Evaluation of Apricot Fruit Quality and Correlations Between Physical and Chemical Attributes

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Abstract

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The fruit of apricot (*Prunus armeniaca* L., Rosaceae) has been used as food in FYR Macedonia since a long time ago. The chemical organic matters from the fruit is a kind material for food processing and has potential nutritional, medical and commercial values. The results based on fruit physical and chemical analyses clearly showed that different apricot genotypes have very important contents of soluble solids, individual sugars, and titratable acidity in limited soil and climatic conditions. In addition, the contents of these chemical compounds in some genotypes were higher than those in the control cultivar Hungarian Best. Using the PC analysis (PC1 = 32.13%, PC2 = 22.86%, and PC3 = 18.32%), apricot genotypes were separated into groups with similar physical and chemical attributes. These relationships may help to select a set of genotypes with better fruit quality performances which, in our study, might be indicated in DL-1/1/04, DL-1/2/03, D-1/04 and K-5/04.

Keywords: apricot; fruit quality; physical attributes; chemical attributes; genotypes

The apricot (*Prunus armeniaca* L.) originated in China and Central Asia (Yuan *et al*. 2007) and has been cultivated in China since 2000 BC. It was spread throughout Europe by the Romans in 100–70 BC (Bailey & Hough 1975). Mehlenbacher *et al*. (1990, 1991) reported that the gene pool of the apricot contains species and varieties that have adapted to the cold winters of Siberia, subtropical climate of North Africa, deserts of Central Asia, and humid areas of Japan and East China.

Apricots are cultivated world-wide mainly for their high-quality fruit, which is consumed fresh, processed by the food industry, or preserved by drying. Fruit quality is a combination of physical and chemical characteristics accompanied by sensory properties (appearance, texture, taste and aroma), nutritional values, chemical compounds, mechanical properties, and functional properties (Kramer & Twigg 1966; Velíšek & Cejpek 2007). Therefore, new apricot cultivars or genotypes must be characterised by high fruit quality attributes which satisfy the consumers (Ruiz & Egea 2008b). However, fruit quality attributes are affected by a number of pomological traits (Bailey & Hough 1975; Crossa-Raynaud & Audergon 1991; Milošević *et al*. 2010) that cannot be analysed separately from the biological properties of the fruit tree and the yield obtained (Balta *et al*. 2002; Asma & Ozturk 2005; Asma *et al*. 2007), agronomic and ecological factors (Guerriero *et al*. 2006) and their correlations (Badenes *et* *al.* 2001; Ledbetter *et al.* 2006; Ruiz & Egea 2008a, b). Accordingly, the selection of valuable individuals within the seedling populations that display great diversity might contribute to the apricot breeding progress.

The objective of our study was to evaluate and compare the fruit quality attributes of twenty apricot genotypes. Furthermore, we wanted to determine which of the chemically analysed compounds in apricot fruits correlate best with physical and chemical traits. In addition, a multivariate analysis was undertaken in order to study the correlations between the variables and to establish the relationships between genotypes regarding the fruit quality attributes.

MATERIAL AND METHODS

Study area. The study was conducted in the Skopje region (42°00'N, 21°26'E, altitude 240–460 m) stretching over a distance of 21 km and 5 km as the crow flies in the east-west and north-south direction, respectively, covering an area of 105 km^2. The city is located in a narrow Vardar River valley surrounded by Mt. Skopska Crna Gora in the north and Mt. Vodno in the south. The majority of the apricot genotypes studied were found at the foot of Mt. Vodno.

The mean maximum annual temperature in the Skopje region was 18.9°C, mean minimum temperature –9.7°C, and total annual precipitation – 507.0 mm (30-year average, i.e. 1975–2004 period). The warmest months were July and August, with the lowest precipitation recorded, and the coldest – January, February, and December. As given by the above data, the climate of the region featured warm dry muggy summers and foggy cold winters.

Plant material. The material used for in situ studies included seedling apricot (*Prunus armeniaca* L.) trees singled out of an abundant population found in the region of Skopje during 2003 and 2004. A total of 19 seedlings having superior fruit and tree characteristics were selected from over 1100 seedlings estimated to be 6–55 years of age. The basic criteria used in the genotype selection were as follows: flowering time, maturity time, yield, fruit size and quality, vitality, tree longevity, and health status. Hungarian Best was used as the control cultivar. As opposed to the genotypes occurring as scattered individuals in the field conditions (*in situ*), the control cultivar was grown at the apricot collection orchard of the Fruit Growing Institute, Skopje. The control cultivar was grafted onto Myrobalan (*Prunus cerasifera* Ehrh.) seedlings. It was planted in 1993 at a spacing of 5 m × 4 m (500 trees/ha) and trained to a vase shape. It produced its first fruit in 1995. The orchard received standard cultural and pomological practices, providing cv. Hungarian Best with the growth and development conditions superior to those found *in situ* for the evaluated genotypes.

Fruit sample. For a period of two harvest seasons, 10 fruits from each genotype of each of three replications were collected and their physical and chemical traits were determined. The apricot genotypes were harvested at the commercial maturity stage in the Skopje region between the first week of June and third week of July in the years of 2004 and 2005. The samples were placed into polyethylene bags and stored at 4°C until the analysis (analysed within four days).

Physical attributes. Fruit physical properties such as the fruit weight (FW) and stone weight (SW), mesocarp percentage (MP) and yield (Y) were measured immediately after picking. The fruit weight (g) and SW (g) were taken using a Tehnica ET-1111 technical scale (Iskra, Kranj, Slovenia). Mesocarp percentage was calculated as the ratio of the weight of the edible portion of the fruit to the total fruit weight (%). An ACS System Electronic Scale (Zhejiang, China) was used to measure the fruit yield (Y) per tree (kg).

Chemical attributes. Fruit chemical attributes such as soluble solids content (SS), total acidity (TA), and pH (pH) were measured immediately after picking.

Soluble solids content (Brix) was determined by an Milwaukee MR 200 (ATC, Rocky Mount, USA) hand digital refractometer, and pH by a CyberScan 510 pH meter (Nijkerk, Netherlands).

The fruit samples were analysed for the contents of sugars (TS, RS, SC) and TA (malic acid). The samples were homogenised with a manual blender (Braun). Ten grams of the mashed fruit were extracted with 50 ml of twice-distilled water for 30 min at room temperature. The extracted sample was centrifuged at 12 000 g at 10°C for 7 min (Eppendorf centrifuge 5810 R, Hamburg, Germany). The supernatant was filtered through a 0.45 µm cellulose ester filter (Macherey-Nagel), transferred into a vial and used for analyses.

HPLC analysis of sugars was performed using a Thermo Separation Products (Riviera Beach, USA) HPLC refractive index detector. The separation of sugars was carried out using a Rezex RCM-monosaccharide column (300 × 7.8 mm) while the column temperature was maintained at 65°C.

Sugars were analysed isocratically according to the method of Šturm *et al.* (2003) on a Rezex RCM column (300 × 7.8 mm, Phenomenex) at 80°C using an RI detector. Deionised water was used as the mobile phase, with an injection volume of 20 µl, and a flow rate of 0.6 ml/min. The content of RS was given by the sum of glucose and fructose contents. The contents of sugars were expressed as percentages of fresh weight.

Titratable acidity was determined by HPLC using an Aminex HPX-87H column (300 × 7.8 mm) (Bio-Rad, Richmond, USA) associated with a UV detector set at 210 nm according to the method described by Šturm *et al.* (2003). The contents were expressed as percentages of fresh weight.

Data analysis. The data of each of the physical and chemical attributes were analysed by one-way analysis of variance (ANOVA) using the MSTAT-C statistical package (Michigan State University, East Lancing, USA). The means and the least significant differences (*LSD* test) at $P \leq 0.05$ were calculated by a one-way ANOVA (Snedecor & Cochran 1989).

The relationships between the fruit physical and chemical attributes were evaluated by Pearson's product moment correlation at $P \leq 0.05$. A Principal component analysis (PCA) was performed using the PRINCOMP procedure of the SAS statistical package (SAS Institute Inc., North Carolina, USA).

RESULTS AND DISCUSSION

Evaluation of physical attributes

There were significant differences between the accessions regarding the physical attributes tested

Table 1. Physical attributes of apricot genotypes from Skopje Region (mean ± SE for 2003 and 2004, $n = 30$), and yield per tree in both years

Genotypes	Fruit weight (g)	Stone weight (g)	Mesocarp (%)	Yield (kg/tree)	
				2003	2004
X-1/1/04	36.12 ± 2.56^{ij}	2.37 ± 0.14^{q}	93.47 ± 2.49^{ab}	17^{j}	4^{o}
X-1/2/04	52.53 ± 3.32^{cd}	4.85 ± 0.17^{a}	90.77 ± 1.43^{hi}	46^{cd}	16^{h}
K-5/04	39.25 ± 2.44^{hi}	2.71 ± 0.42^{o}	93.09 ± 2.13$^{b–e}$	62^{b}	34^{b}
ZO-1/03	23.40 ± 1.62^{k}	1.81 ± 0.13^{r}	92.26 ± 1.66^{def}	40^{def}	17^{g}
VB-1/04	40.78 ± 3.38^{gh}	2.52 ± 0.14^{p}	93.82 ± 1.11^{a}	37$^{e–h}$	21^{e}
DL-1/2/04	53.56 ± 3.32^{cd}	3.93 ± 0.17^{f}	92.66 ± 1.09$^{c–f}$	82^{a}	42^{a}
ZL-1/3/04	40.98 ± 2.55^{gh}	3.36 ± 0.16^{k}	91.69 ± 1.89$^{f–i}$	35^{fgh}	9^{l}
K-3/1/04	47.11 ± 3.43^{ef}	3.22 ± 0.15^{m}	93.17 ± 1.99^{bcd}	41^{def}	12^{i}
T-7/04	51.79 ± 3.32^{cd}	3.91 ± 0.16^{g}	92.36 ± 1.55$^{c–f}$	47^{cd}	12^{i}
G-12/04	35.23 ± 2.24^{j}	2.94 ± 0.15^{n}	90.60 ± 1.57^{ij}	18^{j}	8^{m}
T-9/03	38.64 ± 2.87^{hij}	3.37 ± 0.15^{k}	91.06 ± 1.54^{ghi}	31^{ghi}	17^{g}
N-4/03	40.75 ± 3.21^{gh}	3.24 ± 0.15^{l}	91.95 ± 2.01^{efg}	37^{e-h}	12^{i}
D-1/04	39.78 ± 2.48^{hi}	4.28 ± 0.17^{c}	88.66 ± 1.22^{j}	52^{c}	24^{d}
ZL-2/03	44.26 ± 3.77^{fg}	3.25 ± 0.15^{l}	92.54 ± 1.13$^{c–f}$	34^{fgh}	5^{n}
N-2/03	49.94 ± 3.46^{cd}	3.97 ± 0.17^{e}	91.85 ± 1.88^{fgh}	45^{cde}	16^{h}
ZL-1/03	51.30 ± 3.77^{d}	3.88 ± 0.16^{h}	92.42 ± 1.97$^{c–f}$	44^{cde}	8^{m}
DL-1/1/04	89.29 ± 2.98^{a}	4.70 ± 0.18^{b}	94.50 ± 2.71^{a}	29^{hi}	10^{k}
L-2/04	55.59 ± 3.42^{c}	3.64 ± 0.16^{i}	93.42 ± 2.57^{abc}	23^{ij}	11^{j}
T-5/04	52.32 ± 2.95^{cd}	3.61 ± 0.16^{j}	93.11 ± 2.69^{bcd}	39$^{d–g}$	18^{f}
HB	61.11 ± 3.78^{b}	4.13 ± 0.17^{d}	93.18 ± 1.88^{bcd}	68^{b}	33^{c}

HB – control apricot cultivar Hungarian Best

The same letter(s) in vertical columns indicate non-significant differences between means at $P \leq 0.05$ by *LSD* test

(Table 1). The fruit weight ranged from 23.40 ± 1.62 g (ZO-1/03) to 89.29 ± 2.98 g (DL-1/1/04). The genotype DL-1/1/04 was followed by L-2/04 (55.59 ± 3.42 g), DL-1/2/04 (53.56 ± 3.32 g), X-1/2/04 (52.53 ± 3.32 g), T-5/04 (52.32 ± 2.95 g), T-7/04 (51.79 ± 3.32 g), and ZL-1/03 (51.30 ± 3.77 g). The fruit weight was below 50 g in the other genotypes. Mesocarp percentage ranged from 88.66 ± 1.22% (D-1/04) to 94.50 ± 2.71% (DL-1/1/04). On the other hand, Y in 2003 was higher than in 2004 (Table 1). In 2003, the highest Y was in DL-1/2/04 (82 kg), and the lowest one in X-1/1/04 and G-12/04 (17 kg and 18 kg, respectively). Moreover, in 2004, the highest Y was in cv. Hungarian Best and K-5/04 (33 kg and 34 kg, respectively), and the lowest one in X-1/1/04 (4 kg) and ZL-2/03 (5 kg).

The characteristics that correlate best with the fruit attractiveness include FW, SW, and MP. The genotypes studied showed noteworthy fruit physical attributes under limited cultural practices (Table 1). Namely, FW was significantly higher in the fruits of the genotype DL-1/1/04 than in the control cultivar, and significantly lower in the others at $P \leq 0.05$. The genotype DL-1/1/04 had a 31.56% higher FW than cv. Hungarian Best. The FW of six genotypes ranged between 30–40 g, 40–50 g, and 50–60 g, respectively. Previous studies on apricot also reported a high variability among cultivars regarding this parameter (Badenes *et al.* 1998; Ruiz & Egea 2008b; Hernandez *et al.* 2010; Milošević *et al.* 2010). In addition, FW is a major quantitative inherited factor determining the yield, fruit quality, and consumers' acceptability (Dirlewanger *et al.* 1999). Therefore, the genotypes may be expected to produce larger fruits under better cultural practices (Balta *et al.* 2002). Paunovic and Paunovic (1995) reported the fruit size of the genotypes *in situ* to range from very small (5.0%) to extremely large (7.5%). In this study, most of the genotypes had a desirable fruit size. Attractive medium-sized fruits are desired for apricot cultivar breeding (Bailey & Hough 1975; Guerriero *et al.* 2006). It is a well-known fact that apricot stones are used in genotype identification and that they have a high utilitarian value (Özcan 2000; Mandal *et al.* 2007). In our study, SW was significantly lower in sixteen genotypes than in cv. Hungarian Best, and MP was significantly higher in two genotypes than in the control at $P \leq 0.05$ (Jackson & Coombe 1966; Gezer *et al.* 2003).

The differences in Y between the accessions and cv. Hungarian Best (Table 1) resulted from the different tree ages, effect of limiting ecological factors, and lack of cultural practices (Balta *et al.* 2002; Arzani & Roosta 2004; Asma & Ozturk 2005).

Evaluation of chemical attributes

A large variability was observed in the set of genotypes examined, and significant differences between them were found, i.e. eleven genotypes had lower SS contents than the control (Table 2). The SS content ranged from 11.70 ± 0.41 Brix (X-1/1/04) to 14.40 ± 0.55 Brix (K-3/1/04). All genotypes, excepting X-1/1/04, had a SS content >12 Brix. Some authors reported that apricot accessions with SS content >12 Brix were characterised by an excellent gustative quality (Egea *et al.* 1994; Gurrieri *et al.* 2001). Ruiz and Egea (2008b) reported that SS content is a very important quality attribute, influencing notably the fruit taste. In addition, Ishag *et al.* (2009) reported that TS contents of the fresh apricot cultivars was 11.8%. Our range of values is in agreement with previous works on apricot (Audergon *et al.* 1990; Ruiz & Egea 2008b), but the values are generally lower than those for a group of Turkish genotypes (Balta *et al.* 2002; Asma & Ozturk 2005; Asma *et al.* 2007). The differences between the present results and those of the above mentioned authors were likely due to the different eco-geographical groups of apricot genotypes studied and the environmental conditions.

The TA of apricot genotypes is given in Table 2. The TA content ranged from 0.89 ± 0.12% to 1.89 ± 0.13% and was lower than 1% in five genotypes (X-1/2/04, ZO-1/03, DL-1/2/04, D-1/04 and ZL-1/03) (Table 2). Six genotypes had significantly lower, and ten genotypes had significantly higher TA contents than cv. Hungarian Best, respectively. Akin *et al.* (2008) reported that malic acid was the predominat organic acid in apricot genotypes (*P. armeniaca* L.). The fruit maturity stage at the harvest date is the key factor affecting fruit acidity and also the SS content. Central Asian and Irano-Caucasian cultivars have lower acidity than European and Japanese cultivars (Mehlenbacher *et al.* 1990, 1991). According to Ishag *et al.* (2009), the TA content of fresh fruit in the apricot cultivars grown in Azad Jammu and Kashmir was 0.94%. The range of TA values obtained in this study is

Table 2. Chemical attributes of apricot genotypes from Skopje Region (mean ± SE for 2003 and 2004)

Genotypes	Soluble solids (Brix)	Titratable acidity (%)	SS/TA ratio	pH value	Sugars (%)		
					reducing	sucrose	total
X-1/1/04	11.70 ± 0.41^{h}	1.32 ± 0.02^{f}	8.86 ± 0.88^{gh}	4.60 ± 0.03^{a}	8.49 ± 0.10^{j}	0.81 ± 0.01^{k}	9.34 ± 0.19^{h}
X-1/2/04	12.10 ± 0.54^{h}	0.96 ± 0.02^{jk}	12.60 ± 0.63^{c}	4.55 ± 0.08^{b}	8.82 ± 0.11^{i}	0.99 ± 0.02^{e}	9.87 ± 0.45^{fg}
K-5/04	13.10 ± 0.57^{fg}	1.46 ± 0.04^{cd}	8.97 ± 0.93^{gh}	3.90 ± 0.06^{m}	9.29 ± 0.12^{h}	0.95 ± 0.02^{f}	10.29 ± 0.15^{e}
ZO-1/03	14.30 ± 0.59^{a}	0.98 ± 0.02^{ij}	14.59 ± 0.66^{ab}	4.55 ± 0.03^{b}	10.23 ± 0.13$^{a–d}$	1.11 ± 0.02^{ab}	11.40 ± 0.32^{a}
VB-1/04	14.10 ± 0.60^{ab}	1.52 ± 0.05^{c}	9.28 ± 0.78^{g}	4.00 ± 0.09^{l}	10.21 ± 0.17$^{a–d}$	1.09 ± 0.03^{b}	11.36 ± 0.19^{a}
DL-1/2/04	13.60 ± 0.43^{cde}	0.99 ± 0.01^{ij}	13.74 ± 0.72^{b}	4.55 ± 0.08^{b}	10.38 ± 0.33^{ab}	0.84 ± 0.02^{j}	11.27 ± 0.32^{abc}
ZL-1/3/04	13.30 ± 0.39^{def}	1.43 ± 0.05^{de}	9.30 ± 0.81^{fg}	4.10 ± 0.07^{j}	9.66 ± 0.19^{fg}	1.06 ± 0.02^{c}	10.78 ± 0.18^{d}
K-3/1/04	14.40 ± 0.55 a	1.51 ± 0.04^{c}	9.53 ± 0.83^{fg}	4.15 ± 0.02^{i}	9.45 ± 0.45^{gh}	0.89 ± 0.01^{g}	10.79 ± 0.54^{d}
T-7/04	13.30 ± 0.46^{def}	1.60 ± 0.05^{b}	8.31 ± 0.49^{h}	4.35 ± 0.03^{f}	9.40 ± 0.16^{gh}	0.82 ± 0.01^{k}	10.26 ± 0.33^{ef}
G-12/04	13.10 ± 0.56^{fg}	1.05 ± 0.02^{i}	12.48 ± 0.59^{c}	4.30 ± 0.02^{g}	8.92 ± 0.45^{i}	0.88 ± 0.03^{gh}	9.85 ± 0.99^{g}
T-9/03	13.60 ± 0.73^{cde}	1.66 ± 0.05^{b}	8.19 ± 0.80^{h}	4.05 ± 0.08^{k}	9.97 ± 0.32^{c-f}	0.84 ± 0.05^{j}	10.85 ± 0.98^{d}
N-4/03	13.20 ± 0.39^{efg}	1.21 ± 0.03^{gh}	10.91 ± 0.75^{ef}	4.45 ± 0.05^{d}	10.39 ± 0.66^{a}	0.86 ± 0.02^{hi}	11.29 ± 0.33^{ab}
D-1/04	13.80 ± 0.43^{bc}	0.97 ± 0.01^{j}	14.23 ± 0.65^{ab}	4.20 ± 0.08^{h}	10.11 ± 0.32$^{a–d}$	0.86 ± 0.01^{hi}	11.02 ± 0.34^{a-d}
ZL-2/03	13.70 ± 0.53^{bcd}	1.89 ± 0.02^{a}	7.25 ± 0.0.43^{i}	4.20 ± 0.03^{h}	9.92 ± 0.31^{def}	0.98 ± 0.02^{e}	10.95 ± 0.97^{bcd}
N-2/03	13.20 ± 0.49^{efg}	1.16 ± 0.05^{h}	11.38 ± 0.49^{de}	4.50 ± 0.04^{c}	10.30 ± 0.51^{abc}	1.03 ± 0.04^{d}	11.39 ± 0.99^{a}
ZL-1/03	13.30 ± 0.58^{def}	0.89 ± 0.01^{k}	14.94 ± 0.95^{a}	4.70 ± 0.08^{a}	10.03 ± 0.66^{cde}	1.20 ± 0.05^{a}	11.32 ± 0.81^{ab}
DL-1/1/04	13.20 ± 0.48^{efg}	1.37 ± 0.04^{ef}	6.63 ± 0.33^{i}	4.30 ± 0.03^{g}	8.89 ± 0.29^{i}	0.66 ± 0.01^{n}	9.59 ± 0.67^{gh}
L-2/04	14.00 ± 0.71^{abc}	1.24 ± 0.03g	11.29 ± 0.48^{de}	4.40 ± 0.03^{e}	9.95 ± 0.19^{def}	0.72 ± 0.01^{m}	10.71 ± 0.31^{d}
T-5/04	12.80 ± 0.33^{g}	1.34 ± 0.04^{f}	9.55 ± 0.85^{fg}	4.30 ± 0.05^{g}	9.70 ± 0.33^{efg}	0.95 ± 0.02^{f}	10.70 ± 0.27^{d}
HB	14.05 ± 0.58^{abc}	1.18 ± 0.03^{gh}	11.91 ± 0.54^{cd}	4.45 ± 0.09^{d}	10.05 ± 0.36^{bcd}	0.79 ± 0.03^{kl}	10.88 ± 0.55^{cd}

HB – control apricot cultivar Hungarian Best

The same letter(s) in vertical columns indicate non-significant differences between means at $P \leq 0.05$ by *LSD* test

in agreement with the previous works on apricot (Audergon *et al.* 1990; Mehlenbacher *et al.* 1991; Egea *et al.* 1997; Milošević *et al.* 2010).

The range of pH was between 3.90 ± 0.06 (K-5/04) and 4.70 ± 0.08 (ZL-1/03) (Table 2). Six genotypes had a significantly higher pH than cv. Hungarian Best at $P \leq 0.05$. In addition, twelve genotypes had a lower pH than the control. Variations in the contents of the SS, TA, and in pH value were found among the accessions, which is in accordance with a previous study carried out on apricot (Dolenc-Šturm *et al.* 1999).

Soluble solids/titratable acidity ratio varied from 6.63 ± 0.33 (DL-1/1/04) to 14.94 ± 0.95 (ZL-1/03) (Table 2). In four genotypes, this ratio was significantly higher than in the control cultivar at $P \leq 0.05$. On the other hand, in eleven genotypes SS/TA ratio was lower than in the control (Gurrieri *et al.* 2001). Fruit maturity controls the quality attributes, such as SS content, TA, firmness, and market life potential. Moreover, the relationship between SS and TA has an important role in consumers' acceptance of some stone fruits such as apricot, peach, nectarine, and plum cultivars. With the cultivars with TA > 0.90% and SS < 12.0%, the consumers' acceptance was controlled by the interaction between TA and SS rather than SS alone (Crisosto *et al.* 2004). Moreover, a single generic RSSC quality index would not be reliable with regard to ensuring consumers' satisfaction across all cultivars (Crisosto & Crisosto 2005). On the basis of the study by Crisosto *et al.* (2004), in our work, some genotypes had positive values of SS/TA ratio for consumers' satisfaction.

The data in Table 2 show that the contents of TS, RS, and SC ranged from 9.34 ± 0.19% (X-1/1/04) to 11.36 ± 0.19% (VB-1/04), 8.49 ± 0.10% (X-1/1/04) to 10.39 ± 0.66% (N-4/03), and 0.66 ± 0.01% (DL-1/1/04) to 1.20 ± 0.05% (ZL-1/03), respectively. The present study showed

Table 3. Correlation matrix among the studied variables

Variable	FW	SW	MP	Y	SS	TA	SS/TA	pH	RS	SU	TS
FW	1.000										
SW	0.755*	1.000									
MP	0.441	–0.197	1.000								
Y	0.111	0.227	–0.018	1.000							
SS	–0.055	–0.156	0.067	0.303	1.000						
TA	0.023	–0.221	0.352	–0.258	0.131	1.000					
SS/TA	–0.281	0.064	–0.472*	0.354	0.153	–0.897*	1.000				
pH	0.137	0.215	0.010	–0.001	–0.303	–0.659*	0.564*	1.000			
RS	–0.180	–0.056	–0.119	0.481*	0.658*	–0.106	0.376	0.025	1.000		
SU	–0.498*	–0.327	–0.170	–0.047	0.062	–0.165	0.360	0.049	0.306	1.000	
TS	–0.275	–0.133	–0.127	0.420	0.662*	–0.112	0.414	0.010	0.965*	0.505*	1.000

*Correlations significant at $P \leq 0.05$ by *LSD* test

FW – fruit weight; SW – stone weight; MP – mesocarp percentage; Y – yield; SS – soluble solids; TA – titratable acidity; SS/TA – soluble solids/titratable ratio; pH – pH value; RS – reducing sugars; SU – sucrose; TS – total sugars

that TS, RS and SC were significantly higher in eight, one, and seventeen genotypes, respectively, at $P \leq 0.05$. The SC content was higher than 1.0% in five genotypes. The same authors determined that sucrose and reducing sugars (glucose and fructose) were the major sugars in apricot genotypes (Dolenc-Šturm *et al.* 1999), which was confirmed by the results in this work. Mehlenbacher *et al.* (1990) reported that the greatest differences in the fruit chemical composition in apricot genotypes (*P. armeniaca* L.) were observed with respect to the dry matter and TS contents. Also, Dolenc-Šturm *et al.* (1999) showed that in sensory and chemical evaluations of apricot fruits, the individual sugars and organic acids as well as their ratios could be crucial in determining the taste of fruit. Our results show low RS, SU and TS contents for apricot genotypes as compared to the results of Akin *et al.* (2008). The differences between our results and those of Akin *et al.* (2008) could be due to the different eco-geographical groups of apricot genotypes studied. The results in this study confirmed the findings by Bailey and Hough (1975) and Valdés *et al.* (2009) who have also reported that organic acids play an important role in fruit taste through sugar/acid ratio. Moreover, apricot quality consists of a balance of sugar and acidity as well as a strong apricot aroma (Hormaza *et al.* 2007; Ishag *et al.* 2009). In generally, it may be concluded that the knowledge of the qualitative and quantitative compositions of acids and sugars in apricot fruits may prove to be a powerful tool in evaluating fruit maturity and quality (Dolenc-Šturm *et al.* 1999).

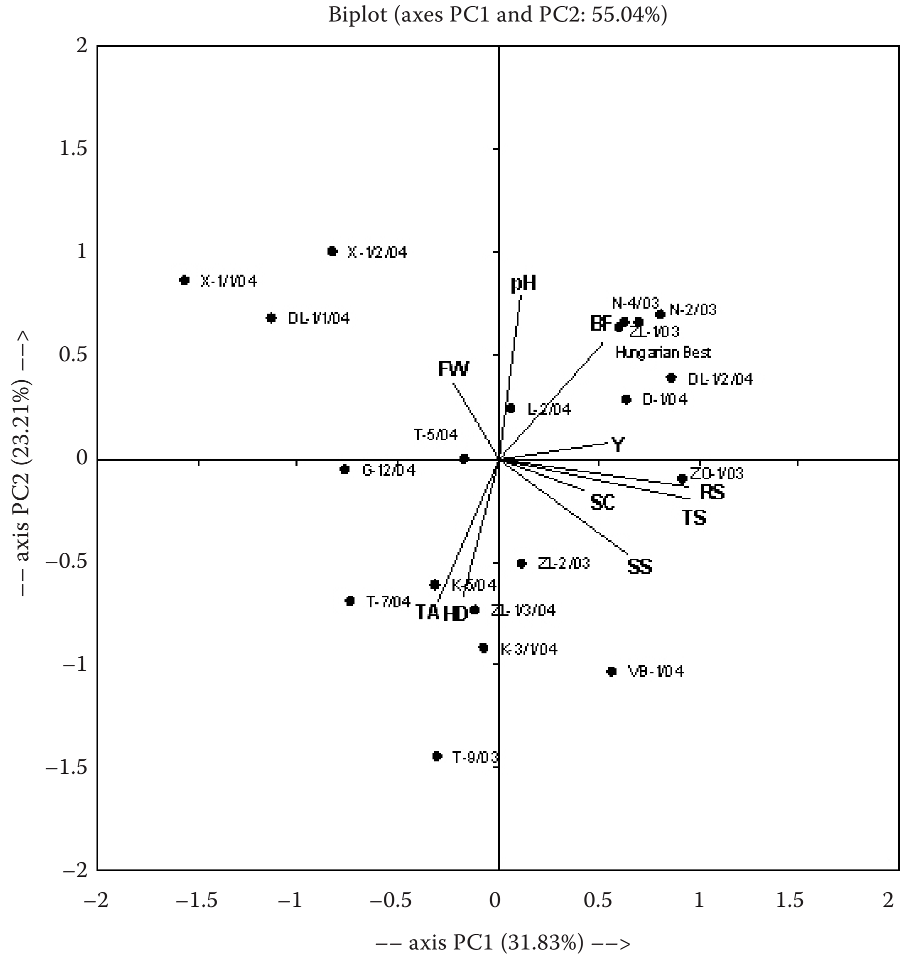
Table 4. Eigenvalues and proportion of total variability among apricot genotypes as explained by the first 11 principal components

Compounds (PC)	Eigenvalues	Percent of variance	Cumulative (%)
1	3.534	32.125	32.125
2	2.515	22.864	54.989
3	2.015	18.318	73.307
4	1.065	9.683	82.990
5	0.715	6.502	89.493
6	0.585	5.314	94.807
7	0.398	3.620	98.427
8	0.137	1.250	99.676
9	0.010	1.199	99.875
10	0.007	0.091	99.966
11	0.004	0.034	100.000

Correlations between variables

Correlations were found in a set of 11 fruit between physical and chemical traits of apricot genotypes (Table 3). Fruit weight was significantly correlated with SW (r = 0.755) in a way that larger fruits generally had larger stones (Milosevic & Milosevic 2010). On the other hand, FW negatively correlated with SU content (r = –0.498). It has been reported that larger fruits have a smaller capacity to accumulate SU, as previously described by Milošević *et al.* (2010). In general, FW was negatively correlated with SS, SS/TA ratio, RS and TS, and positively correlated with MP, Y, TA, and pH, but the correlation was not significant (Badenes *et al.* 1998; Asma & Ozturk 2005; Hernandez *et al.* 2010). Mesocarp percentage negatively correlated with SS/TA ratio (r = –0.472). A positive relationship between Y and RS was also observed (r = 0.481). It was reported that higher Y have a higher RS content.

SS was significantly correlated with RS or TS (r = 0.658 and r = 0.662, respectively) (Gurrieri *et al.* 2001; Ledbetter *et al.* 2006), while no relationship between SS and TA was found, as reported previously by Ruiz and Egea (2008b) (Table 3). A negative significant correlation was observed for TA versus SS/TA ratio (r = –0.897), and TA versus pH (r = –0.659) indicating the tendency of higher TA content to have smaller SS/TA ratio and lower pH. Similar findings were reported by Hernadez *et al.* (2010). In addition, there was no significant correlation between SS/TA and other chemical attributes such as SS, RS, SC, and TS, which is in contrast with the results reported by Badenes *et al.* (1998). The differences between our results and those of Badenes *et al.* (1998) were most



SS – soluble solids; TS – total sugars; RS – reducing sugars; SU – sucrose; Y – yield; SS/TA – soluble solids/titratable acids ratio; pH – pH value; SW – stone weight; FW – fruit weight; MP – mesocarp percentage; TA – titratable acidity

Figure 1. Biplot based on principal components analysis (PCA) for fruit quality atributes and tree characteristics in 20 apricot genotypes

likely due to the differences in the plant material used and in the size of the group of the cultivars studied. Total sugars showed a significant positive correlation versus RS (r = 0.965) or SU (r = 0.505), in a way that higher RS and SU contents generally meant a higher TS content, as previously reported (Ledbetter *et al*. 2006) (Table 3).

In general, the correlation coefficients between the apricot genotype variables were evaluated. This study suggests that the physical and chemical attributes of the genotypes tested can be improved under horticultural practices.

Principal component analysis (PCA) and grouping of genotypes

Principal components analysis (PCA) is a way of identifying the patterns in the data, and expressing the data in such a way as to highlight their similarities and differences (Winterová *et al.* 2008). It has been used previously to establish the relationships among genotypes, i.e. cultivars, and to study the correlations between fruit physical and chemical traits and other characteristics within sets of apricot genotypes (Badenes *et al.* 1998; Gurrieri *et al.* 2001; Azodanlou *et al.* 2003; Ruiz & Egea 2008b). The PCA used in our work showed that more than 73.31% of the variability observed was explained by the first three components (Table 4). PC1, PC2, and PC3 accounted for 32.12%, 22.86%, and 18.32%, respectively, of the variability. The correlation between the original variables and the first three principal components is shown in Table 5. Positive values for PC1 correspond to the genotypes with higher contens of total sugars, reducing sugars, and sucrose, lower pH values, and lower soluble solids/titratable acidity ratios as shown in Figure 1. Genotypes ZL-1/03, ZO-1/03, DL-1/2/04, N-4/03, D-1/04, and N-2/03 were included in this group. The highest negative values for PC1 indicate the genotypes with lower contents of total sugars, reduc-

Table 5. Component loadings for quality variables and component scores for 20 apricot genotypes

Variable/factors	Component loading			Genotypes	Component scores		
	PC1, λ = 32.13	PC2, λ = 22.86	PC3, λ = 18.32		PC1	PC2	PC3
Fruit weight	–0.440	–0.364	0.755	X-1/1/04	–3.352	–1.103	–2.950
Stone weight	–0.138	–0.603	0.590	X-1/2/04	–0.911	–3.487	–1.129
Mesocarp %	–0.394	0.264	0.350	K-5/04	–0.909	1.645	–0.275
Yield	0.483	–0.088	0.558	ZO-1/03	3.458	0.720	–1.863
Soluble solids	0.508	0.518	0.451	VB-1/04	0.781	3.061	–0.036
Titratable acidity	–0.521	0.775	0.126	DL-1/2/04	2.323	–1.431	2.113
SS/TA ratio	0.794	–0.532	–0.154	ZL-1/3/04	–0.143	1.177	–0.894
pH value	0.236	–0.742	–0.083	K-3/1/04	–0.480	1.645	0.562
Reducing sugars	0.814	0.299	0.373	T-7/04	–1.668	0.182	0.576
Sucrose	0.556	0.183	–0.462	G-12/04	–0.692	–1.018	–2.456
Total sugars	0.863	0.343	0.247	T-9/03	–0.493	1.897	–0.052
				N-4/03	1.168	0.049	0.010
				D-1/04	2.308	–1.169	0.115
				ZL-2/03	–0.847	2.484	0.038
				N-2/03	1.514	–0.616	0.325
				ZL-1/03	2.489	–1.847	–0.525
				DL-1/1/04	–4.359	–1.241	2.567
				L-2/04	–0.289	–0.159	1.243
				T-5/04	–0.688	0.005	0.121
				HB	0.788	–0.793	2.507

HB – control apricot cultivar Hungarian Best ing sugars, and sucrose, higher pH values, and higher soluble solids/titratable acidity ratios. This group includes genotypes: X-1/1/04, T-7/04, DL-1/1/04 and T-5/04 (Figure 1). The genotype X-1/2/04 which had the lowest PC2 value stands out especially due to the low contents of soluble solids and titratable acidity (Figure 1). The group of genotypes with the highest PC2 values were characterised by higher contents of soluble solids and titratable acidity. Genotypes such as K-5/04, VB-1/04, ZL-1/3/04, K-3/1/04, T-9/03, and ZL-2/03 belong to this group as shown in Figure 1. The highest positive PC3 values indicate the genotypes that had higher fruit and stone weights, higher mesocarp percentage and yield (cv. Hungarian Best and L-2/04), as shown in Figure 1. On the other hand, a lower negative PC3 value indicates lower yield, fruit and stone weights, and mesocarp percentage. These caracteristics were observed in genotype G-12/04 (Figure 1).

In generally, PC analysis may help to select a set of genotypes with better fruit quality performances (Gurrieri *et al*. 2001; Azodanlou *et al*. 2003; Ruiz & Egea 2008b), which, in our study, might be indicated in DL-1/1/04, DL-1/2/03, D-1/04, and K-5/04.

CONCLUSION

The apricot genotypes selected in the region of Skopje (Povardarie) showed substantial variability in terms of the tested physical and chemical attributes. Under non-cultural practices, many genotypes produced large fruits and a high mesocarp percentage, as well as higher contents of soluble solids, sugars (reducing sugars, sucrose, total sugars) and a stable titratable acidity and pH as compared to the control.

A high correlation was found among some apricot quality attributes, which could reduce the number of fruit quality traits to be studied in apricot germplasm. These relationship and PC analysis may help to select a set of genotypes with better fruit quality performances, which in our study might be indicated in DL-1/1/04, DL-1/2/03, D-1/04, and K-5/04.

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