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Impact of Harvest Time on the Main Agronomic and Fruit Quality Traits of Three Apricot Cultivars

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Fruit quality and sensorial traits of three apricot cultivars as affected by harvest time were evaluated. High variability and significant differences were found among cultivars in all studied traits, except flowering date, yield efficiency, stone weight, titratable acidity, and sucrose. Additionally, all evaluated traits significantly depended on the harvest time. Year-by-year variation also was observed. Mid-late season 'Hungarian Best' and late ripening 'Kecskemét Rosè' cultivars had better fruit quality and sensorial traits than the early ripening cultivar 'Senetate', and can be recommended for fresh consumption, storage, and processing. On a principal component analysis, mid- and late-harvest time was shown to be positively associated with a good yield, sweetness, flavor, juiciness, and aroma, and negatively associated with sourness of the apricot.

KEYWORDS *chemical composition, maturity,* Prunus armeniaca *L., yield efficiency*

INTRODUCTION

Apricot (*Prunus armeniaca* L.) is one of the most important and desirable of the temperate tree fruits (Ruiz and Egea, 2008; Trivedi et al., 2011).

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Apricots are cultivated worldwide 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 and Twigg, 1966). Therefore, apricot cultivars must be characterized by fruit quality features that satisfy consumers (Crisosto et al., 2004). However, fruit quality attributes are affected by a number of pomological traits (Milosevic et al., 2010) that cannot be analyzed separately from the biological properties of the fruit tree and the yield obtained (Asma et al., 2007; Akin et al., 2008), agronomical and ecological factors (Licznar-Małańczuk and Sosna, 2005; Guerriero et al., 2006), and their correlations (Badenes et al., 1998; Ruiz and Egea, 2008; Infante et al., 2008).

Among the quality parameters that define the eating quality of apricot, important traits, such as texture and flavor, influence final acceptance (Infante et al., 2008). Flavor has been defined as a complex attribute of quality in which a mixture of sugars, acids, and volatile compounds play a primary role (Baldwin, 2002). Fruit shape, color intensity, aroma, sweetness, sourness, flesh firmness, and juiciness are all basic sensory descriptors for apricot (Infante et al., 2006).

In order to attain an acceptable, pleasant flavor, apricots should generally be harvested when they are ready to eat. Nevertheless, for long-term storage or transport, fruits are harvested at the pre-climacteric stage, before they attain their full flavor and color, but are more tolerant to handling and prolonged cold storage (Aubert and Chanforan, 2007). This commercial practice affects their eating quality attributes, resulting in fruits with an undesirable taste and aroma (Manolopoulou and Mallidis, 1999; Dong et al., 2002).

The aim of this study was to evaluate the effect of harvest maturity on the main agronomic, fruit quality, and sensory attributes of early ('Senetate'), mid-late ('Hungarian Best'), and late ripening ('Kecskemét Rosè') apricot cultivars in Macedonia.

MATERIALS AND METHODS

Plant Material and Field Trial

Three commercial ('Senetate', 'Hungarian Best', 'Kecskemét Rosè') apricot cultivars grafted onto Myrobalan rootstock were compared in a trial during a 2-year production period (2003–2004). This choice was due to the possible interest in these three cultivars in the region of Skopje (Macedonia), because of their maturity time and good fruit quality.

The trial was conducted at an experimental orchard located near Skopje, Macedonia (42° 00′ N latitude, 21° 26′ E longitude, 240 m altitude). The orchard was planted in 1993 at a spacing of 5 m × 4 m (500 trees ha^{-1}) and trained to open vase. Standard cultural practices (pruning, thinning, fertilization, pest and disease control) were performed. The orchard was not irrigated. The experiment was established in a randomized block design with five trees in four replications for each cultivar.

Phenology, Growth Measurement, and Yield

Phenological characteristics, such as the beginning of flowering (BF), full flowering (FF), end of flowering (EF), flowering duration (FD), harvest time (HT), and period of fruit development (FDe), were evaluated according to IBPGR descriptors for apricot (Guerriero and Watkins, 1984).

Trunk circumference was measured during the end of the vegetative cycle 20 cm above the graft union, and the trunk cross-sectional area (TCSA) was calculated (cm^2). Yield per tree (Y), cumulative yield per tree (CY), and yield efficiency (YE) (ratio of final yield in kg per final TCSA in cm^2) of each cultivar were computed from the harvest data. The data are given in kg $tree^{-1}$ and kg cm^{-2}, respectively.

Fruit Quality and Sensory Traits

Fruit quality traits, such as fruit weight (FW), stone weight (SW), flesh percentage (FP), soluble solids content (SS), total sugars (TS), reducing sugars (RS), sucrose (SU), titratable acidity (TA), soluble solids/titratable acidity ratio or ripening index (SS/TA ratio or RI), total sugars/titratable acidity ratio or index of sweetnes (IS), juice pH, skin ground color (GC), flesh color (FC), and kernel taste (KT), were measured immediately after picking (commercial maturity stage). The FW and SW were taken using a Tehnica ET-1111 technical scale (Iskra, Horjul, Slovenia), and are expressed in g. On the basis of the measured data, FP was calculated.

Five panelists evaluated apricot cultivars' sensory traits. The described GC, FC, and KT were categorized according to IBPGR descriptors for apricot: (1) skin ground color (GC) with seven categories: 1 = green-yellowish through 7 = dark orange, flesh color (FC) with nine categories: 1 = white-greenish through 9 = red; (2) kernel taste (KT): 1 = sweet, 2 = weak bitterness, 3 = strong bitterness. The samples of 20 fruits per tree were harvested randomly.

The SS (°Brix) was determined by a Milwaukee MR 200 hand refractometer (ATC, Rocky Mount, NC, USA), and pH juice by a Cyber Scan 510 pH meter (Eutech, Nijkerk, Netherlands). Total and reducing sugars content was determined using the Luff-Schoorl method and is expressed as percentage of fresh weight. The TA was measured by neutralization to pH 7.0 with 0.1 N NaOH, and data are given as percentage of malic acid. On the basis of the measured data, SS/TA ratio (RI) and TS/TA ratio (IS) ratio was calculated.

Statistical Analysis

Statistical analyses were performed using the MSTAT-C statistical computer package (Michigan State University, East Lansing, MI, USA). A basic descriptive statistical analysis was followed by an analysis on variance test for mean comparisons. The method used to discriminate among the means was the Fisher's Least Significant Difference (LSD) procedure at 95.0% ($P \leq 0.05$) confidence level. To determine associations between agronomic, fruit quality, and sensorial traits, a principal component analysis (PCA) was performed using the PRINCOMP procedure of the SAS statistical package with the same factorial design (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Data in Table 1 showed that BF was earlier in 'Senetate' and 'Hungarian Best' than in 'Kecskemét Rosè', when FF varied from 24 March ('Senetate') to 25 March in the other two cultivars. The EF varied from 31 March ('Hungarian Best' and 'Kecskemét Rosè') to 1 April ('Senetate'). In general, the BF, FF, and EF in this study were earlier in 2003 than those of the second year (data not shown). The FD ranged from 8 to 10 days (Table 1). Ristevski and Mitreski (1986) reported that apricot flowering in the FYR Macedonia lasted for 8–10 days, as confirmed by the results obtained in this study. In addition, the differences in flowering time among cultivars in our study were due to physiological factors, and year-by-year differences were induced by ecological factors, such as temperature, rainfall, solar radiation, soil, and altitude (Arzani and Roosta, 2004; Licznar-Małańczuk and Sosna, 2005; Trivedi et al., 2011).

All cultivars used were harvested between 22 June and 11 July (Table 1); there were large variations in the harvest season between the evaluated cultivars. 'Senetate' cultivar harvested earlier more than 'Hungarian Best'. The latest cultivar was 'Kecskemét Rosè', which had a harvest date of 11 July; the period of FD varied from 88 to 100 days, which is in agreement with a previous study in apricot (Milatović et al., 2000). Year-by-year variations

TABLE 1 Phenological Traits of Three Apricot Cultivars in Skopje Region in the 10 and 11 Years after Planting (Mean Values)

Cultivar	Flowering			Flowering duration (days)	Harvest time	Period of fruit development (days)
	Beginning	Full	End			
Senetate	23 Mar	24 Mar	01 Apr	10	22 Jun	88
Hungarian Best	23 Mar	25 Mar	31 Mar	8	02 Jul	99
Kecskemét Rosè	24 Mar	25 Mar	31 Mar	9	11 Jul	100

for HT and FD also were found (data not shown), which could be due to the influence of environmental conditions, especially temperature (Licznar-Małańczuk and Sosna, 2005; Ruiz and Egea, 2008). Also, in an earlier study, Badenes et al. (1998) showed a strong correlation of both HT and FD period with the BF.

Vigor and Yield Characteristics

The significantly greatest TCSA was exhibited in 'Senetate' and 'Hungarian Best', and was lowest in 'Kecskemét Rosè', whereas the highest yield was obtained in 'Hungarian Best', and the lowest in 'Senetate' (Table 2). Yield variation was observed (data not shown) and was higher in 2003 when compared with 2004 (Milatović et al., 2000). Also, in a previous study of apricot, alternate bearing was observed (Licznar-Małańczuk and Sosna, 2005).

The higher CY was found in 'Hungarian Best', and the lowest in 'Senetate'. It may be concluded that 'Hungarian Best' was the most productive cultivar. For this reason, it is the predominant cultivar in the apricot orchards of Serbia and Macedonia (Milosevic et al., 2010). Moreover, the best YE was exhibited in 'Hungarian Best', probably due to its higher yield and cumulative production, but differences among cultivars were not significant (Table 2). These opposing responses in tree development and yield traits may be due to a better or worse adaptation of these cultivars to a typical warm Skopje environment. Low Y and YE shown by 'Senetate' has already been reported by Milatović et al. (2000).

Fruit Quality Traits

The FW is a major quantitative factor determining yield, fruit quality, and consumer acceptability (Ruiz and Egea, 2008). The FW ranged from 36.51 g ('Kecskemét Rosè') to 61.11 g ('Hungarian Best') and differences among cultivars were highly significant (Table 3). Licznar-Małańczuk and Sosna (2005) reported that FW depended on the cultivar and crop load. Previous works on apricot also reported a high variability among cultivars regarding

TABLE 2 Trunk Cross-Sectional Area (TCSA), Yield, Cumulative Yield, and Yield Efficiency of Three Apricot Cultivars in the 10 to 11 Years after Planting (Mean Values)

Cultivar	TCSA (cm^2)	Yield (kg $tree^{-1}$) (2004)	Cumulative yield (kg $tree^{-1}$) (2003–2004)	Yield efficiency (kg cm^{-2})
Senetate	34.11a[z]	17.48c	57.44c	0.512a
Hungarian Best	33.56a	32.56a	100.16a	0.970a
Kecskemét Rosè	31.72b	23.61b	82.97b	0.744a

[z]The same letters in columns show the insignificant difference at $P \leq 0.01$ by LSD test.

TABLE 3 Fruit and Stone Weight, Flesh Percent, Soluble Solids, Titratable Acidity, pH Juice, and SS/TA Ratio (RI) of Three Apricot Cultivars (Mean Values from Two Successive Years)

Cultivar	FW[z] (g)	SW (g)	FP (%)	SS (°Brix)	TA (%)	pH juice	SS/TA ratio
Senetate	39.11b[y]	3.25a	91.64ab	12.25c	1.15a	4.35ab	10.65c
Hungarian Best	61.11a	4.13a	93.18a	14.05b	1.18a	4.45a	11.91b
Kecskemét Rosè	36.51c	3.37a	90.32b	14.40a	1.16a	4.25b	12.41a

[z]For explanation of character symbols, see "Materials and Methods."
[y]The same letters in columns shows the insignificant difference at $P \leq 0.01$ by LSD test.

this parameter (Badenes et al., 1998; Milatović et al., 2000; Milosevic et al., 2010). Year-by-year variations were significant (data not shown), which is in accordance with results described by Ruiz and Egea (2008). Differences for SW among cultivars were insignificant. Values of FP were lower in 'Kecskemét Rosè' (90.3%) than in 'Hungarian Best' (93.2%), while differences between 'Hungarian Best' and 'Senetate', and 'Kecskemét Rosè' and 'Senetate' were not found (Table 3).

The SS content ranged from 12.3 °Brix ('Senetate') to 14.4 °Brix ('Kecskemét Rosè') (Table 3), although all of the cultivars showed values higher than 12 °Brix. Year-by-year variation was observed (data not shown), which is in accordance with previous work in apricot (Ruiz and Egea, 2008). Some authors reported that apricot cultivars which that SS content >12 °Brix had good flavor characteristics (Crisosto et al., 2004). Ruiz and Egea (2008) also reported that SS content is a very important quality attribute, influencing notably the fruit taste.

Our range values of TA were in agreement with previous work on apricots (Milatović et al., 2000; Gurrieri et al., 2001), but differences among cultivars were insignificant. On the other hand, the TA in our study was lower when compared with results obtained by Infante et al. (2008). This may be due to the differences in cultivars studied, cultural practices, and geographical factors (Badenes et al., 1998). The fruit maturity stage at the harvest date is the principal factor affecting TA and also the SS content (Infante et al., 2008; Ruiz and Egea, 2008).

The juice pH was significantly affected by cultivar (Table 3). The higher values were found in 'Hungarian Best' (4.45) and the lower in 'Kecskemét Rosè' (4.25). These values are usual for normal acidity fruit. Non significant year-by-year variation was observed in the case of this trait (data not shown).

The RI (SS/TA ratio) ranged from 10.7 ('Senetate') to 12.4 ('Kecskemét Rosè'), depending on their SS and TA. Ruiz and Egea (2008) reported that the relationship between TA and SS has an important role in consumer acceptance of some apricot, peach, nectarine, and plum cultivars. Also, Crisosto et al. (2004) stated that in the case of cultivars with TA < 0.90% and SS >12.0%, consumer acceptance was controlled by the interaction between TA

TABLE 4 Sugar Content, TS/TA Ratio (IS), and Main Sensory Traits of Three Apricot Cultivars (Mean Values from Two Successive Years)

Cultivar	Sugars			TS/TA^{y} ratio	GC	FC	KT
	Reducing	Sucrose	Total				
Senetate	8.80c^{z}	0.80a	9.64c	8.38c	5^{x}	6^{x}	3^{x}
Hungarian Best	10.05a	0.79a	10.88a	9.22a	5	7	1
Kecskemét Rosè	9.58b	0.91a	10.54b	9.09b	6	7	3

^{z}The same letters in columns shows the insignificant difference at $P \leq 0.01$ by LSD test.
^{y}For explanation of character symbols, see "Materials and Methods."
^{x}GC: 5 = light orange; 6 = orange; FC: 6 = light orange; 7 = orange; KT: 1 = sweet; 3 = strong bitterness (Guerriero and Watkins, 1984).

and SS rather than SSC alone. In our study, all cultivars showed a good value for this trait. Infante et al. (2008) concluded that FW, SS, and flesh firmness were major fruit quality traits for stone fruit industry.

The RS, TS, and IS significantly depend on the cultivars, whereas no significant differences were observed among cultivars regarding SU content (Table 4). The highest values of RS, TS, and IS were found in 'Hungarian Best', and the lowest in 'Senetate'. In 'Kecskemét Rosè', content of these sugars were intermediate. Regarding SU, differences among cultivars were not observed. Our results showed a low RS, SU, and TS contents for apricot cultivars 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 sugar/acid ratio (IS) is commonly used as a quality index. In our study, significantly higher value was observed in 'Hungarian Best' (9.3), and lower in 'Senetate' (8.4). The RI plays an important role in consumer acceptance of some peach, nectarine, and plum cultivars (Crisosto et al., 2004). In addition, apricot quality consists of a balance of sugar and acidity as well as a strong apricot aroma (Manolopoulou and Mallidis, 1999; Dong et al., 2002; Ishag et al., 2009).

The GC and FC ranged from light orange to orange (Table 4). The visual evaluation showed a high coincidence between the GC and the FC for each apricot cultivar studied, which is in agreement with a previous study in apricot (Ruiz and Egea, 2008). The KT in 'Senetate' and 'Kecskemét Rosè' was strong bitterness, whereas in 'Hungarian Best' it was sweet (Guerriero and Watkins, 1984). In addition, KT determined its use.

Principal Component Analysis (PCA)

PCA is used to establish relationships among cultivars and to study of segregation of main agronomic, fruit quality, and sensorial traits within cultivars (Infante et al., 2008; Ruiz and Egea, 2008).

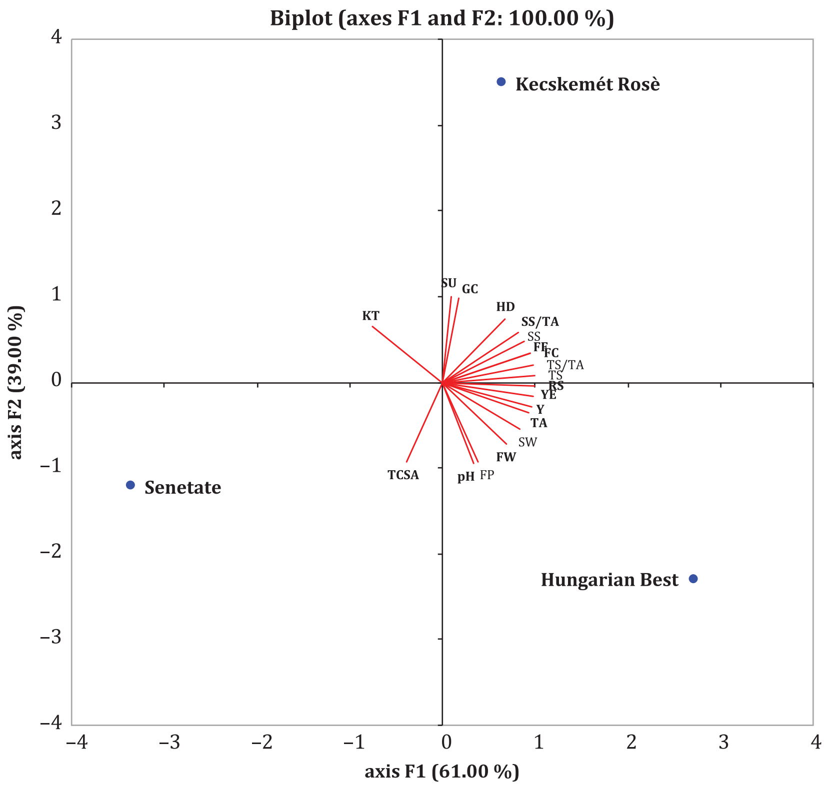

FIGURE 1 Biplot based on principal components analysis (PCA) for main agronomic, fruit quality, and sensorial traits in three apricot cultivars. For explanation of character symbols, see Materials and Methods section (color figure available online).

Total variation of the plot (100.00%) (Fig. 1) was explained by PC1 and PC2. PC1 (61.00%) represents Y, YE, SW, SS, TA, SS/TA, RS, TS, TS/TA, FC, KT, and FF, while PC2 (39.00%) was associated with TCSA, FW, FP, pH, SU, GC, and HT. Positive values for PC1 indicated that mid-late cultivar ('Hungarian Best') had the highest Y, YE, SW, FP, TA, RS, TS, and TS/TA ratio, whereas early ripening cultivar ('Senetate') had the lowest SW, SS, TA, and IS. Positive values of PC2 showed that late ripening cultivar ('Kecskemét Rosè') had the highest value of SU and orange GC. On the other hand, negative values of PC2 were associated with lowest TCSA, FW, FP, and juice pH in 'Kecskemét Rosè'.

In conclusion, comparing our results with data from the literature it could be said that mid-late and late ripening cultivars are more suitable for growing under poor soil and warm summer conditions of Skopje region, than early ripening cultivars. Also, 'Hungarian Best' and 'Kecskemét Rosè' have better fruit quality and sensorial traits and can be recommended for fresh consumption, storage, and processing (Manolopoulou and Mallidis, 1999; Infante et al., 2006, 2008).

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