

Effects of genotype and harvest year on phytochemical and fruit quality properties of Turkish fig genotypes

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Abstract

This study was conducted over three harvest years to determine effects of Turkish fig genotypes grown in the eastern Mediterranean region of Turkey on phytochemical and fruit quality characters. Fruit quality characters such as fruit weight, fruit width, fruit neck length, total soluble solids (TSS), pH, acidity, and TSS/acidity were examined. Total phenolics (TP), total anthocyanins (TA), antioxidant capacity (TAC), fructose (FRUC), glucose (GLUC), sucrose (SUC), and variables describing fruit skin and flesh colors (L^* , a^* , C , and h°) were also determined. Analysis of the data obtained from 12 fig genotypes, and three harvest years demonstrated a highly significant influence of genotype on phytochemical and fruit quality characters. 'Bursa Siyahı', which has dark black fruit skin, had the highest levels of TA (113.6 μg cy-3-rutinoside g^{-1} fw), TP (105.2 mg GAE/100 g fw), and TAC (10.9 mmol Fe^{2+} kg^{-1} fw). Three yearly averages of fruit weight ranged from 22.8 g ('Sarı İncir') to 57.5 g ('Bursa Siyahı'), and ostiole width ranged from 0.9 mm ('Bursa Siyahı') to 3.7 mm (31-IN-16). These results indicate that TP ($r = 0.77$) contents correlated moderately to TAC, more so than with TA ($r = 0.56$). Both FRUC and SUC were negatively correlated with TA ($r = -0.34$ and $r = -0.42$, respectively). These data demonstrate that genotype is the main influence on the phytochemical and fruit quality characters of figs.

Additional key words: antioxidant capacity; *Ficus carica*; fruit characters; fruit color; genotype; harvest year.

Resumen

Efectos del genotipo y el año de cosecha en las propiedades fitoquímicas y de calidad de la fruta de genotipos turcos de higuera

Este trabajo se llevó a cabo para determinar los efectos que producen distintos genotipos turcos de higuera cultivados en la región mediterránea del este de Turquía sobre los caracteres fitoquímicos y de calidad de la fruta (como peso del fruto, ancho del fruto, longitud del cuello del fruto, sólidos solubles totales (TSS), pH, acidez y TSS/acidez). También se determinaron los fenoles totales (TP), antocianinas totales (TA), capacidad antioxidante (TAC), fructosa (FRUC), glucosa (GLUC), sacarosa (SUC) y las variables que describe la piel del fruto y colores de su carne (L^* , a^* , C y h°). El análisis de los datos obtenidos con 12 genotipos en tres años de cultivo demostró que hay una influencia altamente significativa del genotipo sobre los caracteres fitoquímicos y de calidad de la fruta. 'Bursa Siyahı', que tiene la piel del fruto negro oscuro, tuvo los niveles de TA más altos (113,6 μg de cianidina-3-rutinósido g^{-1} peso fresco), TP (105,2 mg GAE/100 g peso fresco) y TAC (10,9 mmol Fe^{2+} kg^{-1} peso fresco). Las tres medias anuales del peso del fruto variaron entre 22,8 g ('Sarı İncir') y 57,5 g ('Bursa Siyahı'), y el ancho del ostiolo varió entre 0,9 mm ('Bursa Siyahı') y 3,7 mm (31-IN-16). Los contenidos de TP ($r = 0,77$) estuvieron moderadamente correlacionados con los de TAC, más que con los de TA ($r = 0,56$). Tanto FRUC como SUC se correlacionaron negativamente con TA ($r = -0,34$ y $r = -0,42$, respectivamente). Estos datos demuestran que el genotipo es el que más influencia tiene sobre los caracteres fitoquímicos y de calidad de los higos.

Palabras clave adicionales: año de la cosecha; capacidad antioxidante; caracteres frutales; color del fruto; *Ficus carica*; genotipo.

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Abbreviations used: FRAP (ferric reducing antioxidant power method); fw (fruit weight); FRUC (fructose); GAE (gallic acid equivalents); GLUC (glucose); SUC (sucrose); TA (total anthocyanins); TAC (total antioxidant capacity); TP (total phenolics); TPTZ [2,4,6-tris(2-pyridyl)-1,3,5-triazine]; TSS (total soluble solids).

Introduction

The fig, *Ficus carica* L., has been of great importance as a source of human food ever since its earliest cultivation as a fruit tree. Seventy percent of the world's figs are produced in the Mediterranean countries, where figs are an important part of the Mediterranean diet, that is thought to be related to health and longevity (Trichopoulou *et al.*, 2006).

In the last decade, there has been refreshed interest in studying and quantifying the phenolic metabolites of fruits and vegetables due to their health-promoting properties. Antioxidant compounds, such as phenolics, organic acids, vitamin E, and carotenoids scavenge free radicals, thus inhibiting the oxidative mechanisms that may lead to degenerative illnesses (Silva *et al.*, 2004). Anthocyanins and other phenolic compounds are responsible for many health benefits (Duthie *et al.*, 2000). Anthocyanins have been identified as key contributors to antioxidant activity *in vitro* and *in vivo* (Wang *et al.*, 1997). Phenolic compounds are common plant secondary metabolites with physiological functions in plants and favorable effects on human health, due to their antioxidant activities. Phenolics may serve this purpose by reducing or donating hydrogen to other compounds, scavenging free radicals, and quenching singlet oxygen (Costa *et al.*, 2009).

A great benefit of the Mediterranean diet is its high level of natural antioxidants derived from fruits, including figs, and vegetables, which contribute antioxidant vitamins (Solomon *et al.*, 2006). The green, yellow, brown, purple and the black colors in figs originate from carotenoid and anthocyanin pigments produced in the fruits during maturation. There have now been more than 50 metabolites identified in fig fruit. The consumption of these health-promoting compounds in figs may provide protection against several human diseases (Oliveira *et al.*, 2010). Figs also are an excellent source of fiber, minerals, and polyphenols. They are low in sodium and have no fat or cholesterol (Vinson, 1999). Previous studies published on fig have examined phytochemical components such as phenolics (Solomon *et al.*, 2006; Del Caro & Piga, 2008; Oliveira *et al.*, 2009), anthocyanins (Solomon *et al.*, 2006; Dueñas *et al.*, 2008), sugars (Melgarejo *et al.*, 2003; Çalışkan & Polat, 2011), and antioxidant capacity (Solomon *et al.*, 2006; Çalışkan & Polat, 2011). Solomon *et al.* (2006) showed that the higher the polyphenol content, particularly anthocyanins, in fig fruit, the higher their antioxidant activity. Çalışkan & Polat

(2011) reported that considerable variation exists in certain phytochemical and antioxidant properties of fig accessions grouped according to fruit skin color groups. Some purple- and black-skinned fig fruits contained 2-fold higher TAC, 15-fold higher TA and 2.5-fold higher TP than the green- and yellow-skinned accessions. However, none of these earlier reports examined the effect of harvest year on these characters.

Turkey is the world's largest producer of dried as well as fresh figs about 21% of the world's annual production. In recent years, the production of fresh figs for export has rapidly increased, mainly in the Mediterranean region of Turkey. However, phytochemical and fruit quality characteristics of important Turkish fig genotypes for fresh consumption have not been investigated in detail. In this work, the influences of year and climatic variables on phytochemical and fruit quality characters were investigated by comparing these characters for each genotype across three years. This information could be useful for the future improvement of phytochemical and fruit quality in fig genotypes.

Material and methods

Plant material

This study was carried out by the Agriculture Faculty at the Mustafa Kemal University, Dörtöyl Experimental Farm (36°54'N, 36°13'E, 198 m elevation) in Hatay, Turkey, during 2008, 2009 and 2010. This study was designed using eight cultivars ('Bursa Siyahı', 'Göklop', 'Morgüz', 'Sarılöp', 'Sarı Zeybek', 'Sarı İncir', 'Yediveren' and 'Yeşilgüz'), and four genotypes (31-IN-01, 31-IN-09, 31-IN-16 and 31-IM-05), which are promising genotypes originated from the eastern Mediterranean Region of Turkey (Ozkaya, 1997). The cultivars 'Bursa Siyahı' and 'Yediveren' are very popular as fresh figs in Turkey. The remaining fig cultivars, except for 'Sarılöp', 'Sarı Zeybek' and the unimproved genotypes, are also used for fresh market consumption. The Mediterranean region where this study was conducted research is not suitable for production of dried figs due to weather conditions such as high relative humidity. Therefore, fig genotypes were evaluated for phytochemical and fruit quality characteristics while in condition for fresh fig use. All genotypes were propagated by cuttings, and the experimental orchard was established in five replicates with 6 m × 6 m plots in 1997.

According to climate data, the minimum temperatures were below 0°C in January during the experimental years in Dörtyol, Hatay (Fig. 1). The mean temperatures and sunshine duration in harvesting periods, August to September, were higher in 2010 than in 2008 and 2009. Also, no precipitation was recorded in August, 2010.

Phytochemical analyses

Fruit extraction

Fig fruits from each variety were harvested at their fully mature stage in triplicate. Then, 500 g of fruit from each genotype within each replicate were homogenized in a blender at room temperature. The homogenate was centrifuged at 10,000 rpm for 10 min at 22°C. The supernatant was removed and stored frozen at -22°C until analysis for phytochemical properties. The phytochemical characters measured included total anthocyanins, total phenolics, and antioxidant capacity following a single extraction procedure as described by Beccaro *et al.* (2006).

Determination of total phenolics

Total phenolics were determined according to the Folin-Ciocalteu reagent method (Slinkard & Singleton, 1977). In this method, each extract was mixed with Folin-Ciocalteu phenol reagent and water 1:12 (v/v) and incubated for 8 min at room temperature, followed by the addition of 10 mL of 15% (w/v) sodium carbonate, and was allowed to stand for 2 h at room temperature. The absorbance of each sample was measured at 750 nm in a spectrophotometer (Shimadzu UV-1208, Japan). Gallic acid was used as a standard. Results are expressed as mg of gallic acid equivalents (GAE/100 g fresh fruit weight (fw)).

Determination of total antioxidant capacity

Total antioxidant capacity was estimated by the ferric reducing antioxidant power method (FRAP). The FRAP method was carried out as described by Pellegrini *et al.* (2003); the FRAP reagent was prepared by mixing 25 mL acetate buffer, 2.5 mL TPTZ [2,4,6-tris(2-pyridyl)-1,3,5-triazine], and 2 mL ferric

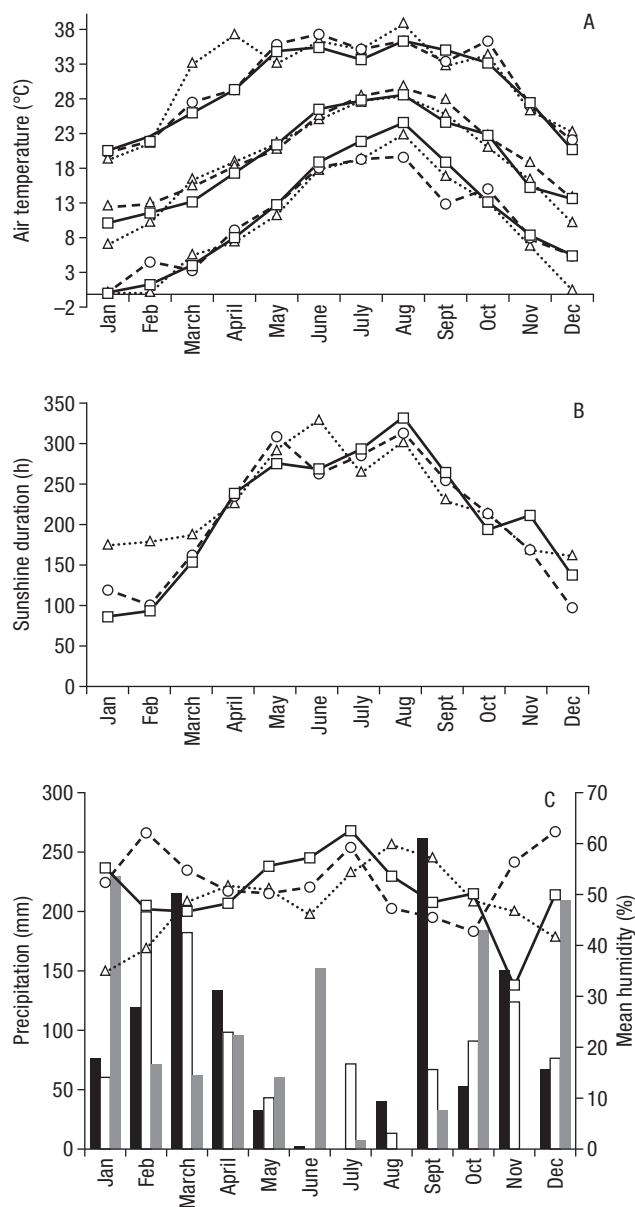


Figure 1. Meteorological data for Hatay, in the eastern Mediterranean region of Turkey. (A) Minimum, maximum and average air temperatures in 2008 (Δ), 2009 (\circ), and 2010 (\square); (B) sunshine duration in 2008 (Δ), 2009 (\circ), and 2010 (\square); (C) precipitation level in 2008 (black columns), 2009 (white columns), and 2010 (grey columns), and mean humidity in 2008 (Δ), 2009 (\circ), and 2010 (\square).

chloride. Then, a 9 mL aliquot of FRAP reagent was combined with 9 mL of methanolic fruit extract. The samples were incubated at 37°C for 30 min, and final absorbance at 593 nm was measured spectrophotometrically (Shimadzu UV-1208, Japan). $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ (10-100 μM) was used as a standard. TAC values were expressed as Fe^{2+} equivalents mmol kg^{-1} fw.

Determination of total anthocyanins

Total anthocyanins were calculated according to the pH differential method (Cheng & Breen, 1991). Absorbance was measured at 520 and 700 nm in buffers at pH 1.0 and pH 4.5 where

$$A = (A_{520} - A_{700})_{pH1.0} - (A_{520} - A_{700})_{pH4.5}$$

Results were expressed as cyanidin-3-rutinoside, molar extinction coefficient of 28.8 and molecular weight of 595.2, μg equivalents g^{-1} fresh weight of fruit.

Sugar analyses

Analyses of sugars were performed according to the method described by Camara *et al.* (1996). Fig fruit homogenates (10 g) were diluted with distilled water (40 mL) to prepare solution for detection of sugar composition, and were centrifuged at 10,000 rpm for 10 min and the supernatants were then removed and filtered through Whatman No. 42 filter paper and membrane filters (0.45 μm , Millipore, USA) before subjecting samples to HPLC. All samples and standards injections were repeated three times for HPLC on an EC 250/4 Nucleosil C18 carbohydrate column (250 mm-4.0 mm i.d.) was used (Macherey-Nagel, USA). The elution solvent contained 75% acetonitrile and 25% deionized water. The column was operated at 30 °C with a flow rate of 1.8 mL min^{-1} .

Fruit quality analysis

Fifty fruits were randomly sampled from each genotype at their fully mature stage. There were five replicates each consisting of ten fruits. The pomological methods used for fruit weight, fruit width, neck length, ostiole width, total soluble solids (TSS), pH, acidity, and TSS/acidity determination have been described by Çalışkan & Polat (2008). Maturity index (MI) also was determined and calculated as TSS/acidity, and varieties were categorized as least sweet, MI < 50; less sweet, MI 51-100; sweet, MI 101-150; or sweetest genotypes, MI > 150.

Fruit skin and flesh color measurements

Fruit skin and flesh colors were measured using a colorimeter (Chroma Meter CR-300, Minolta Co.,

Osaka, Japan). Color characters were expressed as L*, a*, C, and h° (reference). Fruit skin color was measured at three random positions per fruit, and the flesh color was measured at two random positions per fruit.

Statistical analysis

Data were analyzed using SAS software and procedures (SAS, 2005). Analysis of variance (ANOVA) tables were constructed with Tukey's Honestly Significant Difference (HSD) method at $p < 0.05$. Restricted maximum likelihood (REML) was used to estimate variance components. Pearson correlation coefficients and their levels of significance were calculated on a genotype mean basis using PROC CORR.

Results and discussion

Phytochemical properties

Phytochemical characters of Turkish fig genotypes are presented in Table 1. These characters were affected to different degrees by genotype, harvest year, and genotype-by-year interaction, but the effect of the genotype on TA, TP and TAC (50% to 96%) was greater than for harvest year (accounting for 1% of total variation compared to 9% of total variation), and genotype-by-year interaction (accounting for 2% of total variation compared to 16% of total variation).

The fig genotypes in this study exhibited great diversity in values for TA (ranging from 2.7-113.6 μg cy-3-rutinoside g^{-1} fw), TP (ranging from 57.9 to 105.2 mg GAE/100 g fw), and TAC (ranging from 5.2 to 10.7 mmol Fe^{2+} kg^{-1}). 'Bursa Siyahı', which has dark black fruit skin, had the highest levels of TA (113.6 μg cy-3-rutinoside g^{-1} fw), TP (105.2 mg GAE/100 g fw), and TAC (10.9 mmol Fe^{2+} kg^{-1} fw). The lowest TA and TAC values were found in the genotype 'Göklop', which has green fruit skin color (2.7 μg cy-3-rutinoside g^{-1} fw and 5.2 mmol Fe^{2+} kg^{-1} fw, respectively). Similarly, the other fig genotypes with darker fruit skin have the higher contents of TA, TP, and TAC, as previously reported by other authors (Solomon *et al.*, 2006; Çalışkan & Polat, 2011). In those studies, total anthocyanins were not detected in some fig genotypes with light fruit skin colors. However, TA was found

Table 1. Effect of genotype and harvest year on phytochemical properties and sugar compositions of fig genotypes grown in Hatay, Turkey

Variable	Phytochemical property			Sugar composition		
	TA, µg cy-3-rutinoside g ⁻¹ of fw	TP, mg GAE/100 g of fw	TAC, mmol Fe ²⁺ kg ⁻¹ of fw	FRUC, g/100 g of fw	GLUC, g/100 g of fw	SUC, g/100 g of fw
<i>Genotype</i>						
Bursa Siyahı	113.6 ^a	105.2 ^a	10.9 ^a	8.1 ^{ef}	6.3 ^{efg}	0.14 ^g
Göklop	2.7 ^d	64.5 ^{ef}	5.2 ^f	10.6 ^a	9.0 ^a	0.23 ^{cd}
Morgüz	22.4 ^b	81.1 ^{b-e}	8.9 ^{abc}	9.1 ^{bcd}	8.1 ^{bc}	0.16 ^{efg}
Sarılop	5.2 ^{cd}	69.7 ^{def}	6.3 ^{def}	10.7 ^a	7.8 ^{bcd}	0.16 ^{fg}
Sarı Zeybek	4.9 ^{cd}	57.9 ^f	7.4 ^{cde}	8.4 ^{def}	7.0 ^{def}	0.19 ^{def}
Sarı İncir	9.3 ^c	85.0 ^{bcd}	10.4 ^a	9.6 ^b	7.4 ^{cd}	0.21 ^{de}
Yediveren	4.2 ^{cd}	90.9 ^{abc}	7.6 ^{cd}	10.6 ^a	8.4 ^{ab}	0.22 ^d
Yeşilgüz	20.4 ^b	59.4 ^f	6.4 ^{def}	7.2 ^g	6.0 ^g	0.15 ^{fg}
31-IN-01	6.3 ^{cd}	73.4 ^{c-f}	6.8 ^{c-f}	8.7 ^{cde}	6.3 ^{efg}	0.28 ^c
31-IN-09	3.6 ^{cd}	60.0 ^f	5.3 ^{ef}	7.7 ^{fg}	6.0 ^g	0.36 ^b
31-IN-16	4.5 ^{cd}	55.9 ^f	8.1 ^{bcd}	9.4 ^{bc}	7.1 ^{de}	0.53 ^a
31-IM-05	9.0 ^{cd}	96.9 ^{ab}	10.0 ^{ab}	8.6 ^{de}	6.2 ^{fg}	0.22 ^d
HSD _{0.05}	6.4	17.7	2.1	0.8	0.8	0.05
<i>Harvest year</i>						
2008	15.5 ^b	74.4 ^b	7.7 ^b	9.3 ^a	6.7 ^b	0.27 ^a
2009	15.9 ^b	76.5 ^a	7.8 ^b	8.8 ^b	6.9 ^b	0.24 ^b
2010	20.1 ^a	73.4 ^b	8.6 ^a	9.1 ^a	7.8 ^a	0.20 ^c
HSD _{0.05}	2.2	2.1	0.6	0.2	0.3	0.02
<i>Analysis of variance(mean square)</i>						
Genotype (G)	8,674.8**	2,499.3**	33.4**	12.0**	9.1**	0.10**
Harvest year (Y)	236.8**	70.5*	1.1*	2.0**	11.8**	0.04**
G×Y	86.1**	375.5*	3.9*	1.2**	3.4**	0.01**
Error	16.1	124.3	1.8	0.3	0.3	0.0
CV(%)	23.4	14.8	17.4	5.6	7.0	13.3
<i>Variance component distributions (%)</i>						
Genotype (G)	96	50	53	67	29	67
Harvest year (Y)	1	9	7	1	11	5
G×Y	2	16	10	17	49	22
Error	2	26	30	15	12	7

Different letters within columns indicate significant differences by Tukey's test at $p < 0.05$. **: Significant at $p < 0.01$; *: Significant at $p < 0.05$; ns: not significant. TA: total anthocyanins; TP: total phenolics; TAC: total antioxidant capacity; FRUC: fructose; GLUC: glucose; SUC: sucrose; fw: fruit weight.

in low concentrations in genotypes with light fruit skin colors in this study. This could be related to the fruit flesh a* values greater than 10 in our data. Also, the TA values of samples in the present study were lower than those in other studies on commercial fig cultivars (Dueñas *et al.*, 2008) and fig accessions (Çalışkan & Polat, 2011), but higher than those reported by Solomon *et al.* (2006). The levels of TP compared to those found in this study were in agreement with those of Piga *et al.* (2008), but lower than found by Çalışkan & Polat (2011). The TAC levels in the present study were much higher than those reported by Solomon *et al.* (2006). Turkish fig geno-

types possess a wide range of levels of TA, TAC, and TP. Some had higher levels of TAC and TP than commercial fig cultivars from the eastern and northern Mediterranean countries.

The effects of the harvest year and genotype-by-year interaction on TP and TAC were also statistically significant ($p < 0.05$). The TA and TAC values were higher in 2010, whereas TP was higher in 2009. This result could be due to higher mean temperature ($>29^{\circ}\text{C}$) and an absence of rainfall at maturity in August, 2010. Sunshine duration also was higher in July and August 2010 (322.9 and 331.4 h per month, respectively) than in other years. Moretti *et al.* (2010) re-

ported that high temperature conditions can significantly increase antioxidant capacity in berries. The TA, TAC, and TP contents of other fruit crops such as apricots, berries, cherries, and grapes vary depending on the phenotype, as well as on fruit tissue type, developmental stage, microclimate, harvest year, and genetic factors (Guerrero *et al.*, 2010; Hegedús *et al.*, 2010). In previous studies of antioxidant activity and total phenolics contents of fruit species, the effect of harvest year was significant (Connor *et al.*, 2005). Therefore, these researchers suggested that antioxidant activity and total phenolics contents should be investigated over more than one year to obtain reliable results. The present study also confirmed that there is variation in these metabolites due to year.

Analyses of variance for FRUC, GLUC, and SUC demonstrated significant ($p < 0.01$) variation depending on genotype, year, or genotype-by-year interaction (Table 1). Analysis of the components of variance indicated that genotype (29% to 67%) contributed more to overall variation in FRUC, GLUC, and SUC than did year (1% to 11%) or genotype-by-year interaction (17% to 49%). The genotypes 'Sarılop', 'Göklop', and 'Yediveren' had the highest FRUC (10.7, 10.6, and 10.6 g/100 g fw, respectively) and GLUC (7.8, 9.0, and 8.4 g/100 g fw, respectively) values. SUC values were very low in figs, but FRUC contents were higher than the values reported by Melgarejo *et al.* (2003). Our results were similar to those of Çalışkan & Polat (2011).

Fruit quality properties of fresh figs include fruit size, skin and flesh color, flavor, sugar content, and acidity (Flaishman *et al.*, 2008). The sugar composition of figs, especially fructose, can influence perceived fruit sweetness (Setser, 1993; Çalışkan & Polat, 2011). The genotype 'Sarılop' had the highest fructose and maturity index values. 'Sarılop' had a particularly sweet taste compared to the other genotypes in this study.

The FRUC, GLUC, and SUC contents were statistically significant ($p < 0.01$) for three harvest years (Table 1). The highest levels of FRUC and GLUC were found in 2010, whereas level of SUC was the lowest in 2010, suggesting that sugar contents are influenced by environmental variables. The year-to-year variation in sugar composition may be explained by differences in climate and crop loads during the harvest year (Brooks *et al.*, 1993). Also, harvest time could introduce variability among years and consequently influence the antioxidant capacity and sugar compositions of fruits among genotypes (Abidi *et al.*, 2011).

Fruit quality characters

Results of analyses of variance showed that genotype was the main factor ($p < 0.01$) affecting fruit quality characters (Table 2). Genotypic effects, which accounted for the largest proportion of variation in all fruit quality traits, varied between 33.1% and 69.4% of variation in these three years. The average fruit weights of these fig genotypes ranged from 22.8 ('Sarı İncir') to 57.5 g ('Bursa Siyahı'). Fruit size is one of the most important fruit quality characteristics for fresh figs. Relative to the fruit widths defined in the 'Fig Descriptor' (IPGRI & CHIEAM, 2003), 'Sarılop' was large (50-60 mm), and other genotypes, except for 31-IN-01 and 'Sarı İncir', were medium (38-49 mm). The results for fruit size in this study were similar to those in the literature for the most important fig cultivars, such as 'Sarılop', 'Bursa Siyahı' and 'Yediveren' (Aksoy *et al.*, 2003), and were higher than those described by Polat & Çalışkan (2008). Fruit neck length was the longest for the genotypes 'Bursa Siyahı' (5.6 mm) and 'Sarılop' (5.6 mm). Large ostiole width is one of the most important problems in the fresh fig trade. The width of the ostiole, the opening of the fig involucre, was 'small' (<1 mm) for 'Bursa Siyahı', but was 'large' (4-5 mm) for 31-IN-16 and 'Yediveren'. The contents of TSS ranged between 20.6 ('Sarılop') and 24.0% ('Morgüz'). Fig genotypes grown in homogenous conditions had great variability in fruit neck length, pH, and acidity, but these characters were not affected by harvest year. The pH of the fruit juice was the highest for 31-IN-01 (5.2) and 31-IM-05 (5.1), while it was the lowest for 'Sarılop' (4.6) and 'Sarı İncir' (4.6). 'Sarı İncir' (0.24%), 'Morgüz' (0.23%), and 'Yediveren' (0.22%) juices had the highest acidity, while juice acidity was lowest for 'Sarı Zeybek' (0.14%). The maturity index (TSS/acidity) can be a good indicator of good fruit taste; furthermore, this ratio can be a valuable descriptive character in selecting cultivars for specific uses (Polat & Çalışkan, 2008). The maturity index (MI) values varied from 145.1 in 'Sarılop' to 91.7 in 'Sarı İncir'. According to the MI classification scheme, 'Bursa Siyahı', 'Yediveren', and 'Sarı İncir' can be grouped in the class of less sweet genotypes, while the rest of genotypes can be classified as sweet. These results displayed that the fig genotypes present a choice of figs with less sweet and sweet tasted for fresh fig market and offer the possibility to choose by consumer preferences.

The effect of harvest year on fruit weight, fruit width, ostiole width and TSS content, and genotype-by-year

Table 2. Effect of genotype and harvest year on fruit quality properties of fig genotypes grown in Hatay, Turkey

Variable	Fruit weight (g)	Fruit width (mm)	Neck length (mm)	Ostiole width (mm)	TSS (%)	pH	Acidity (%)	TSS/Acidity
<i>Genotype</i>								
Bursa Siyahı	57.5 ^a	46.0 ^{abc}	5.6 ^a	0.9 ^d	20.2 ^{cd}	4.6 ^{de}	0.21 ^{ab}	96.6 ^d
Göklop	50.6 ^{ab}	47.5 ^{ab}	3.6 ^{bcd}	2.6 ^{abc}	22.3 ^{a-d}	4.7 ^{cde}	0.20 ^{abc}	106.7 ^{cd}
Morgüz	37.2 ^{cd}	42.5 ^c	2.6 ^{efg}	1.4 ^{cd}	24.0 ^a	4.9 ^{bc}	0.23 ^a	103.4 ^{cd}
Sarılop	56.5 ^a	50.1 ^a	5.6 ^a	3.2 ^{ab}	20.6 ^d	4.6 ^e	0.15 ^{de}	145.1 ^a
Sarı Zeybek	44.1 ^{bc}	45.6 ^{bc}	3.4 ^{c-f}	1.6 ^{cd}	22.0 ^{bcd}	4.8 ^{bcd}	0.14 ^e	142.1 ^{ab}
Sarı İncir	22.8 ^e	32.8 ^d	2.5 ^{fg}	1.2 ^d	21.6 ^{bcd}	4.6 ^e	0.24 ^a	91.7 ^d
Yediveren	44.2 ^{bc}	44.6 ^{bc}	4.5 ^b	3.5 ^a	22.0 ^{bcd}	4.7 ^{cde}	0.22 ^a	99.3 ^d
Yeşilgüz	37.1 ^{cd}	43.2 ^{bc}	3.5 ^{cde}	1.1 ^d	22.7 ^{abc}	4.8 ^{bcd}	0.19 ^{bc}	122.6 ^{a-d}
31-IN-01	32.3 ^d	37.1 ^d	1.9 ^g	2.8 ^{ab}	23.0 ^{ab}	5.2 ^a	0.19 ^{bc}	131.6 ^{abc}
31-IN-09	41.3 ^c	43.7 ^{bc}	2.8 ^{d-g}	2.2 ^{bcd}	22.1 ^{bcd}	5.0 ^{ab}	0.21 ^{ab}	104.5 ^{cd}
31-IN-16	42.8 ^{bc}	43.0 ^c	3.9 ^{bc}	3.7 ^a	21.2 ^{cd}	5.0 ^{ab}	0.18 ^{bcd}	119.9 ^{a-d}
31-IM-05	44.3 ^{bc}	44.8 ^{bc}	3.7 ^{bcd}	2.9 ^{ab}	22.3 ^{a-d}	5.1 ^a	0.20 ^{abc}	111.3 ^{bcd}
HSD _{0.05}	8.7	4.4	0.9	1.2	1.7	0.2	0.03	30.9
<i>Harvest year</i>								
2008	40.3 ^b	42.2 ^b	3.6	1.9 ^b	22.1 ^{ab}	4.9	0.21	118.3 ^a
2009	42.6 ^{ab}	43.4 ^{ab}	3.6	2.4 ^a	21.7 ^b	4.6	0.19	117.2 ^b
2010	44.8 ^a	44.6 ^a	3.7	2.5 ^a	22.4 ^a	4.8	0.19	109.8 ^c
HSD _{0.05}	3.1	1.5	ns	0.4	0.6	ns	ns	7.9
<i>Analysis of variance(mean square)</i>								
Genotype (G)	856.5**	186.8**	12.3**	8.7**	7.1**	0.4**	0.007**	2,653.8**
Harvest year (Y)	185.3*	54.5**	0.4ns	3.7*	4.4*	0.0 ns	0.001ns	751.3ns
G×Y	46.5ns	20.9**	24.5*	0.4ns	1.2ns	0.0ns	0.001ns	422.4ns
Error	30.5	7.7	0.3	0.6	1.2	0.1	0.001	378.1
CV(%)	12.9	6.4	16.8	24.4	4.9	2.8	10.7	16.8
<i>Variance component distributions (%)</i>								
Genotype (G)	69	59	67	58	33	69	59	38
Harvest year (Y)	3	3	0	6	5	0	0	0
G×Y	4	14	12	0	0	0	0	0
Error	24	25	20	36	61	31	37	58

Different letters within columns indicate significant differences by Tukey's test at $p < 0.05$. **: Significant at $p < 0.01$; *: Significant at $p < 0.05$; ns: not significant. TSS: total soluble solids.

interaction on fruit width and neck length was significant (Table 2). However, no significant effect of harvest year on neck length, pH, acidity, and TSS/acidity was observed. Mean values for fruit weight (44.8 g), fruit width (44.6 mm), ostiole width (2.5 mm), and TSS (22.4%) were highest in 2010, whereas TSS/acidity (118.3) was highest in 2008. This can be explained by changing environmental conditions and fruit-bearing loads from year to year (Botti *et al.*, 2003; Polat & Caliskan, 2009).

Fruit skin and flesh color measurements

Fruit skin and flesh color of fig genotypes differed significantly depending on genotype, harvest year, and

genotype-by-year interaction (Table 3). Genotype had the main effect ($p < 0.01$) on fruit skin and flesh color properties, and its effects were ranged from between 16% (h°) and 73% (a^*) of the variation for fruit skin color and 11% (C) and 43% (a^*) of the variation for fruit flesh color.

Fruit skin and flesh color of fresh figs are very important for consumer preferences. Fresh figs with pink and red flesh color are preferred by consumers. In addition, fruit skin and flesh color are used to assess ripening in figs (Tsantili, 1990). In general, lower L^* , C and h° values are associated with darker fig skin colors, whereas higher values of these variables are consistent with lighter fig skin colors. The fruit skin L^* value was lightest for 'Yeşilgüz', and 'Sarılop' (72.6 and 72.5), respectively. The fruit skin a^* value, which indicates

Table 3. Effect of genotype and harvest year on fruit skin and flesh color characters of fig genotypes grown in Hatay, Turkey

Variable	Fruit skin color				Fruit flesh color			
	L*	a*	C	h°	L*	a*	C	h°
<i>Genotype</i>								
Bursa Siyahı	28.1 ^f	13.6 ^a	20.2 ^c	60.8 ^c	43.3 ^{ab}	13.6 ^{cd}	27.5 ^d	58.7 ^{bcd}
Göklop	64.5 ^c	-19.8 ^{gf}	59.7 ^a	96.4 ^a	40.9 ^{bc}	15.0 ^{bc}	33.8 ^{abc}	61.4 ^{abc}
Morgüz	58.8 ^d	1.9 ^b	40.2 ^b	65.4 ^{bc}	35.0 ^{de}	17.8 ^b	31.9 ^{a-d}	51.7 ^{cd}
Sarılop	72.5 ^a	-17.0 ^{ef}	64.1 ^a	94.7 ^{ab}	42.1 ^{bc}	11.5 ^{cd}	30.6 ^{cd}	66.1 ^{ab}
Sarı Zeybek	70.9 ^{ab}	-21.6 ^g	59.6 ^a	97.7 ^a	48.3 ^a	11.3 ^{cd}	31.4 ^{bcd}	67.7 ^{ab}
Sarı İncir	56.0 ^d	-9.3 ^c	45.3 ^b	91.6 ^{ab}	34.7 ^e	13.0 ^{cd}	27.9 ^d	72.0 ^a
Yediveren	67.4 ^{bc}	-20.9 ^{gf}	59.4 ^a	96.6 ^{ab}	40.2 ^{b-c}	17.6 ^{bcd}	30.5 ^{cd}	60.1 ^{a-d}
Yeşilgüz	72.6 ^a	-12.0 ^{cd}	43.7 ^b	82.1 ^{ab}	41.5 ^{bc}	21.8 ^a	35.7 ^{ab}	48.1 ^d
31-IN-01	66.6 ^c	-15.0 ^{de}	60.9 ^a	76.0 ^{abc}	37.1 ^{cde}	11.8 ^{cd}	36.8 ^a	70.1 ^{ab}
31-IN-09	65.1 ^c	-16.5 ^{def}	61.0 ^a	73.9 ^{abc}	40.5 ^{bcd}	10.8 ^d	33.6 ^{abc}	71.4 ^a
31-IN-16	65.4 ^c	-15.0 ^{de}	60.5 ^a	76.1 ^{abc}	40.6 ^{bcd}	10.7 ^d	35.6 ^{abc}	72.2 ^a
31-IM-05	36.6 ^e	11.0 ^a	23.7 ^c	47.5 ^c	44.6 ^{ab}	13.1 ^{cd}	33.1 ^{abc}	66.8 ^{ab}
HSD _{0.05}	4.9	4.6	5.2	33.9	5.7	3.9	5.1	12.3
<i>Harvest year</i>								
2008	55.2 ^c	-12.5 ^c	51.6 ^a	63.3 ^b	40.0 ^b	13.1 ^b	36.3 ^a	68.4 ^a
2009	67.0 ^a	-10.1 ^b	47.3 ^a	90.4 ^a	40.0 ^b	13.4 ^b	29.2 ^c	60.7 ^b
2010	58.9 ^b	-7.6 ^a	43.1 ^b	97.3 ^a	42.3 ^a	14.9 ^a	31.3 ^b	62.5 ^b
HSD _{0.05}	1.7	1.6	1.8	12.0	2.0	1.4	1.7	4.3
<i>Analysis of variance (mean square)</i>								
Genotype (G)	1,791.4**	1,337.0**	2,094.5**	2,501.5**	135.3**	96.5**	74.1**	573.6**
Harvest year (Y)	1,293.7**	217.8**	222.9**	11,675.8**	66.0*	34.1*	486.9**	582.7**
G×Y	337.0**	121.8**	367.0**	921.2*	255.6**	19.9**	159.1**	239.3**
Error	9.7	8.4	10.7	452.4	13.1	6.2	10.1	60.3
CV(%)	5.1	-28.9	6.5	25.4	8.9	18.1	3.1	7.7
<i>Variance component distributions (%)</i>								
Genotype (G)	53	73	51	16	15	43	11	22
Harvest year (Y)	9	1	10	28	3	2	13	6
G×Y	36	21	36	14	65	23	62	36
Error	3	5	3	42	15	32	15	36

Different letters within columns indicate significant differences by Tukey's test at $p < 0.05$. **: Significant at $p < 0.01$; *: Significant at $p < 0.05$; ns: not significant.

red color, was positive for 'Bursa Siyahı' (13.6) and 31-IM-05 (11.0), whereas it was negative (green color) for 'Sarı Zeybek' (-21.6). The darkest fruit skin color, C, was found for 'Bursa Siyahı' (20.2) and 31-IM-05 (23.7). Fruits with lower values for h° (60.8 for 'Bursa Siyahı' and 47.5 for 31-IM-05) are redder, and some researches have indicated that h° values would be suitable for estimating carotenoid levels of fruit species (Ruiz *et al.*, 2005). 'Göklop' and 'Sarı Zeybek', the genotypes with the highest h° values can be regarded as having the lowest carotenoid levels in this study, whereas 31-IM-05 and 'Bursa Siyahı' with the lowest h° values are likely to be the richest in carotenoids.

The lightest fruit flesh L* value found in this study was 48.3 for 'Sarı Zeybek', while the a* value, which

indicates the redness of fruit flesh, was highest for 'Yeşilgüz' (21.8). The genotypes 'Bursa Siyahı' (27.5) and 'Sarı İncir' (27.9) had the darkest flesh colors with the lowest h° values, followed by the genotypes 'Yediveren' and 'Sarılop' (30.5 and 30.6, respectively). These genotypes with reddish flesh color tend to be preferred by consumers for fresh figs.

The effect of year on fruit skin and flesh color was highly significant ($p < 0.01$), except for flesh L* value, but the contribution of this effect to total variation was minor (Table 3). The harvest year had the lowest effect on both fruit skin and flesh color a* values (1% and 2%, respectively). The lowest fruit skin C values (lower values are darker in color) of these fig genotypes were found in 2010. This color density may be related to

temperatures that reached 29.7°C, and an absence of precipitation at maturity in August, 2010. Fruit color can vary from year to year depending on light and temperature. Temperature in particular has a strong effect on anthocyanin synthesis that provides coloration in fruit species (Wang *et al.*, 2011).

Correlation analyses

We found significant positive correlations ($p < 0.01$) between either TA or TP contents and TAC ($r = 0.56$ and $r = 0.77$, respectively), are important components of the antioxidant capacity of figs, as found by Solomon *et al.* (2006) and Çalışkan & Polat (2011). Fruit skin L^* , a^* , and C values were found to be moderately correlated with TA, TAC, and TP levels (Table 4). Lightness (L^*) and C values were negatively related to TA, TAC, and TP contents in these fig genotypes, whereas a^* values were positively correlated with TA, TAC, and TP levels. The phenolic compounds, especially anthocyanins (cy-3-rutinoside), cinnamic acid, and flavonoids, are prominent in fig fruit skins (Del Caro & Piga, 2008); therefore, a correlation between fruit skin colors and TP or TAC can be expected. Moreover, FRUC and SUC values were showed negative significant correlations with TA ($r = -0.34$ and $r = -0.42$, at $p < 0.01$). In contrast to our results, Abidi *et al.* (2011) reported a positive correlation in grapes between sugar

content and total anthocyanins. This is likely because fig genotypes with green or brown fruit skin color have higher FRUC, GLUC, and SUC than do genotypes with black fruit skin color (Çalışkan & Polat, 2011). In agreement with the above results, fruit skin a^* values were negatively correlated with FRUC, GLUC, and SUC contents, whereas fruit skin C values were positively related to FRUC and SUC. These findings support to the relationship between either FRUC or SUC and TA levels.

The a^* values of fruit fresh were positively related to TA and GLUC, while flesh h° values were inversely related to TA and GLUC in these fig accessions. Fruit weight, fruit size, and fruit neck length were not correlated with TA, TAC, and TP (data not shown). Moyer *et al.* (2002) indicated that within the same fruit species and genotypes, smaller fruits tend to have higher TP content and TAC, as compounds resulting in higher TP and TAC are usually richest in fruit skin, and genotypes with smaller fruits have a relatively larger skin area compared to that of larger genotypes. Surprisingly, pomological characteristics such as fruit weight, fruit size, and fruit neck length were not correlated with fruit skin and flesh color values, as well as TA, TP, and TAC. This result may be explaining the lack of correlation among these traits by the color of the fruit skin (data not shown). Thus, pomological characters of species such as figs, which occur in different fruit color groups, have limited effects on the phytochemical characteristics. In addition,

Table 4. Correlation coefficients (r) of phytochemical and color properties of fig genotypes in 2008, 2009 and 2010 years

Variable	TA	TAC	TP	FRUC	GLUC	SUC
Skin L^*	-0.46**	-0.52**	-0.47**	0.18	0.21*	0.09
Skin a^*	0.60**	0.51**	0.47**	-0.33**	-0.22*	-0.22*
Skin C	-0.57**	-0.48**	-0.39**	0.36**	0.17	0.33**
Skin h°	0.28**	0.00	0.01	0.06	0.34**	-0.28**
Flesh L^*	0.04	-0.06	-0.12	0.02	-0.04	-0.07
Flesh a^*	0.29**	-0.06	-0.05	-0.17	0.20*	-0.40**
Flesh C	-0.18	-0.11	-0.11	0.08	-0.06	0.16
Flesh h°	-0.34**	-0.02	0.03	0.16	-0.20*	0.40**
TA	1	0.56**	0.59**	-0.34**	0.10	-0.42**
TAC		1	0.77**	-0.14	-0.11	-0.14
TP			1	0.03	-0.07	-0.29**
FRUC				1	0.65**	0.02
GLUC					1	-0.19*
SUC						1

Significance: ** $p < 0.01$, * $p < 0.05$; TA: total anthocyanins; TP: total phenolics; TAC: total antioxidant capacity; FRUC: fructose; GLUC: glucose; SUC: sucrose.

these results could be explained by the fact that the physical fruit growth and the chemical component accumulation and biosynthesis are different process.

The genotypes with black fruit skin color, 'Bursa Siyahi', had the most excellent fruit quality and richest phytochemical characters. 'Sarilop', which is the most important dried fig genotype had as good fruit quality as fresh fig genotypes, but had lower phytochemical profiles associated with yellow fruit. 'Göklop' and 'Yediveren' with green fruit skin color, 31-IN-16 with yellow fruit skin color, and 31-IM-05 with brown fruit skin color are promising for export markets in terms of fruit quality characters; however their phytochemical compositions, except for 31-IM-05, were lower due to green or yellow fruit colors. 'Bursa Siyahi' may be useful in a breeding study as a donor genotype for both high phytochemical levels and excellent fruit quality characters. Phenotypic and heritability calculations in several fruit species showed that the improvement of TA and TP is possible through selective breeding (Connor *et al.*, 2005; Abidi *et al.*, 2011). Therefore, the favorable fruit characters defined by 'Bursa Siyahi' should be useful in hybridization studies.

As conclusions, this study provides the first data describing the phytochemical characters and sugar compositions of some important Turkish fig genotypes. The results indicated that considerable variation in phytochemical and fruit quality characters, and sugar compositions occurs in fig genotypes based on genotype, harvest year, and genotype-by-year interactions. The genotype with black fruit skin, 'Bursa Siyahi', had the highest levels of TA, TP, and TAC. Genotype had a highly significant effect on TA, TP, and TAC properties in figs. Harvest year had no effect on fruit neck length, pH, and acidity; however, harvest year did have a significant effect on variation in fruit color and phytochemical characters.

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