGO ATC-1, Tokyo, Japan). The Shimadzu HPLC system, equipped with a pump and a refractive index detector (RID-10A), was used for sugar analysis (fructose, glucose, sucrose). The sugar contents were determined by using an Inertsil NH2 column (4.6 mm × 250 mm) maintained at 40 °C. The organic acid contents (citric, malic, L-ascorbic acid) were analyzed by using an HPLC system (Agilent 1100 series G1322A; Germany) according to the method of Bozan, Tunalıer, Koşar, Altıntaş and Başer (1997). An Aminex HPX-87H column (300 mm × 7.8 mm) was used in the HPLC system, which was controlled by Agilent software run on a personal computer. The organic acid content of the samples was determined qualitatively and quantitatively at a wavelength of 210 nm by comparison of the external standard calibration curve and the retention time of the standard.

Vitamin C analysis of the fruit juice of the strawberries was carried out by using an HPLC system (LC-10A HPLC series; Shimadzu, Kyoto, Japan), a UV detector, and a Prevail organic acid column (150 mm × 4.6 mm, 5 μm), according to the method developed by Bozan, Tunalıer, Koşar, Altıntaş and Başer (1997). Determination of the vitamin C content of the samples was performed qualitatively and quantitatively at a wavelength of 242 nm by comparison of the external standard calibration curve and the retention time of the standard.

The total phenolic content of the fruit juices was determined by using a Folin–Ciocalteu reagent with the modified method of Spanos and Wrolstad (1990). The absorbance of all samples was measured at 760 nm utilizing a Multiskan GO microplate spectrophotometer. The results were expressed as mg gallic acid equivalent/g weight (mg GAE/g FW) (Bayır, 2007).

The FRAP assay was done according to the method of Benzie and Strain (1996), with some modifications. The results were expressed in μmol TE/g fresh mass. Additional dilution was needed if the FRAP value measured was over the linear range of the standard curve. The content of myricetin and quercetin was determined according to the method of Kosar et al. (2004) by using of HPLC/fluorescence detector.

The experiment was conducted as a three factors randomized complete block design with split split plot with three replications. The data obtained were analyzed with the statistical program JMP version 5.0.1 (SAS Institute Inc., Cary, NC). ANOVA was carried out to determine the differences between the cultivars, irrigation regimes and bio-stimulant application in terms of taste-related and health-related compounds. A least significant difference test was conducted to examine the differences among the groups. The comparisons that yielded $P \leq 0.05$ were considered to be statistically significant.

3. Results and discussion

3.1. Taste related fruit quality indicators

Significant differences between the cultivars treated with varying irrigation regimes were determined for TSS and individual sugars (Table 2). The TSS, fructose and glucose levels are higher in 'Rubygem' than 'Kabarla'. However, Kabarla has a higher sucrose level. These results highlight the differences in the sugar accumulation mechanisms between the 'Rubygem' and 'Kabarla' cultivars with different contents of total soluble solids (TSS) and amounts of individual sugars. Our