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Analysis of Morphological and Pomological Characteristics of Apricot Germplasm in FYR Macedonia

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ABSTRACT

Morphological and pomological features were studied for two consecutive years in wild apricot seedlings grown under Macedonian environmental conditions. The population comprised of 19 seedlings, i.e. genotypes, that showed notable fruit and tree traits. Their flowering time and desirable fruit quality features were determined in comparison with 'Hungarian Best'. In all genotypes, flowering occurred two days earlier than the control in both years, with the exception of end of flowering in the second year, whereas harvest time was later in seven genotypes than in 'Hungarian Best'. Genotypes showed a range of 23.40±1.62 g to 89.29±2.98 g for fruit weight, 1.81±0.13 to 4.85±0.17 g for stone weight, 11.70±0.41 to14.40±0.55 ºBrix for soluble solids, and 0.89±0.01 to1.89±0.02% for titratable acidity. Soluble solids was higher than 12% in eighteen genotypes. The pH ranged between 3.90±0.06 and 4.70±0.08. The contents of reducing sugars, sucrose, and total sugars ranged from 8.49±0.10 to 10.39±0.66%, 0.66±0.01 to 1.20±0.05%, and 9.34±0.19 to 11.36±0.19%, respectively. The genotypes were grouped into four clusters according to their potential. A high correlation was found among some quality traits. Using a principal component analysis, apricot genotypes were segregated into groups with similar physical and chemical features. These relationships may help in selection of a set of genotypes with better fruit quality performances, which, in our study, wre observed in DL-1/1/04, DL-1/2/03, D-1/04, and K-5/04. Based on this evaluation, 19 outstanding genotypes were pre-selected from the initial breeding population for further studies.

Keywords: Apricot, Fruit quality, Genotypes, *Prunus armeniaca* L.

INTRODUCTION

Apricot trees (*Prunus armeniaca* L.) originated in China and Central Asia..The origin center of apricot (center of diversity or gene center) is in Xinjiang, China (Yuan *et al*., 2007). Its germplasm resources in the world are extremely abundant (He *et al*., 2007). It has been cultivated in China since 2000 BC. During the long period of cultivation, it moved westwards "via the Silk Road" to Central Asia and Asia Minor, and arrived in Greece in 400-300 BC (Martínez-Mora *et al*., 2009). It was spread throughout Europe by the Romans in 100-70 BC (Bailey and Hough, 1975). Mehlenbacher *et al*. (1991) reported that the gene pool of apricot contains species and varieties that have adapted to the cold winters of Siberia, the subtropical climate of North Africa, the deserts of Central Asia, and humid areas of Japan and East China. Apricots are cultivated worldwide mainly for their high-quality fruit, which is consumed fresh, processed by the

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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, and mechanical and functional properties (Kramer and Twigg, 1966). Therefore, new fruit cultivars, including apricot, must be characterized by fruit quality features that satisfy the consumers (Padilla-Bernal and Pérez-Veyna, 2008). However, fruit quality features are affected by a number of pomological traits (Bailey and Hough, 1975; Crossa-Raynaud and Audergon, 1991) that cannot be analyzed separately from the biological properties of the fruit tree and the yield obtained (Balta *et al*., 2002; Asma and Ozturk, 2005; Asma *et al*., 2007; Akin *et al*., 2008), agronomical and ecological factors (Guerriero *et al*., 2006), and their correlations (Badenes *et al*., 1998; Ruiz and Egea, 2008). Accordingly, selection of the valuable individuals within seedling populations that display great diversity might contribute to the apricot breeding programs.

Apricot cultivation has a long history in the FYR Macedonia, specifically in its central fruit growing region of Povardarie, primarily the Skopje region, that has a large wealth of germplasm resources. Specifically, it hosts a highly diverse population of apricot seedlings, found either individually or in groups, that are adapted to the existing environmental conditions. They show huge differences in biological properties, with some standing out as having positive pomological traits. In view of the above, substantial attention has been focused on apricot germplasm preservation in FYR Macedonia. Here, as in other countries, the goal of the breeding program is to select promising genotypes from these seedlings for high fruit quality, resistance to late spring frost, late flowering, and an extended ripening season (Ristevski and Mitreski, 1986). Characterization of such seedlings for phenological and morphological traits resulted in the selection of some promising genotypes (Balta *et al*., 2002; Asma *et al*., 2007).

The present study was performed to select native apricot seedlings in the Skopje region (North FYR Macedonia) and characterize them with respect to fruit quality and tree traits and evaluate the relationships among biological traits related to fruit quality features. Another objective was to study correlations among variables in order to establish relationships among genotypes regarding fruit quality features.

MATERIALS AND METHODS

The Study Area and Plant Material

The study was conducted in the Skopje region (42º N latitude, 21º E longitude and 240-460 m altitude) stretching over a distance of 21 km and 5 km "as the crow flies" in an east-west and north-south direction, respectively, covering an area of 105 km^2. The city is located in the narrow Vardar River valley surrounded by Mt. Skopska Crna Gora in the north and Mt. Vodno in the south. The material used for *in situ* studies included seedling apricot (*Prunus armeniaca* L.) trees singled out of an abundant population during 2003 and 2004. A total of 19 seedlings, i.e. genotypes, having superior fruit and tree characteristics were selected from over 1,100 native seedling trees estimated to be 5-55 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 under 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 on Myrobalan (*Prunus cerasifera* Ehrh.) seedlings. It was planted in 1993 at a spacing of 5 m×4 m (500 trees ha^{-1}) and trained to a vase shape. The orchard received standard cultural practices, providing 'Hungarian Best' with the growth and

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development conditions superior to those found *in situ* for the studied genotypes.

Experimental Procedure and Analysis of Tree Traits and Fruit Quality Features

All variables were examined in two consecutive years (2003-2004). Phenological characteristics such as beginning of flowering (BF), full flowering (FF), end of flowering (EF), harvest date (HD), and period of fruit development (FD) were recorded. Tree traits were evaluated through age of tree (AT), total height (trunk height+crown height) (TH), crown height (CH), crown width (CW) and crown volume (CV) (m and m^3, respectively) and trunk circumference (TC) measured at 60 cm above ground level (cm). Ten fruits per genotype in three replications were collected at the commercial maturity stage, on the basis of their skin ground colour (fully-coloured). Fruit quality features such as fruit weight (FW) and stone weight (SW), fruit dimensions - fruit height (FH), fruit width (FWi), fruit thickness (FT), mesocarp percentage (MP), flesh colour (FC), kernel taste (KT), soluble solids content (SS), titratable acidity (TA), pH (pH) and sugars content [reducing sugars (RS), sucrose (SC) and total sugars (TS)] were measured.

Fruit weight (g) and SW (g) were taken using a Tehnica ET-1111 technical scale (Iskra, Slovenia). Mesocarp percentage was calculated as the ratio of the weight of the edible portion of the fruit to the total fruit weight (%). The described FC and KT were categorized according to IBPGR descriptors for apricot (Guerriero and Watkins, 1984): (1) flesh colour (FC) with nine categories: 1= White-greenish, through 9= Red; (2) kernel taste (KT): 1= Sweet, 2= Weak bitterness, 3= Strong bitterness. Yield (Y) was determined for each seedling tree in both years. An ACS System Electronic Scale (Zhejiang, China) was used to measure fruit yield (kg $tree^{-1}$).

Soluble solids content (ºBrix) was determined by an Milwaukee MR 200 (ATC, Belgium) hand refractometer, and pH by a Cyber Scan 510 pH meter (Nijkerk, Netherlands). An HPLC analysis of sugars was performed using a Thermo separation products (Riviera beach, USA) HPLC refractive index detector. Separation of sugars was carried out using a Rezex RCM-monosaccharide column (300×7.8 mm) and the column temperature was maintained at 65ºC. Sugars were analyzed isocratically according to the method of Šturm *et al*. (2003) with a Rezex RCM column (300×7.8 mm, Phenomenex) at 80°C using an RI detector. Deionized water was used as the mobile phase, with an injection volume of 20 µl, and a flow rate of 0.6 ml/min. Content of RS was the sum of glucose and fructose contents. Total sugars contents were the sum of RS and SC. The content of sugars were expressed as percentage of fresh weight. Titratable acidity was analyzed by HPLC using an Aminex HPX-87H column (300×7.8 mm) (Bio-Rad, USA) associated with a UV detector set at 210 nm according to the method described by Šturm *et al*. (2003). Data are given as % malic acid of fresh weight, since this is the dominant organic acid in apricot.

Data Analysis

All data in the present study were subjected to analysis of variance (ANOVA) using the MSTAT-C statistical package (M-STAT, 1990) and the means were separeted by LSD test at $P \leq 0.05$. Clustering of genotypes into similarity groups was done using the method of UPGA (Unweighted Pair Group Average). The Statistica 6.0 (StatSoft, Inc., Tulsa, Oklahoma, USA) was employed to make a graphic representation of the cluster analysis. 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 Phenological and Tree Traits

The phenological traits of apricot genotypes are given in Table 1. The BF

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Table 1. Phenological characteristics of apricot genotypes from Skopje region.

Genotypes	Flowering						Flowering duration (days)		Harvest date		Period of fruit development (days)	
	Beginning		Full		End							
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
X-1/1/04	15 Mar	22 Mar	17 Mar	24 Mar	23 Mar	31 Mar	9	10	28 May	03 Jun	75	75
X-1/2/04	16 Mar	23 Mar	18 Mar	25 Mar	24 Mar	31 Mar	9	9	03 Jun	08 Jun	80	79
K-5/04	16 Mar	22 Mar	18 mar	25 Mar	25 Mar	31 Mar	10	10	06 Jun	10 Jun	82	80
ZO-1/03	17 Mar	23 Mar	19 Mar	25 Mar	24 Mar	31 Mar	8	9	08 Jun	11 Jun	83	81
VB-1/04	16 Mar	24 Mar	18 Mar	26 Mar	25 Mar	31 Mar	10	8	13 Jun	18 Jun	86	90
DL-1/2/04	18 Mar	25 Mar	20 Mar	27 Mar	29 Mar	01 Apr	12	8	15 Jun	21 Jun	89	91
ZL-1/3/04	17 Mar	23 Mar	20 Mar	26 Mar	27 Mar	01 Apr	11	10	16 Jun	21 Jun	90	91
K-3/1/04	16 Mar	23 Mar	19 Mar	25 Mar	25 Mar	31 Mar	10	9	18 Jun	24 Jun	94	95
T-7/04	14 Mar	20 Mar	16 Mar	22 Mar	25 Mar	30 Mar	12	11	21 Jun	26 Jun	99	101
G-12/04	18 Mar	25 Mar	20 Mar	27 Mar	28 Mar	01 Apr	11	8	24 Jun	29 Jun	97	99
T-9/03	13 Mar	20 Mar	15 Mar	22 Mar	24 Mar	31 Mar	12	12	25 Jun	29 Jun	104	103
N-4/03	23 Mar	28 Mar	26 Mar	30 Mar	01 Apr	03 Apr	10	7	30 Jun	04 Jul	97	101
D-1/04	19 Mar	26 Mar	21 Mar	28 Mar	31 Mar	02 Apr	12	8	01 Jul	06 Jul	104	104
ZL-2/03	19 Mar	25 Mar	22 Mar	28 Mar	30 Mar	02 Apr	12	9	01 Jul	05 Jul	102	104
N-2/03	24 Mar	28 Mar	26 Mar	30 Mar	01 Apr	03 Apr	9	7	03 Jul	07 Jul	100	103
ZL-1/03	18 Mar	24 Mar	21 Mar	27 Mar	30 Mar	02 Apr	13	10	07 Jul	11 Jul	109	112
DL-1/1/04	18 Mar	25 Mar	20 Mar	27 Mar	26 Mar	31 Mar	9	7	08 Jul	11 Jul	110	111
L-2/04	17 Mar	25 Mar	19 Mar	27 Mar	27 Mar	01 Apr	11	8	08 Jul	11 Jul	112	109
T-5/04	17 Mar	24 Mar	20 Mar	26 Mar	28 Mar	31 Mar	12	8	13 Jul	17 Jul	117	117
Mean over genotypes	17 Mar	24 Mar	20 Mar	26 Mar	27 Mar	01 Apr	11	9	23 Jun	27 Jun	96	97
Hungarian Best [a]	20 Mar	26 Mar	22 Mar	28 Mar	29 Mar	01 Apr	10	7	30 Jun	04 Jul	102	97

[a] The control apricot cultivar 'Hungarian Best'.

varied from 13-24 March in 2003 to 20-28 March in 2004. The FF was between 15-26 March in 2003 and between 22-30 March in 2004; the EF occurred between March 23rd and April 1st in 2003, and between March 30th and April 3rd in 2004. The flowering duration of the selected genotypes ranged from 8-13 days in 2003 and 7-12 days in 2004, whereas in 'Hungarian Best' it was 10 days in 2003 and 7 days in 2004. In addition, HD continued from 28 May to 13 July in 2003, and from 3 June to 17 July in 2004: there were large variations in harvest season among the tested genotypes. Fruit development in all genotypes lasted for 75-117 days in both years. Average seedling FD was shorter on the average (96 days) than in 'Hungarian Best' (102 days) in the first year, and was identical to the control in the second season (97 days). Given the fact that apricot (*Prunus armeniaca* L.) is a fruit species originating in China and Central Asia (Yuan *et al*., 2007; He *et al*., 2007), it has not been adapted sufficiently to the climate of FYR Macedonia, BF being its major phenophase during the growing cycle due to bud damage by early spring frosts. The BF in our study was later in 2 genotypes (N-4/03 and N-2/03) and 1 genotype (N-2/03) in the first and second year, respectively, as compared to 'Hungarian Best' (Table 1). It was earlier in the other genotypes than the control. Apart from mutual differences in BF during one year, year-by-year differences in flowering time were also observed. Generally, the BF, FF, and EF in this study were earlier in 2003 than those of the second year. In the majority of genotypes, BF, FF and EF occurred (excepting 2004) two to three days earlier than 'Hungarian Best' in both years. 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. Similar data were reported by Balta *et al*. (2002) and Asma *et al*. (2007). The significant differences in flowering time among the genotypes in our study were due to physiological factors, and year-by-year differences were induced by ecological factors such as temperature, rainfall, solar radiation and soil (Arzani and Roosta, 2004).

In an earlier study, Badenes *et al*. (1998) showed a correlation of both HD and FD period with the BF. Year-by-year variations for HD and FD were registered according to data shown in Table 1. As compared to the control, later HD were reported for 7 genotypes in both years. On the other hand, longer FD was observed for 6 genotypes in 2003 and 11 genotypes in 2004. The HD of the first year (June 23rd) was earlier than that of the second year (June 27th). Differences between years, especially for HD, were found for the set of evaluated genotypes, being likely induced by environmental conditions (Ristevski and Mitreski, 1986; Ruiz and Egea, 2008).

The age of the genotype trees ranged from 5 (DL-1/1/04) to 55 years (N-4/03) and their total tree heights (trunk+crown) varied from 2.95 m to 9.25 m (Table 2). In addition, the tested genotypes ranged from 1.80 m to 7.20 m for TH, 3.20 to 8.70 m for TW, 12.85 to 433.37 m^3 for CV and 9.96 cm to 50.90cm for TC. As for 'Hungarian Best', the total tree height was 4.90 m, CH, CW and CV were 4.20 m, 5.40 m and 74.31 m^3, respectively. Significant differences between these traits were found for the set of genotypes, which could be due to the influence of tree age. Yield ranged from 17 kg to 82 kg in 2003 and 4 kg to 42 kg in 2004 in X-1/1/04 and DL-1/2/04, respectively. In addition, Y of 'Hungarian Best' ranged from 33 kg in 2004 to 68 kg in 2003. Differences among genotypes were significant at $P \leq 0.05$ in both years (Table 2). Also, year-by-year variations were observed, which is in agreement with previous work in apricot (Ristevski and Mitreski, 1986). The differences in tree and crown dimensions, TC and Y between genotypes and 'Hungarian Best' resulted from different tree age, effect of ecological factors, and lack of cultural practices (Balta *et al*., 2002; Arzani and Roosta, 2004).

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Table 2. Tree characteristics of apricot genotypes from Skopje region.

Genotypes	Age of trees (year)	Total height of trees (m)	Crown			Trunk circumference (cm)	Yield (kg tree^{-1})	
			Height (m)	Width (m)	Volume (m^3)		2003	2004
X-1/1/04	13	6.85	5.00	7.20	190.35	24.07	17 j	4 o
X-1/2/04	10	4.15	2.50	3.90	23.43	22.67	46 cd	16 h
K-5/04	12	4.65	2.60	3.90	23.37	22.50	62 b	34 b
ZO-1/03	24	7.60	5.30	6.00	121.27	27.33	40 def	17 g
VB-1/04	6	5.40	3.40	3.30	24.27	16.80	37 e-h	21 e
DL-1/2/04	18	6.50	4.30	3.60	42.52	21.83	82 a	42 a
ZL-1/3/04	27	8.35	6.30	8.10	273.33	38.70	35 fgh	9 l
K-3/1/04	17	6.40	5.00	7.30	165.01	25.16	41 def	12 i
T-7/04	31	7.20	5.10	8.30	232.54	33.63	47 cd	12 i
G-12/04	26	8.90	7.20	8.70	342.14	31.06	18 j	8 m
T-9/03	50	5.00	3.10	5.90	64.26	43.93	31 ghi	17 g
N-4/03	55	9.25	7.30	9.50	433.37	50.90	37 e-h	12 i
D-1/04	16	8.45	6.30	5.70	122.22	21.43	52 c	24 d
ZL-2/03	40	8.70	7.00	8.70	347.11	41.66	34 fgh	5 n
N-2/03	23	5.30	3.70	6.30	88.04	29.43	45 cde	16 h
ZL-1/03	40	8.30	6.50	8.20	296.47	40.03	44 cde	8 m
DL-1/1/04	5	2.95	1.80	3.20	12.85	9.96	29 hi	10 k
L-2/04	6	5.70	4.20	5.10	79.43	14.60	23 ij	11 j
T-5/04	7	4.10	2.70	4.70	39.21	15.46	39 d-g	18 f
HB [a]	11	4.90	4.20	5.40	74.31	20.53	68 b	33 c

[a] The control apricot cultivar 'Hungarian Best'.
The same letter(s) in each of the last two columns indicate insignificant differences between means (LSD test, P≤ 0.05).

Evaluation of Fruit Physical and Sensorial Features

There were significant differences among accessions regarding the physical features (Table 3). 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). In addition, FW was less than 50 g in other genotypes. As for fruit dimensions, the genotypes had a range of 3.82±0.07–5.65±0.09 cm for FH, 3.46±0.04-5.57±0.06 cm for FWi and 3.33±0.02–5.11±0.07 cm for FT. In addition, SW ranged from 1.81±0.13 g to 4.85±0.17 g. Mesocarp percentage ranged from 88.66±1.22% to 94.50±2.71%.

The characteristics that correlate best with fruit attractiveness include fruit dimensions (FH, FWi, FT), FW, SW and MP (Badenes *et al.*, 1998). The studied genotypes showed noteworthy fruit physical features in absence of cultural practices (Table 3). Specifically, FW was significantly higher (31.5%) in DL-1/1/04 than the control, and significantly lower in other genotypes at p≤0.05. Of the remaining 18 genotypes, 5 ranged from 30-40 g, and 6 each ranged from 40-50 g to 50-60 g, respectively. Previous study on apricot also reported a high variability among accessions regarding this parameter (Ruiz and Egea, 2008). Therefore, the genotypes may be expected to produce larger fruits under better cultural practices (Balta et al., 2002). Paunovic and Paunovic (1995) reported that fruit size of genotypes in situ varied from very small (5.0%) to extremely large (7.5%). In our study, most genotypes had desirable fruit sizes. Attractive medium-sized fruits are

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Table 3. Physical and sensorial features of fruit apricot genotypes from Skopje region.

Genotypes	Fruit				Stone weight (g)	Mesocarp percentage (%)	IBPGR descriptor [b]	
	Weight (g)	Height (cm)	Width (cm)	Thickness (cm)			Flash colour	Kernel taste
X-1/1/04	36.12 ± 2.56 ij	3.82 ± 0.07 n	3.96 ± 0.02 de	3.89 ± 0.02 kl	2.37 ± 0.14 q	93.47±2.49 ab	6	1
X-1/2/04	52.53 ± 3.32 cd	4.81 ± 0.06 e	4.95 ± 0.08 ab	4.96 ± 0.04 b	4.85 ± 0.17 a	90.77±1.43 hi	6	1
K-5/04	39.25 ± 2.44 hi	4.21 ± 0.06 k	4.08 ± 0.05 cde	3.61 ± 0.03 l	2.71 ± 0.42 o	93.09±2.13 b-e	6	1
ZO-1/03	23.40 ± 1.62 k	3.47 ± 0.02 o	3.46 ± 0.04 e	3.33 ± 0.02 m	1.81 ± 0.13 r	92.26±1.66 def	7	1
VB-1/04	40.78 ± 3.38 gh	4.25 ± 0.05 j	4.21 ± 0.03 b-e	3.89 ± 0.03 kl	2.52 ± 0.14 p	93.82±1.11 a	7	2
DL-1/2/04	53.56 ± 3.32 cd	4.68 ± 0.07 f	4.80 ± 0.07 abc	4.50 ± 0.05 d	3.93 ± 0.17 f	92.66±1.09 c-f	8	1
ZL-1/3/04	40.98 ± 2.55 gh	4.15 ± 0.05 m	4.23 ± 0.02 b-e	4.13 ± 0.04 h	3.36 ± 0.16 k	91.69±1.89 f-i	7	1
K-3/1/04	47.11 ± 3.43 ef	4.40 ± 0.08 g	4.55 ± 0.03 bcd	4.27 ± 0.06 g	3.22 ± 0.15 m	93.17±1.99 bcd	7	1
T-7/04	51.79 ± 3.32 cd	4.82 ± 0.09 e	4.92 ± 0.07 ab	4.36 ± 0.06 ef	3.91 ± 0.16 g	92.36±1.55 c-f	7	1
G-12/04	35.23 ± 2.24 j	4.28 ± 0.06 i	3.97 ± 0.04 de	3.54 ± 0.03 l	2.94 ± 0.15 n	90.60±1.57 ij	7	3
T-9/03	38.64 ± 2.87 hij	4.44 ± 0.07 f	4.32 ± 0.05 bcd	3.94 ± 0.02 j	3.37 ± 0.15 k	91.06±1.54 ghi	7	1
N-4/03	40.75 ± 3.21 gh	4.18 ± 0.04 l	4.08 ± 0.04 cde	3.78 ± 0.02 l	3.24 ± 0.15 l	91.95±2.01 efg	7	1
D-1/04	39.78 ± 2.48 hi	4.27 ± 0.04 ij	4.41 ± 0.07 bcd	3.81 ± 0.03 l	4.28 ± 0.17 c	88.66±1.22 j	7	1
ZL-2/03	44.26 ± 3.77 fg	4.35 ± 0.06 h	4.15 ± 0.05 b-e	3.92 ± 0.03 jk	3.25 ± 0.15 l	92.54±1.13 c-f	7	1
N-2/03	49.94 ± 3.46 dc	4.91 ± 0.07 d	4.88 ± 0.08 abc	4.60 ± 0.04 c	3.97 ± 0.17 e	91.85±1.88 fgh	7	1
ZL-1/03	51.30 ± 3.77 d	4.80 ± 0.06 e	4.64 ± 0.07 bcd	4.38 ± 0.03 e	3.88 ± 0.16 h	92.42±1.97 c-f	7	3
DL-1/1/04	89.29 ± 2.98 a	5.65 ± 0.09 a	5.57 ± 0.06 a	5.11 ± 0.07 a	4.70 ± 0.18 b	94.50±2.71 a	8	3
L-2/04	55.59 ± 3.42 c	5.10 ± 0.05 b	4.88 ± 0.05 abc	4.29 ± 0.05 fg	3.64 ± 0.16 i	93.42±2.57 abc	8	1
T-5/04	52.32 ± 2.95 cd	5.03 ± 0.08 c	4.84 ± 0.05 abc	4.02 ± 0.02 i	3.61 ± 0.16 j	93.11±2.69 bcd	7	1
HB [a]	61.11 ± 3.78 b	4.91 ± 0.07 d	4.92 ± 0.05 ab	4.64 ± 0.05 c	4.13 ± 0.17 d	93.18±1.88 bcd	7	1

[a] The control apricot cultivar 'Hungarian Best'.
[b] (Flash colour): 6= Light orange; 7= Orange, 8= Deep orange; (Kernel taste): 1= Sweet, 2= Weak bitterness, 3= Strong bitterness.
The same letter(s) in columns indicate insignificant differences between means (LSD test, P≤ 0.05).

desired for apricot cultivar breeding (Bailey and Hough, 1975; Guerriero *et al*., 2006). It is a well-known fact that apricot stones are used in genotype identification and have a high utilization value (Özcan, 2000; Mandal *et al*., 2007). In our study, SW was significantly lower in 16 genotypes than 'Hungarian Best', and MP was significantly higher in 2 genotypes than the control at $P \leq 0.05$. Similar data for SW and MP features in apricot has been reported by Jackson and Coombe (1966) and Gezer *et al*. (2003). The orange FC and sweet KT were registered in most genotypes (Table 3), which is in agreement with the results obtained by Milošević *et al*. (2010) for apricot genotypes in Serbian conditions.

Evaluation of Fruit Chemical Features

The SS content ranged from 11.70±0.41 ºBrix (X-1/1/04) to 14.40±0.55 ºBrix (K-3/1/04) (Table 4). All genotypes, excepting X-1/1/04 and the control, had a SS content >12 ºBrix. Ruiz and Egea (2008) reported SS content as a very important quality feature, influencing notably the sweetness and fruit taste. Our range of values is in agreement with previous work on apricot (Audergon *et al*., 1991; Ruiz and Egea, 2008), but the values are generally lower than those for a group of Turkish genotypes (Balta *et al*., 2002; Asma and Ozturk, 2005; Asma *et al*., 2007). The differences between the present results and those of the above authors were likely due to the different eco-geographical groups of apricot genotypes.

The TA content ranged from 0.89±0.12% to 1.89±0.13%; it was lower than 1% in 5 genotypes (X-1/2/04, ZO-1/03, DL-1/2/04, D-1/04 and ZL-1/03) (Table 4). Values of pH ranged between 3.90±0.06 (K-5/04) and 4.70±0.08 (ZL-1/03). In addition, the content of TS, RS and SC varied 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 results in our study showed that RS, SC and TS were significantly higher than 'Hungarian Best' in 8, 1, and 17 genotypes, respectively, at $P \leq 0.05$. The SC content was higher than 1.0% in 5 genotypes, whereas TA was significantly higher in 10 genotypes. Six genotypes had a higher pH than 'Hungarian Best' at $P \leq 0.05$. Akin *et al*. (2008) reported that the largest differences in the fruit chemical composition in apricot genotypes were observed with respect to the dry matter and TS contents, with malic acid being the predominant organic acid found. Moreover, some authors determined that sucrose, glucose, and fructose were the major sugars in apricot (Ledbetter *et al*., 2006), which was confirmed by the results in our study. The range of TA values in our study is in agreement with previous studies on apricot (Audergon *et al*., 1991; Mehlenbacher *et al*., 1991). Similar data on the said content in apricot fruit, considered as fresh type, has been reported by Bailey and Hough (1975), Asma *et al*. (2007) and Valdés *et al*. (2009). Generally, the fruit maturity stage at HD is the principal factor affecting fruit acidity and also the SS content.

Cluster Analysis

The dendrogram generated from the average linkage cluster analysis based on UPGA distance classified 20 genotypes into 4 main groups (Figure 1). The first group included one genotype (DL-1/1/04) or 5.0% of the total genotypes in this population. It had the largest FW, FH, FWi, FT and MP, but small dimensions of the crown and the lowest TC and SC contents. The second group was made up of eight genotypes (ZL-1/03, ZL-2/03, N-4/03, T-9/03, G-12/04, T-7/04, ZL-1/3/04 and ZO-1/03), or 40.0% of the total genotypes, that had the largest TH, CH, CW and CV, medium HD period, lower values of FW and SW, excepting ZL-1/03 and T-7/04. They also gave low contents of MP and SC. The third group included as few as four genotypes (DL-1/2/04, D-1/04, K-5/04 and 'Hungarian Best') or 20.0% of the total genotypes. These genotypes had the youngest trees and gave the highest Y and SS content, but the lowest SC content. The fourth group comprised seven genotypes

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Table 4. Pomological features of fruits of apricot genotypes from Skopje region.

Genotypes	Soluble solids (ºBrix)	Titratable acidity (%)	pH value	Sugars (%)		
				Reducing	Sucrose	Total
X-1/1/04	11.70±0.41 h	1.32±0.02 f	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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±0.03 g	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	4.30±0.05 g	9.70±0.33 efg	0.95±0.02 f	10.70±0.27 d
Hungarian Best [a]	14.05±0.58 abc	1.18±0.03 gh	4.45±0.09 d	10.05±0.36 bcd	0.79±0.03 kl	10.88±0.55 cd

[a] The control apricot cultivar 'Hungarian Best'.

The same letter(s) in vertical columns indicate insignificant differences between means (LSD test, P≤ 0.05).

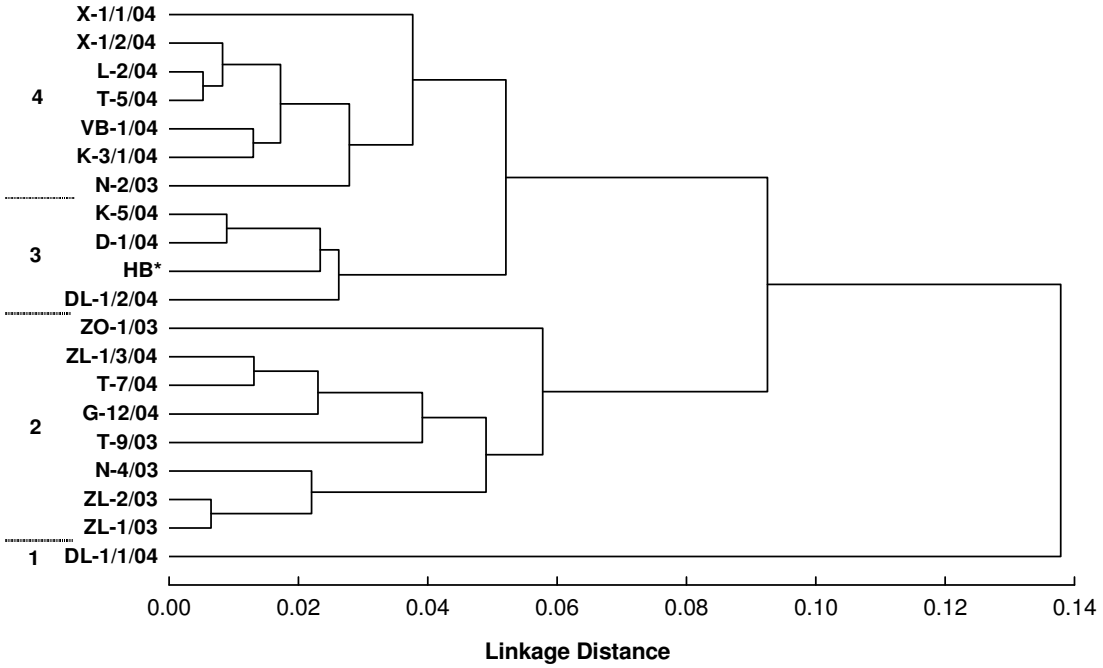


Figure 1. Dendrogram of 20 apricot genotypes obtained by UPGA cluster analysis based on 16 phenological, fruit quality, and tree traits. (* Is the control cultivar 'Hungarian Best').

(N-2/03, K-3/1/04, VB-1/04, T-5/04, L-2/04, X-1/1/04 and X-1/2/04) or 35.0% of the total genotypes. Their characteristics included early flowering, large fruits, higher MP and pH, and, low SW and RS contents, excepting VB-1/04. The lowest dissimilarity level (d= 0.006) in this group was found in T-5/04 and L-2/04, which caused their close relationship. The dissimilarity level, i.e. genetic distance (d) ranged from 0.006 to 0.138, indicating a high similarity degree and a low genetic distance between the genotypes. However, traditional fruit morphological and geographical origin classification could not completely reflect the pedigree relationship among the studied apricot genotypes (Yuan *et al*., 2007; Martínez-Mora *et al*., 2009).

Principal Component Analysis and Segragation of Genotypes

Principal components analysis is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences (Mattos *et al*., 2010; Milosevic and Milosevic, 2010). It has been used previously to establish genetic relationships among genotypes and to study correlations among fruit traits, tree and phenological characteristics within sets of apricot genotypes (Badenes *et al*., 1998; Gurrieri *et al*., 2001; Azodanlou *et al*., 2003). The PCA used in our work showed that more than 80% of the variability observed was explained by the first 4 components. PC1, PC2 and PC3 accounted for 31.83%, 23.21% and 15.80%, respectively, of the variability. Correlation between the original variables and the first three principal components is shown in Table 5. The highest negative values for PC1 indicated genotypes that had lower Y and content of SS, TS and RS and included genotypes: X-1/1/04, T-7/04, G-12/04, DL-1/1/04 and T-5/04 (Figure 2). Positive values for PC1 corresponded to genotypes that had higher Y and content

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

Variable/factors	Component loading			Genotypes	Component scores		
	PC1, λ= 31.83	PC2, λ= 23.21	PC3, λ= 15.80		PC1	PC2	PC3
Fruit weight	-0.216	0.362	-0.738	X-1/1/04	-3.937	1.860	1.674
Soluble solid	0.654	-0.465	-0.344	X-1/2/04	-2.082	2.168	1.301
Titratable acidity	-0.305	-0.698	-0.266	K-5/04	-0.772	-1.328	-0.155
pH value	0.112	0.796	0.252	ZO-1/03	2.328	-0.213	2.142
Total sugar	0.957	-0.194	0.066	VB-1/04	1.442	-2.242	0.333
Reducing sugar	0.946	-0.132	-0.100	DL-1/2/04	2.192	0.842	-1.255
Sucrose	0.430	-0.155	0.751	ZL-1/3/04	-0.275	-1.591	0.915
Begining of flowering	0.525	0.565	-0.246	K-3/1/04	-0.176	-1.984	-0.677
Harvest date	-0.179	-0.669	-0.006	T-7/04	-1.838	-1.497	-0.482
Yield	0.548	0.076	-0.379	G-12/04	-1.911	-0.119	1.014
				T-9/03	-0.759	-3.118	-0.151
				N-4/03	1.780	1.423	-0.137
				D-1/04	1.616	0.608	-0.395
				ZL-2/03	0.309	-1.111	-0.156
				N-2/03	2.042	1.508	0.299
				ZL-1/03	1.591	1.432	1.892
				DL-1/1/04	-2.842	1.467	-2.896
				L-2/04	0.181	0.526	-1.377
				T-5/04	-0.419	-0.006	0.124
				HB [a]	1.531	1.374	-2.014

[a] The control apricot cultivar 'Hungarian Best'.

of SS, RS and TS. Genotypes ZO-1/03, DL-1/2/04, N-4/03, D-1/04 and N-2/03 were included in this group. The genotype X-1/2/04, which had the lowest PC2 value, stood out especially due to the low content of TA and early ripening date (Figure 2). The group of genotypes with the highest PC2 values were characterized by early flowering and lower pH. 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 2. The highest positive PC3 value belonged to the genotype that had the highest percentage of SC (ZL-1/03) (Figure 2). Negative values for PC3 indicated the genotypes that had higher FW. This group included genotypes DL-1/1/04, L-2/04 and 'Hungarian Best'. In general, PCA may help in selection of a set of genotypes with better fruit quality traits (Gurrieri *et al*., 2001; Ruiz and Egea, 2008; Milosevic and Milosevic, 2010), which, in our study, were observed in DL-1/1/04, DL-1/2/03, D-1/04 and K-5/04.

CONCLUSIONS

The apricot genotypes selected in the region of Skopje (FYR Macedonia) showed substantial variability in terms of the tested features. Flowering time was later in 2 genotypes, and harvest date was later in 8 genotypes than in 'Hungarian Best'. Significant year-by-year variations were observed for time of flowering, harvest date, and yield. In absence of cultural practices, some genotypes produced large fruits and a high mesocarp percentage, as well as higher content of soluble solids, sugars (reducing sugars, sucrose and total sugars), stable titratable acidity and pH as compared to the control. The cluster analysis was used to classify genotypes into four groups according to their potential characteristics. The group 1 and 3 of the genotypes were superior in terms of fruit quality features and tree traits. PC analysis may help in selection of a set of genotypes with better fruit quality features, which, in our study, were observed

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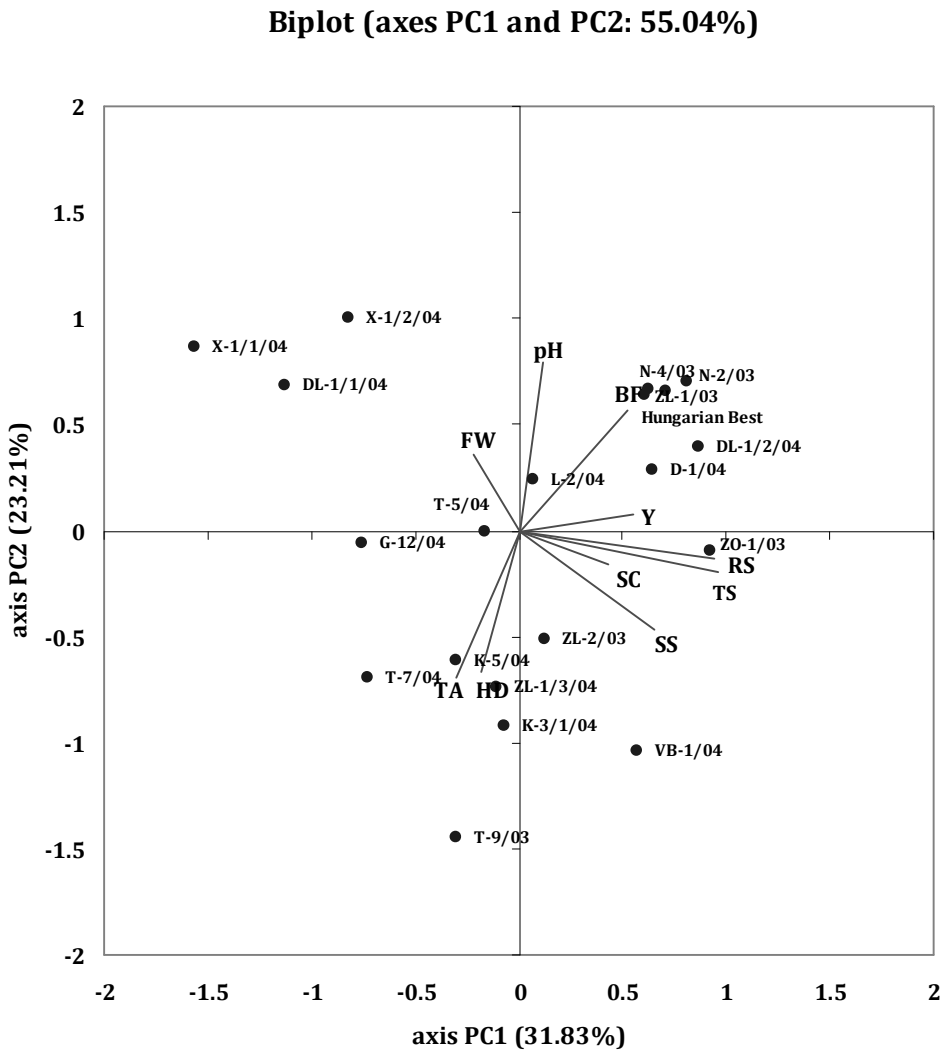


Figure 2. Segregation of 20 apricot genotypes according to their fruit quality and tree characteristics determined by principal component analysis (PCA). Vectors represent the loadings of phenological and quality traits data along with the principal component scores. Abbreviations in biplot are: SS: soluble solids content; SC: Sucrose content; TS: Total sugars content; RS: Reducing sugars content; Y: Yield per tree; BF: Beginning of flowering; pH: pH value; FW: Fruit weight; TA: Titratable acidity; HD: Harvest date.

in DL-1/1/04, DL-1/2/03, D-1/04 and K-5/04. Based on this evaluation, the top19 genotypes were pre-selected from the initial breeding population for further studies.

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تحلیل ویژگی های ریخت شناسانه و میوه ای ژرم پلاسمهای زرد آلو در مقدونیه

ا. مارتینیک، ب. پوپوسکی، ت. میلوشویچ و م. پوپوسکا

چکیده

ویژگی های ریخت شناسانه و میوه ای زرد آلو های وحشی در شرایط محیطی مقدونیه طی دو سال پیاپی بررسی شدند. جامعه مطالعه شده شامل ۱۹ ژنوتیپ بود که صفت های قابل توجهی در درخت و میوه نشان میدادند. در این تحقیق، زمان گلدهی و صفات کیفی مطلوب آنها در مقایسه با رقم "Hungarian Best " که رقم شاهد بود تعیین شدند. گلدهی همه ژنوتیپ ها ی انتخابی در هر دو سال آزمایش دو روز زودتر از رقم شاهد آغاز شد در حالی که زمان برداشت آنها در ۷ ژنوتیپ دیرتر از رقم شاهد بود. محدوده تغییرات پارامترهای مختلف این ژنوتیپ ها به این شرح به دست آمد: وزن میوه g 1.62±23.40- 2.98±89.29 g، وزن هسته g 0.13±1.81تا g 0.17±4.85، املاح محلول ºBrix 0.41±11.70- 0.55±14.40 ºBrix، و اسید قابل تیتر 0.01±0.89تا. 0.02±1.89%. جامدات محاول در ۱۸ ژنوتیپ ۱۲٪ بیشتر از شاهد بود و pH بین 0.06±3.90 و0.08±4.70 متغیر بود. مقدار قند های کاهنده (مونوساکاریدها)، سوکروز، و قند کل به ترتیب در محدوده های 0.10±8.49تا 0.66±10.39% ، 0.01±0.66 تا 0.05±1.20%، و0.19±9.34 تا 0.19±11.36%, نوسان می کرد. در تجزیه آماری، ژنوتیپ های مزبور بر پایه استعداد هایشان در جهار خوشه قرار گرفتند که بین شماری از صفات کیفی آنها همبستگی زیادی به دست آمد. با استفاده از روش تجزیه به مؤلفه های اصلی، ژنوتیپ های زرد آلو در دسته بندی هایی با ویژگی های شیمیایی و فیزیکی مشابه ، از هم جدا شدند. این دسته بندی ها می تواند در انتخاب ژنوتیپ های دارای صفات میوه ای مطلوب (همانند آنچه که در این مطالعه در مورد ژنوتیپ های DL-1/1/04, DL-1/2/03, D-1/04, K-5/04 وجود داشت)، کمک مؤثری داشته باشد. بر مبنای ارزیابی های این تحقیق، ۱۹ ژنوتیپ ممتاز برای مطالعات بیشتر بعدی انتخاب شدند.

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