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Early tree performances, precocity and fruit quality attributes of newly introduced apricot cultivars grown under western Serbian conditions

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Abstract: In this work, 19 newly introduced and some traditional apricot cultivars were evaluated by 20 phenological and agronomical traits and fruit quality attributes. The results showed a wide variation in phenological data, tree vigour (TCSA), productivity [yield per tree, cumulative yield (CY) and yield efficiency (YE)], and fruit quality attributes such as fruit and stone weight, flesh/stone ratio, fruit dimensions, size, shape index, soluble solids content (SSC), titratable acidity (TA) and ripening index (RI). The average onset of blossoming varied from 16 March to 20 March, whereas harvest was between 1 June and 12 September. The most vigorous trees were 'Ketch Pshar'. The best productivity was observed in 'Fardao' and the poorest in 'Farbaly'. More apricots were relatively small to medium in fruit size, whereas 'Candela' had very large fruits. Most cultivars tended towards a round shape, whereas some had round/flat and/or ovoid-shaped fruits. The highest values for SSC were observed in 'Ketch Pshar', 'Candela' and 'Fardao', TA in 'Candela' and RI in 'Hungarian Best'. There was a medium to high correlation between yield properties, fruit and stone size and flesh/seed ratio, also between SSC versus acidity and RI. As observed by PCA, the first three components represented 74.3% of total variance (38.3%, 22.1% and 19.8% for PC1, PC2 and PC3, respectively).

Key words: Bloom date, ripening time, fruit size, productivity, *Prunus armeniaca* L., soluble solids, tree vigour

1. Introduction

Apricots belong to the family *Rosaceae* Juss., genus *Prunus* L., section (subgenera) *Armeniaca* (Lam.) Koch, which includes 12 known and described species. The last having been discovered is *Prunus cathayana* [sin.: *Armeniaca cathayana* (D.L. Fu, B.R. Li & J. Hong Li)], recently described by Fu et al. (2010). It originates in Zhuolu, Hebei Province, China and is derived from spontaneous (natural) crossing between *P. armeniaca* L. and *P. sibirica* L. The most important species for growers, consumers, scientists, and others are *P. armeniaca* L., also known as *A. vulgaris* Lam.

World apricot production in 2019 was 4,083,861 tons produced on 561,750 ha of harvested area (FAOSTAT, 2021). The major growing areas are China, the Irano-Caucasian region (Turkey and Iran), Central Asia (Uzbekistan and Afghanistan), Europe and North America. According to above source, Turkey is the highest world producer of apricot, followed by Uzbekistan, Iran, Italy, and Algeria.

Cultivar plays a key role in fruit production. It is estimated that there are over 2000 cultivars of apricot in the world. In the last few decades, over 650 new cultivars have been created through different public and private sector breeding programs, especially after the 1990s using various breeding techniques. For example, from 1980 to 2007, 563 new apricot cultivars plus 61 hybrids (apricot × plum, plum × apricot) had been listed in the National register of cultivated varieties (Fideghelli and Della Strada, 2010). Recently, a new genotype, Aprikyra, has been developed by crossing apricot (*P. armeniaca* L.) with sand cherry (*P. pumila* var. *besseyi*) (Milošević and Milošević, 2018). Most new cultivars have been created in the USA, France, Russian Federation, Spain, Romania, Ukraine, Czech Republic, Turkey, and some in Serbia.

Breeding goals differ by country, but the most important ones are as follows: adaptability to different climatic conditions ("chilling requirements" and "heat requirements") (Layne et al., 1996), resistance to winter and spring frost (Ozturk et al., 2006; Szabó et al., 2010; Milošević et al., 2010), resistance to *Plum pox virus* (Egea et al., 1999; Krška et al., 2011; Krška, 2018) and other diseases (Benedikova, 2006), improvement of self-fertility (Herrera et al., 2018), yield, fruit size and fruit quality (Milosevic

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and Milosevic, 2013) - especially sugar profile (Ledbetter et al., 2006), extension of the harvest season, and increased storage life (Topor et al., 2008). Additional or secondary objectives of apricot breeding programs include resistance to "apoplexy" (term used to describe sudden wilting and death of a tree or part of tree), and good pomological fruit properties, e.g. large fruit size, freestone, firm flesh and resistance to skin cracking (Layne et al. 1996).

Recently, a large number of cultivars have been commercialized, and the breeding industry is particularly dynamic, with new cultivars being released annually (Egea et al., 1999; Milošević et al., 2010; Krška, 2018). However, experience with new cultivars and their performance in different environmental conditions are unknown to many growers around the world, including Serbia. Namely, new apricot cultivars have been selected in environmental conditions noticeably different from those of the main Serbian apricot growing areas (Milošević et al., 2010). Furthermore, the difficulty of several apricot cultivars to adapt to environments differing from their origin is well known, so that the introduction of new cultivars often causes commercial failures. This phenomenon can be particularly evident when cultivars originating from continental (cold) zones are introduced into coastal (warm) areas and vice versa (Mehlenbacher et al., 1991).

For these reasons, the main objective of this study was to evaluate the phenology, productivity, and main fruit quality attributes of 19 newly-bred and several traditional early, mid- and late-season apricots at an early tree development stage grown in the region of Čačak, Serbia.

2. Material and methods

2.1. Plant material and orchard layout

The orchard was established in the March of 2015 in Prislonica village (43°33'N, 16°21'E, 280 m a.s.l.) near Čačak town, western Serbia. For investigation, 19 cultivars of apricot were used in this study (Table 1). All trees of each cultivar were grafted onto seedlings of Myrobalan (*Prunus cerasifera* Ehrh.) and planted at the same time with spacing of 5.5 m × 3.0 m. Trees were trained in an open vase system and their vigour was controlled by pruning in the summer. Standard cultural practices were used, except irrigation. The trial was set up in a randomized block design with four replications, each containing five trees of each cultivar (n = 20), total 380 trees.

The orchard soil is clay-loamy textured with low pH value in KCl (4.92) under 0–30 cm soil depth. Soil contained 1.9% organic matter or 3.3% humus, 0.17% N total, 5.43 mg P_2O_5 and 23.96 mg K_2O per 100 g of dry soil, respectively and without lime.

Table 1. List of studied apricot cultivars and their origin used in this study.

Cultivar	Origin
Goldrich (syn.: Sungiant)	USDA and Washington State University, Prosser, Washington, USA
Zerdelija	Horticultural Faculty in Lednice, Czech Republic
Farbaly	Marie-France BOIS, France
Ketch Pshar	Local cultivar from Central Asia
Candela	Horticultural Faculty in Lednice, Czech Republic
Adriana	Horticultural Faculty in Lednice, Czech Republic
Fardao	Marie-France BOIS, France
Betinka	Horticultural Faculty in Lednice, Czech Republic
Čačansko Zlato	Fruit Research Institute, Čačak, Serbia
Spring Blush®	Escande EARL, France
Wonder Cot	COT International, France
Orange Red (syn.: Barth®)	Rutgers University, The State University of New Jersey, USA
Tsunami®	Escande EARL, France
Novosadska Kasnocvetna	Faculty of Agriculture, Novi Sad, Serbia
Bergeron	Saint-Cyr-au-Mont-d'Or, France
Aurora	Rutgers University, The State University of New Jersey, USA
Roxana	Unknown, Afghanistan
Precoce de Tirynthe	Random seedling, Greece
Hungarian Best (syn.: Magyar Kajszi)	Random seedling, Hungary

Long-term average (1965–2010) weather data were characterized by an annual temperature of 11.3 °C and total annual rainfall of 690 mm. The average air temperature during the vegetative cycle was 17.0°C. However, from 2012 to 2019, the average annual temperature was 12.9 °C, and total annual rainfall was 811 mm. Total rainfalls and mean air temperature for the vegetative cycle from 2012 to 2019 was 547 mm and 18.2 °C, respectively. Limited physical and most chemical soil traits, long dry periods during the summer months and adequate rainfall only in the first part of the vegetative period (data not shown) did not provide normal conditions for optimal growth and development of apricot trees during experimental period.

2.2. Measurements

2.2.1. Flowering and ripening phenology

Bloom data were obtained using the recommendations of the International Working Group for Pollination: start of flowering - 10% open flowers, full bloom - 80% open flowers, end of flowering - 90% petal fall (Wertheim, 1996). In order to determine the variation of average flowering and ripening dates for three years, we converted the dates on specimen labels to the day of year (DOY, where January 1 = 1 DOY, February 1 = 32 DOY, and so on).

The date of ripening was considered to be the time of commercial harvest of the fruits by visual observation (Egea et al., 2004) based on colour change (from green to yellow and/or red), appearance, and taste (Ruiz and Egea, 2008; Son and Bahar, 2018).

2.2.2. Vegetative growth, yield, and fruit quality attributes

Trunk diameter was measured during the dormant season at 20 cm above the graft union, and the trunk cross-sectional area (TCSA, cm^2) was calculated. Yield per tree (kg), cumulative yield per tree (kg) and yield efficiency (cumulative yield in kg per final TCSA, kg cm^{-2}) of each cultivar were computed from the harvest data. Yields were performed every year using ACS System Electronic Scale (Zhejiang, China).

At final harvest (2019), 20 fruits in four replicates (n = 80) were sampled from each tree replication and were immediately used to determine fruit and stone weight (g), fruit dimensions (length, width, thickness, all in mm), soluble solids content (SSC, °Brix), and titratable acidity (TA, % of malic acid). Fruit and stone weight were measured using a digital balance (FCB 6 K 0.02B, Kern & Sohn GmbH,Belingen, Germany). The flesh/stone ratio (F/S ratio, %) was calculated by subtracting the stone weight from the whole apricot fruit weight.

Polar [length (L)], suture [width (W)] and equatorial [thickness (T)] diameters for each fruit were measured with a caliper gauge (Starrett 727, Athol, MA, USA), and then transformed to the parameter denominated "fruit size", or geometric mean diameter (D_g) and sphericity (φ) were calculated by using the following formulas (Mohsenin, 1980):

$$D_g = \sqrt[3]{LWT}$$

where D_g is the geometric mean diameter (mm).

$$\varphi = \frac{D_g}{L}$$

where φ is the sphericity.

Fruit juice SSC from each sample was measured using a hand refractometer (Milwaukee MR 200 ATC, Rocky Mount, USA) at room temperature (20 °C). Titratable acidity (TA) was determined in a sample of prepared juice by titration with 0.1 mol L^{-1} NaOH, up to pH = 8.1 using a titrimeter (Metrohm 719S, Titrino, Herisau, Switzerland). The ripening index (RI) was calculated based on the SSC/TA ratio.

The values presented for each measurement are the means of triplicate measures on equidistant points of each fruit.

2.3. Data analysis

Data were evaluated by analysis of variance (ANOVA) with Microsoft Office Excel software (Microsoft Corp., Redmond, WA, USA). When the F test was significant, means were separated by LSD test ($P \leq 0.05$). Pearson's rank correlation matrix ($P \leq 0.05$) was done using the R corrplot package (Wei and Simko, 2017). Principal components analysis (PCA) was performed, and a biplot PCA was designed using the XLSTAT software package v. 7.0 (Addinsoft, Paris, France).

3. Results and discussion

3.1. Flowering and fruit ripening period

During the three years of the present study (Table 2), the earliest beginning of flowering was observed in 'Adriana', 'Wonder Cot' and 'Precoce de Tyrinthe' (16 March or 75 DOY), whereas the latest was in 'Novosadska Kasnocvetna' (20 March or 79 DOY). Six cultivars ('Goldrich', 'Candela', 'Adriana', 'Wonder Cot', 'Aurora' and 'Precoce de Tirynthe') began flowering earlier than 'Hungarian Best' (the predominant cultivar in Serbia), whereas three apricots ('Farbaly', 'Betinka' and 'Tsunami') had simultaneous first flowering, and the other nine apricots began flowering later than 'Hungarian Best'.

Bloom is the most important and most critical phenophase during the growing season. Onset of apricot flowering is dependent on the temperature increase after dormancy and is correlated with air temperature up to the end of March (Blasse and Hofmann, 1993). Temperatures after dormancy that range from 7 °C to 9 °C determine the start of the phenophase "beginning of flowering" (Vachůn, 1974, 2003a). Other authors stated that date of apricot bloom was also influenced by the sum of active

Table 2. Average blossoming data for apricots evaluated from 2017 to 2019.

Cultivar	First blossoming		Full blossoming		End of blossoming		Harvest date	
	Date	Mean ± SD*	Date	Mean ± SD*	Date	Mean ± SD*	Date	Mean ± SD*
Goldrich	17 Mar	75 ± 3	19 Mar	78 ± 2	27 Mar	86 ± 1	3 Jul	184 ± 2
Zerdelija	19 Mar	78 ± 2	23 Mar	82 ± 1	30 Mar	89 ± 1	28 Jun	179 ± 1
Farbaly	18 Mar	77 ± 3	21 Mar	80 ± 3	28 Mar	87 ± 1	22 Aug	234 ± 1
Ketch Pshar	19 Mar	78 ± 2	21 Mar	80 ± 2	29 Mar	88 ± 1	11 Sep	254 ± 2
Candela	17 Mar	76 ± 4	19 Mar	78 ± 3	25 Mar	84 ± 0	22 Jun	173 ± 2
Adriana	16 Mar	75 ± 4	18 Mar	77 ± 4	24 Mar	83 ± 2	8 Jul	189 ± 1
Fardao	19 Mar	78 ± 3	21 Mar	80 ± 3	30 Mar	89 ± 0	12 Sep	255 ± 2
Betinka	18 Mar	77 ± 3	20 Mar	79 ± 3	28 Mar	87 ± 1	1 Jul	182 ± 2
Čačansko Zlato	19 Mar	78 ± 3	22 Mar	81 ± 4	27 Mar	86 ± 1	5 Jul	186 ± 3
Spring Blush	19 Mar	78 ± 1	21 Mar	80 ± 1	28 Mar	87 ± 1	11 Jun	162 ± 2
Wonder Cot	16 Mar	75 ± 1	20 Mar	79 ± 2	24 Mar	83 ± 1	3 Jun	154 ± 1
Orange Red	19 Mar	78 ± 3	21 Mar	80 ± 3	26 Mar	85 ± 1	22 Jun	173 ± 1
Tsunami	18 Mar	77 ± 3	20 Mar	79 ± 3	26 Mar	85 ± 0	2 Jun	153 ± 2
N. Kasnocvetna	20 Mar	79 ± 2	23 Mar	82 ± 2	29 Mar	88 ± 1	5 Jul	186 ± 2
Bergeron	19 Mar	78 ± 1	21 Mar	80 ± 2	28 Mar	87 ± 3	14 Jul	195 ± 2
Aurora	17 Mar	76 ± 3	19 Mar	78 ± 3	24 Mar	83 ± 1	1 Jun	152 ± 2
Roxana	19 Mar	78 ± 3	21 Mar	80 ± 3	28 Mar	87 ± 1	12 Jul	193 ± 1
P. de Tirynthe	16 Mar	75 ± 2	19 Mar	78 ± 1	25 Mar	84 ± 1	16 Jun	167 ± 1
Hungarian Best	18 Mar	77 ± 2	21 Mar	80 ± 3	26 Mar	85 ± 1	8 Jul	189 ± 2

* Blossoming middle-days after January the 1st, 2017 to 2019.

temperatures above 5.5°C (Bažant et al., 1999). However, it does not exclude the influence of lower temperatures on this phenomenon.

The beginning of bloom for the same apricot genotype can differ from year to year by 25 to 40 days, depending on the cultivar and weather conditions (Bažant et al., 1999). However, this was not the case in our study because the differences between the earliest and the latest onset of bloom date were only 4 days, which is in agreement with data presented by Milošević (1997), who noted that, in central Serbia, apricots start to bloom towards the end of March or at the beginning of April, on average, the difference in the first bloom among the genotypes being 2–4 days under favourable weather conditions or 6–8 days when conditions were less favourable. Obviously, the apricots in the current study had an earlier onset of flowering that previous study, possibly due to the effects of global warming. Results similar to ours were found by Vachůn (2003a) who noted that the average amplitude between the earliest and latest beginning of bloom for apricot genotypes was relatively low and varied from 3 to 9 days according to year. Mehlenbacher et al. (1991) reported that, in northern areas, the differences between bloom phenophases of different genotypes, from the earliest to the latest blossoming ones, was less pronounced. In a warmer climate such as Central Italy, the differences in bloom time tend to be much more important; the start of the bloom between the first and last cultivars was taking greater than one month (Della Strada et al., 1989). Based on standard deviations, the more stable time for onset of flowering in our study was observed in 'Wonder Cot', 'Novosadska Kasnocvetna' and 'Precoce de Tyrinthe' and was less stable in 'Adriana'. These differences are a consequence of different reactions of cultivars to the increase in temperatures after dormancy (Mehlenbacher et al., 1991).

The earliest full bloom date was characteristic of 'Adriana' with an average deviation of 4 days. The latest full bloom date was observed in 'Zerdelija' and 'Novosadska Kasnocvetna', respectively. Both of these cultivars had a stable full bloom time, with a standard deviation (SD) from the three-year average of only one and/or two days.

This result indicates their good adaptation to climatic conditions of this region. The end of flowering was the earliest in 'Wonder Cot' and 'Aurora', and the least in 'Zerdelija' and 'Fardao' with very small deviations from the average.

Comparison of our results for apricot bloom with data from other authors is very difficult due to different reactions of the same genotype to specific environmental conditions. For example, Bahar and Son (2017) reported that trees of 'Precoce de Tyrinthe' had delayed first bloom in comparison with those of 'Aurora' in the Silifke area (Turkey, Mediterranean basin). This delay was around 15 days, which is quite contrary to our observations for trees of 'Precoce de Tyrinthe', which began to bloom earlier than 'Aurora' and a difference between them was only one day. In other studies, both of these cultivars were also targeted as early-flowering (Bozhkova et al., 2013; Son and Bahar, 2018), whereas 'Orange Red' and 'Bergeron' blooms around the second week of March under Mediterranean conditions (Murcia, Spain) with a shorter flowering cycle of 'Orange Red' than 'Bergeron' (Egea et al., 2004), consistent with our results. In a trial of Milatović et al. (2012) under conditions similar to ours, 'Aurora' bloomed at the end of March or two days earlier than 'Hungarian Best'. Generally, in moderate and continental areas where low temperatures often occur in spring, late-blooming apricots should be cultivated (Milošević et al., 2010). Miodragović et al. (2019) found that the duration of bloom for 'Novosadska Kasnocvetna' was 9 days, consistent with our results. In general, our data for bloom duration (7–11 days) were consistent with the results of Bozhkova et al. (2013).

Fruits of all cultivars were harvested between the beginning of June and the first two weeks of September (Table 2). The earliest ripening cultivars were 'Aurora', 'Tsunami', 'Wonder Cot', and 'Precoce de Tirynthe'. The last ripening cultivars were 'Ketch Pshar' and 'Fardao'. These results are in agreement with other studies on apricot ripening time that reported cultivars and ecological conditions affected maturation date (Ruiz and Egea, 2008; Caliscan et al., 2012; Son and Bahar, 2018). For example, 'Precoce de Tyrinthe' grown in the Mut Valley (Mediterranean region) in Turkey was harvested 15–20 days earlier than in Spain (Badenes et al., 1998). Similarly, Egea et al. (2004) reported that 'Orange Red' ripened at the end of May, i.e. 22 days earlier than our harvest time for this cultivar. In the present study, eight cultivars (42%) matured in the first half of July. For this reason, supply competition at this timeframe in the Serbian apricot market is at its highest, causing a dramatic fall in prices. Conversely, early production is one of the most important reasons for growing fresh apricot due to higher prices. Apricot cultivars that ripen in August or September, such as 'Farbaly', 'Fardao' or 'Ketch Pshar', are not popular among Serbian consumers, nor for the processing industry due to inexperience with these apricots.

3.2. Vegetative growth and yield attributes

Tree growth, as assessed by TCSA, was significantly affected by cultivar beginning the third year after planting (Figure 1), which is consistent with our earlier apricot study (Milošević and Milošević, 2019).

'Precoce de Tyrinthe', together with 'Spring Blush', 'Hungarian Best' and 'Farbaly', by far exhibited the lowest tree growth intensity and annual rate of increase during the experiment, whereas 'Ketch Pshar' had the highest. Final TCSA significantly varied among apricot genotypes (Table 3). 'Ketch Pshar' had the highest tree vigour, whereas the smallest trees were 'Precoce de Tyrinthe', 'Spring Blush', 'Hungarian Best' and 'Farbaly', with no significant differences among them. For example, 'Ketch Pshar' had

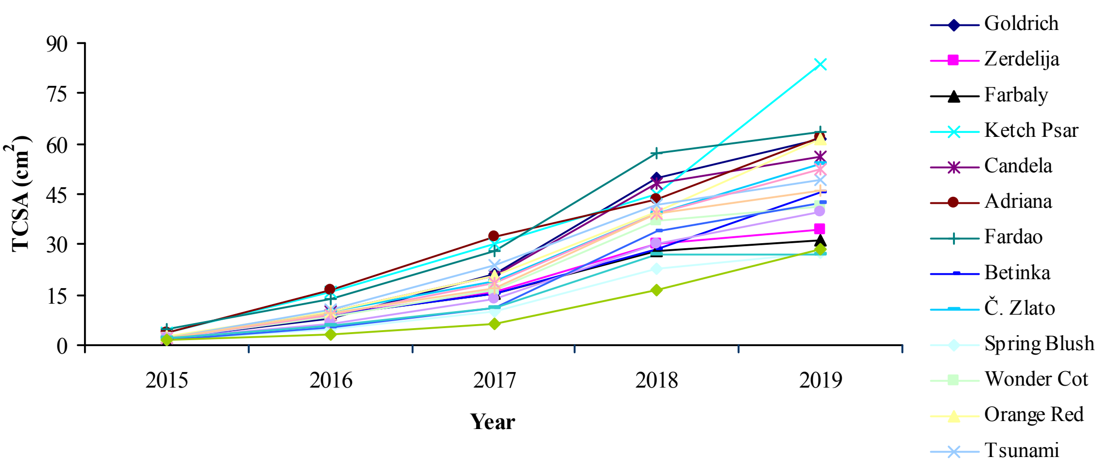

Figure 1. Dynamics of tree growth (assessed as TCSA) of 19 apricot cultivars from the first (2015) to the fifth (2019) year after planting.

Table 3. Effect of rootstock on TCSA, yield, cumulative yield, and yield efficiency of 19 apricot cultivars, from the second (2017) to the fifth (2019) year after planting.

Cultivar	Final TCSA (cm^2) Year - 2019	Final yield (kg $tree^{-1}$) Year - 2019	Cumulative yield (kg $tree^{-1}$) (2017-2019)	Yield efficiency (kg cm^{-2}) Year – 2017/2019
Goldrich	61.58 ± 6.58 bc	14.15 ± 1.22 ef	15.22 ± 0.32 ef	0.311 ± 0.04 f-i
Zerdelija	34.41 ± 1.29 jkl	9.65 ± 0.46 j	11.65 ± 0.34 hi	0.347 ± 0.02 efg
Farbaly	31.28 ± 1.86 klm	5.10 ± 0.44 n	7.20 ± 0.50 k	0.234 ± 0.01 hij
Ketch Pshar	83.69 ± 5.23 a	11.80 ± 0.66 hi	13.10 ± 0.26 g	0.171 ± 0.01 j
Candela	56.14 ± 1.80 cd	9.45 ± 0.40 jk	11.75 ± 0.30 h	0.213 ± 0.01 ij
Adriana	61.82 ± 3.46 bc	14.57 ± 0.13 de	15.37 ± 0.21 ef	0.257 ± 0.01 g-j
Fardao	63.78 ± 2.77 b	23.25 ± 1.21 a	26.35 ± 0.57 a	0.426 ± 0.02 cde
Betinka	45.78 ± 2.73 fgh	13.34 ± 0.56 efg	16.34 ± 0.24 de	0.382 ± 0.02 c-f
Čačansko Zlato	54.02 ± 5.71 de	8.26 ± 0.14 kl	8.96 ± 0.45 j	0.210 ± 0.03 ij
Spring Blush	27.30 ± 2.25 m	19.09 ± 0.39 b	20.49 ± 0.55 b	0.844 ± 0.07 a
Wonder Cot	41.54 ± 2.69 ghi	16.62 ± 0.68 cd	17.32 ± 0.65 cd	0.439 ± 0.02 b-e
Orange Red	61.28 ± 2.04 bc	12.88 ± 0.59 fgh	14.28 ± 0.39 fg	0.239 ± 0.01 hij
Tsunami	49.14 ± 2.82 ef	17.83 ± 0.69 bc	21.44 ± 0.66 b	0.458 ± 0.03 bcd
N. Kasnocvetna	52.61 ± 2.07 de	7.85 ± 0.38 lm	9.85 ± 0.50 ij	0.190 ± 0.01 j
Bergeron	39.78 ± 2.15 hij	12.10 ± 0.90 ghi	13.80 ± 0.61 g	0.369 ± 0.03 def
Aurora	46.26 ± 1.39 fg	16.52 ± 0.68 cd	17.92 ± 0.50 c	0.395 ± 0.02 c-f
Roxana	35.54 ± 3.25 ijk	7.20 ± 0.96 lm	10.46 ± 0.45 i	0.321 ± 0.02 fgh
P. de Tirynthe	27.01 ± 2.15 m	11.40 ± 0.36 i	13.80 ± 0.36 g	0.544 ± 0.03 b
Hungarian Best	28.61 ± 3.39 lm	6.55 ± 0.43 m	8.75 ± 0.57 j	0.481 ± 0.15 bc

No statistically significant differences between means denoted with the same letter in columns by LSD test at $p \leq 0.05$.

over three times greater tree size than 'Precoce de Tyrinthe'. 'Ketch Pshar' is from Central Asia, found by Kostina 1930 (Mehlenbacher et al., 1991), belongs to the Ferghana subgroup of cultivars and is characterized by vigorous trees ranging from 5 to 15 m tall (Mirzaev, 2000). In Serbian (Milošević, 1997; Milošević et al., 2019) and other apricot orchards on the Balkan peninsula (Tabakov and Yordanov, 2012), 'Hungarian Best' on Myrobalan seedling rootstock produces vigorous trees, which was not the case in our trial. Slow adaptation of this scion/rootstock combination to heavy, shallow and acidic soil in the first years after planting was identified in our earlier study (Milošević, 1997), probably due to poor root development preventing suitable soil anchoring and nutrient uptake in this soil type. In addition, moderate tree vigour of 'Roxana' on Myrobalan rootstock was described previously (Milošević et al., 2013a). The size-controlling properties of 'Precoce de Tyrinthe', 'Spring Blush', 'Farbaly', 'Zerdelija', 'Bergeron', 'Roxana', 'Wonder Cot', 'Betinka' and 'Aurora' in our trial is of high interest for reducing production costs, particularly pruning and harvest, due to smaller tree size. Today, new apricot orchards worldwide are planted more intensively than a few decades ago. Reasons for this trend toward semi-dense or high-density planting systems (HDP) are universal: earlier returns on capital, economical labor inputs, and production of high yields of quality fruits. The high vigour shown by other cultivars grafted on invigorating Myrobalan rootstock in our study may be recommended when planting on poor soils or under replant conditions (Milošević et al., 2013b, Milošević and Milošević, 2019).

All cultivars in the present study started to produce in the second year after planting (data not shown), with no significant differences in the first bearing years (2017 and 2018) due to the very low yields that ranged from 0.3 to 0.5 kg per tree. Later (i.e. in 2019), significant differences in yield among apricots became evident (Table 3). These data are in agreement with our earlier study on apricot (Milošević et al., 2013a, b). Egea et al. (2004) reported that 'Orange Red' started to produce in the third year after planting under Murcia conditions (Spain). Similar data for 'Aurora' and 'Hungarian Best' have been reported in Bulgaria (Bozhkova et al., 2013).

Regularity bearing is the most important parameter for apricot cultivation, whereas irregularity of yield is one of the main handicaps in temperate fruit production, including apricot and has been shown to be due to different problems concerning climatic adaptation, chill accumulation, and flower development (Egea et al., 2004).

Data in Table 3 showed that the highest final yield per tree and CY was exhibited by 'Fardao', and the lowest by 'Farbaly'. In a study by Tarantino et al. (2017), 'Farbaly' gave a much higher yield than ours. In general, good yield per tree and CY was also observed in 'Spring Blush', 'Tsunami', 'Aurora', and 'Wonder Cot'. These results indicated great potential for adaptability to growing conditions although the difficulty of apricot cultivars to adapt to environments differing from their origin is well known (Mehlenbacher et al., 1991). Miodragović et al. (2019) also reported low average yield for 'Novosadska Kasnocvetna' but higher CY than ours at a similar tree age, but the trees in that study were grafted with *P. spinosa* L. (blackthorn) as an interstock on Myrobalan stock. Bozhkova et al. (2013) reported lower yield per tree for 'Aurora' and higher for 'Hungarian Best' than our data, whereas Egea et al. (2004) stated that yield per tree of 'Orange Red' grafted on Manicot and GF.31 rootstocks was much higher than those found in our study. In our earlier work, 'Roxana' at the same tree age had a much higher yield per tree on sandy-loam textured soil (Milošević et al., 2013a), whereas Bahar and Son (2017) recorded a higher yield per tree for 'Aurora' and much higher for 'Precoce de Tyrinthe' than ours. Our yield per tree was higher for 'Candela', lower for 'Betinka' and 'Roxana' and similar for 'Hungarian Best' in comparison with data of Milatović et al. (2017). These differing tree yields may be due to better or worse adaptation of newly-bred foreign and/or Serbian apricots on Myrobalan seedlings to a typical clay-loamy and acidic soil due to the poor buffering capacity of Myrobalan roots (Milošević, 1997). Most apricot cultivars are highly specific in their environmental requirements and low yields are often obtained when grown in other regions. The causes behind this poor climatic adaptability are not clear although no vegetative problems are usually recorded.

On the basis of tree yield, Pejkić and Ninkovski (1987) classified apricot cultivars into four groups: poor <10 kg/tree, medium 10–15 kg/tree, good 15–20 kg/tree and excellent >20 kg/tree. In the present study, only 'Fardao' had excellent productivity, whereas 'Spring Blush', 'Tsunami', 'Wonder Cot', and 'Aurora' productivities were good. Seven apricots ('Zerdelija', 'Farbaly', 'Candela', 'Čačansko Zlato', 'Novosadska Kasnocvetna', 'Roxana' and 'Hungarian Best') had poor yield per tree. This property values of other seven cultivars were medium.

Yield efficiency is an index of the plant's growth and productivity. In our trial, the best YE value was found in 'Spring Blush' (Table 3) due to its moderate vigour and high cumulative yield. Relatively good YE was found in 'Precoce de Tirynthe', 'Hungarian Best', 'Tsunami' and 'Fardao'. In the literature, apricot YE values vary widely. For example, Milatović et al. (2017) reported that in conditions like ours, YE of 30 apricots ranged from 0.10 to 0.85, which is consistent with our values. These authors also reported that YE values for 'Candela', 'Betinka', 'Roxana', and 'Hungarian Best' were 0.21, 0.52, 0.85, and 0.28, respectively. On the other hand, Miodragović et al. (2019) reported YE of 0.40 for 'Novosadska Kasnocvetna', which is much higher than those obtained in our study for the same cultivar.

3.3. Fruit physical properties

Fruit weight is a function of crop load, tree capacity and preharvest growing conditions (Egea et al., 2004) due to competition between fruit for carbohydrates. In addition, fruit weight is a major quantitative inherited factor that affects yield, fruit quality, and consumers' acceptability.

Fruit and stone weight and flesh/stone ratio significantly differed among cultivars (Table 4). The highest fruit weight was observed in 'Candela' and the lowest in 'Wonder Cot' and 'Zerdelija'. Good fruit weights were also obtained from 'Goldrich', 'Orange Red', 'Novosadska Kasnocvetna' and 'Roxana'. Twelve cultivars had lower fruit weight than 'Hungarian Best', whereas six cultivars had higher. Previous studies also recorded high variability among cultivars for fruit weight (Ruiz and Egea, 2008; Milosevic and Milosevic 2013; Milošević et al., 2010, 2019). According to the IPBGR (1984) descriptor for apricot, fruit size for two genotypes ('Zerdelija' and 'Wonder Cot') was extremely small (<20 g), one ('Ketch Pshar') was very small (20–30 g), four ('Fardao', 'Spring Blush', 'Tsunami' and 'Aurora') were small (31–40 g), four ('Farbaly', 'Betinka', 'Precoce de Tirynthe' and 'Bergeron') were medium/small (41–46 g), three ('Adriana', 'Čačansko Zlato' and 'Hungarian Best') were medium (46–55 g), two ('Roxana' and 'Novosadska Kasnocvetna') were medium/large (56–60 g), two ('Goldrich' and 'Orange Red') were large (61-70 g) and one ('Candela') was very large (71–85 g). Pedryc and Szabó (1995) reported that 'Kech Pshar' has small fruits, similar to our results. Only a few cultivars had medium to large fruits. During fruit ripening in all three years, dry periods occurred with very high air temperatures (data not shown). This could be the main reason for the preponderance of low average fruit weights. Under Serbian conditions, the fruit weight in dry years may be reduced by 50%–60%, depending on the genotype (Milošević, 1997).

Our values for fruit weight differed greatly from those of other researchers for the same cultivars. For example, Egea et al. (2004) and Tarantino et al. (2017) reported much higher fruit weight for 'Orange Red' and 'Farbaly'. Our data for 'Aurora' were lower than those obtained by Milatović et al. (2012) and Bozhkova et al. (2013).

Table 4. Fruit and stone weight and flesh rate (flesh/stone ratio) of evaluated apricot cultivars. Data are the mean ± SE for three consecutive years.

Cultivar	Fruit weight (g)	Stone weight (g)	Flesh/stone ratio (%)
Goldrich	67.83 ± 2.36 b	4.29 ± 0.12 a	93.57 ± 0.25 ef
Zerdelija	19.64 ± 0.66 i	1.84 ± 0.11 h	90.46 ± 0.63 j
Farbaly	43.20 ± 1.60 f	2.95 ± 0.17 de	93.09 ± 0.41 fg
Ketch Pshar	27.88 ± 0.54 h	2.77 ± 0.03 ef	90.02 ± 0.19 j
Candela	80.47 ± 1.80 a	3.92 ± 0.15 b	95.07 ± 0.24 c
Adriana	53.08 ± 1.01 d	3.65 ± 0.07 bc	93.06 ± 0.23 fg
Fardao	37.67 ± 0.79 g	2.89 ± 0.06 de	92.28 ± 0.18 h
Betinka	45.45 ± 1.20 f	3.91 ± 0.08 b	91.26 ± 0.33 i
Čačansko Zlato	46.22 ± 1.80 ef	3.53 ± 0.10 d	92.08 ± 0.45 h
Spring Blush	34.77 ± 0.87 g	1.97 ± 0.04 h	94.22 ± 0.20 d
Wonder Cot	17.11 ± 0.60 i	1.25 ± 0.03 i	92.46 ± 0.38 gh
Orange Red	65.17 ± 1.50 b	3.14 ± 0.06 d	95.12 ± 0.16 c
Tsunami	38.42 ± 1.49 g	0.79 ± 0.05 j	97.83 ± 0.21 a
N. Kasnocvetna	60.34 ± 1.38 c	2.56 ± 0.14 fg	95.73 ± 0.26 bc
Bergeron	43.45 ± 1.36 f	2.45 ± 0.09 g	94.27 ± 0.29 d
Aurora	36.75 ± 1.05 g	1.35 ± 0.03 i	96.28 ± 0.11 b
Roxana	60.06 ± 1.96 c	3.65 ± 0.12 bc	93.88 ± 0.24 de
P. de Tirynthe	45.49 ± 1.59 f	2.88 ± 0.06 de	93.51 ± 0.28 ef
Hungarian Best	50.01 ± 1.05 de	3.07 ± 0.09 d	93.82 ± 0.22 de

No statistically significant differences between means denoted with the same letter in columns by LSD test at $p \leq 0.05$.

However, both of those studies reported lower fruit weight for 'Hungarian Best' compared to our value. Our fruit weight values were lower for 'Aurora' and higher for 'Hungarian Best' than those of Milatović et al. (2012) and our value for 'Novosadska Kasnocvetna' was lower than that of Miodragović et al. (2019). Additionaly, our average fruit weight for Czech cultivars ('Adriana', 'Candela' and 'Betinka') differed from the results of Krška and Vachůn (2016). These discrepancies can be attributed to the influence of environmental factors, crop load, tree age, and cultural management. Therefore, the apricots may produce larger fruits under better cultural practices.

Properties of the stones of *Prunus* taxa tend to be stable and are used in genotype identification (Özcan, 2000). The highest stone weight we observed was in 'Goldrich' and the lowest in 'Tsunami'. Tarantino et al. (2017) reported much a higher stone weight for 'Farbaly' than our value. High variability of this trait was also observed in our earlier study on apricot (Milosevic and Milosevic, 2013). 'Tsunami' had the highest flesh/stone ratio, while 'Ketch Pshar' had the lowest (Table 4). Also, the flesh/stone ratio was good in 'Aurora', 'Novosadska Kasnocvetna', 'Orange Red' and 'Candela'. In most cases, cultivars with a lower stone weight had a higher flesh/stone ratio and vice versa. Vachůn (2003b) reported flesh/stone ratio varied from 90.1 to 95.1%, which is close to our results. High ratios are desirable for fresh consumption, processing, and drying (Milošević et al., 2013b).

Fruit size is important for attracting consumers for the fresh market and is the most pertinent criteria used during the sorting process. There were significant differences among cultivars for fruit dimensions, geometric mean diameter, and fruit shape index (Table 5). 'Candela' had the highest fruit dimensions and geometric mean diameter, and the lowest was observed in 'Adriana' and 'Wonder Cot'. Several cultivars ('Candela', 'Goldrich', 'Orange Red', 'Novosadska Kasnocvetna' and 'Roxana') had statistically similar high fruit lengths. Our linear fruit dimensions for 'Farbaly' were much lower than those obtained by Tarantino et al. (2017) but similar to those of Miodragović et al. (2019) for 'Novosadska Kasnocvetna'. Previous studies also indicated a high variability among cultivars regarding fruit size characteristics (Ruiz and Egea, 2008; Milošević et al., 2014).

Table 5. Fruit linear dimensions (length, width, and thickness), geometric mean diameter and fruit shape index (sphericity). Data are the mean ± SE for three consecutive years.

Cultivar	∅L (mm)	∅W (mm)	∅T (mm)	D_g (mm)	Sphericity
Goldrich	52.76 ± 0.74 a	50.20 ± 0.63 b	44.39 ± 0.57 b	48.98 ± 0.59 b	0.929 ± 0.005 l
Zerdelija	36.66 ± 0.44 f	32.03 ± 0.38 i	29.98 ± 0.38 g	32.76 ± 0.31 j	0.894 ± 0.007 p
Farbaly	46.00 ± 0.93 bc	42.59 ± 0.73 f	39.25 ± 0.75 e	42.50 ± 0.72 ef	0.925 ± 0.009 m
Ketch Pshar	34.56 ± 0.33 fg	37.08 ± 0.34 h	36.76 ± 0.23 f	36.11 ± 0.27 i	1.045 ± 0.005 a
Candela	51.92 ± 0.37 a	54.26 ± 0.36 a	50.56 ± 0.42 a	52.22 ± 0.33 a	1.001 ± 0.003 b
Adriana	33.65 ± 0.31 g	32.47 ± 0.46 i	26.83 ± 0.44 h	30.81 ± 0.32 k	0.916 ± 0.007 o
Fardao	45.05 ± 0.33 bcd	39.97 ± 0.42 g	36.72 ± 0.39 f	40.43 ± 0.33 gh	0.898 ± 0.005 p
Betinka	43.91 ± 0.41 cd	42.65 ± 0.43 f	39.05 ± 0.50 e	41.81 ± 0.40 efg	0.952 ± 0.005 h
Čačansko Zlato	44.57 ± 0.65 bcd	44.64 ± 0.71 e	42.01 ± 0.67 cd	43.71 ± 0.63 de	0.981 ± 0.007 d
Spring Blush	40.23 ± 0.39 e	40.40 ± 0.42 g	37.16 ± 0.45 f	39.22 ± 0.33 h	0.975 ± 0.008 e
Wonder Cot	34.19 ± 0.40 fg	32.66 ± 0.50 i	29.44 ± 0.52 g	32.02 ± 0.44 jk	0.936 ± 0.005 k
Orange Red	51.13 ± 0.25 a	50.55 ± 0.42 b	45.27 ± 0.43 b	48.90 ± 0.31 b	0.956 ± 0.004 g
Tsunami	44.35 ± 0.60 cd	39.90 ± 0.56 g	38.36 ± 0.45 ef	40.78 ± 0.51 fgh	0.920 ± 0.004 n
N. Kasnocvetna	51.67 ± 0.48 a	49.03 ± 0.49 bc	45.24 ± 0.39 b	48.56 ± 0.39 b	0.940 ± 0.005 j
Bergeron	42.88 ± 0.43 de	42.11 ± 0.41 f	41.11 ± 0.52 d	42.02 ± 0.42 efg	0.980 ± 0.004 d
Aurora	41.99 ± 0.51 de	39.99 ± 0.47 g	37.09 ± 0.48 f	39.62 ± 0.40 h	0.945 ± 0.007 i
Roxana	50.34 ± 0.58 a	47.97 ± 0.64 cd	45.32 ± 0.71 b	47.80 ± 0.51 b	0.953 ± 0.007 h
P. de Tirynthe	47.07 ± 0.59 b	45.85 ± 0.76 de	44.17 ± 0.77 b	45.65 ± 0.61 c	0.971 ± 0.011 f
Hungarian Best	46.15 ± 0.35 bc	46.76 ± 0.49 d	43.66 ± 0.39 bc	45.49 ± 0.30 cd	0.986 ± 0.007 c

Values with different letters in same column indicate statistically significant differences at the $p \leq 0.05$, according to the LSD test.

Sphericity index is used to describe fruit shape, and knowledge of this property is important for sorting and sizing of fruits (Mohsenin, 1980). In our study, all cultivars showed statistically different values of sphericity (Table 5). The highest value was observed in 'Ketch Pshar' and the lowest and statistically similar in 'Zerdelija' and 'Fardao'. If sphericity values are around 1, fruit shape tends to be round, while if these values are higher than 1, fruits correspond to an ovoid shape. In our earlier study, sphericity values of different genotypes ranged from 0.91 to 1.04 (Milošević et al., 2014). Most cultivars tend towards a round shape, although some had round/flat or ovoid-shaped fruits, such as 'Novosadska Kasnocvetna' (Miodragović et al., 2019).

3.3. Fruit chemical properties

SSC is one of the main fruit quality attributes that affect fruit taste. Also, high SSC is very desirable in apricot fruit juice, associated with sweetness and flavor especially if it combined with acidity and tannin concentration.

Cultivars varied widely and significantly for SSC (Table 6). The highest SSC was in 'Ketch Pshar', 'Candela' and 'Fardao' fruits, with no significant differences among them. The lowest SSC was in fruits of 'Precoce de Tirynthe'. 'Čačansko Zlato', 'Spring Blush', and 'Tsunami' had statistically similar levels of SSC. In most cases, our SSC values were much higher than those of other authors for the same cultivars, such as Davarynejad et al. (2010) for 'Bergeron, Bozhkova et al. (2013) for 'Aurora', Tarantino et al. (2017) for 'Farbaly', Miodragović et al. (2019) for 'Novosadska Kasnocvetna' and Milošević et al. (2013a, 2019) for 'Roxana' and 'Hungarian Best'. This may be due to the influence of warm periods during harvest in our trial (data not shown). In addition, late maturing apricots have higher SSC than early- or mid-season maturing cultivars (Lo Bianco et al., 2010), with which our results were consistent. Kader (1999) considered mean values of SSC higher than 10% as the minimum value for consumer acceptance for apricots, and 10% SSC also was established as an EU minimum for market apricots (R-CE No.112/2001). In our study, all cultivars had much higher SSC than this threshold.

Titratable acidity varied significantly among cultivars. The highest was in 'Candela' and the lowest in 'Roxana' and 'Hungarian Best' (Table 6). In our earlier studies, 'Roxana' and 'Hungarian Best' also had low acidity (Milošević et al., 2013a, 2019). Although of different origin, 'Zerdelija', 'Farbaly', Čačansko Zlato', Tsunami', 'Novosadska

Table 6. Soluble solids content, acidity, and ripening index of apricot cultivars. Data are the mean ± SE for two consecutive years.

Cultivar	Soluble solids content (°Brix)	Titratable acidity (%)	Ripening index
Goldrich	18.40 ± 0.30 fg	1.71 ± 0.08 b	11.12 ± 0.51 hi
Zerdelija	20.07 ± 0.19 de	1.26 ± 0.03 ghi	16.08 ± 0.42 cde
Farbaly	24.42 ± 0.24 b	1.29 ± 0.05 ghi	19.43 ± 0.69 b
Ketch Pshar	25.93 ± 0.18 a	1.46 ± 0.05 de	18.09 ± 0.64 bc
Candela	25.52 ± 0.32 ab	1.98 ± 0.06 a	13.11 ± 0.47 gh
Adriana	22.61 ± 0.25 c	1.65 ± 0.05 bc	14.00 ± 0.52 efg
Fardao	25.09 ± 0.47 ab	1.39 ± 0.05 efg	18.52 ± 0.82 b
Betinka	20.95 ± 0.57 d	1.54 ± 0.03 cd	13.76 ± 0.52 fg
Čačansko Zlato	16.59 ± 0.24 i	1.22 ± 0.02 i	13.61 ± 0.30 fg
Spring Blush	16.25 ± 0.17 i	1.43 ± 0.01 def	11.34 ± 0.14 hi
Wonder Cot	16.62 ± 0.42 hi	1.38 ± 0.03 efg	12.17 ± 0.39 gh
Orange Red	17.46 ± 0.13 gh	1.36 ± 0.04 e-h	13.02 ± 0.37 gh
Tsunami	16.06 ± 0.34 i	1.29 ± 0.01 ghi	12.51 ± 0.30 gh
N. Kasnocvetna	19.96 ± 0.55 de	1.28 ± 0.02 ghi	15.71 ± 0.47 def
Bergeron	21.16 ± 0.65 d	1.23 ± 0.03 hi	17.30 ± 0.66 bcd
Aurora	19.55 ± 0.30 ef	1.64 ± 0.01 bc	11.91 ± 0.22 gh
Roxana	18.19 ± 0.59 g	0.98 ± 0.02 j	18.72 ± 0.69 b
P. de Tirynthe	12.52 ± 0.19 j	1.31 ± 0.01 f-i	9.57 ± 0.13 i
Hungarian Best	21.09 ± 0.47 d	0.95 ± 0.02 j	22.32 ± 0.63 a

No statistically significant differences between means denoted with the same letter in columns by LSD test at $p \leq 0.05$.

Kasnocvetna', 'Bergeron' and 'Precoce de Tirynthe' contained similar TA. In general, our range of values were comparable to previous reports (Ruiz and Egea, 2008; Milošević et al., 2013b; Gündoğdu, 2019). However, for some cultivars, such as 'Bergeron', 'Aurora', 'Hungarian Best', 'Farbaly' and 'Novosadska Kasnocvetna', acidity was lower than previously reported (Davarynejad et al., 2010; Bozhkova et al., 2013; Tarantino et al., 2017; Miodragović et al., 2019). Leccese et al. (2008) reported that 'Precoce de Tyrinthe' grown in the Mediterranean basin had lower acidity in comparison with continental areas. According to Ruiz and Egea (2008), fruit maturity stage at harvest and weather conditions before harvest are the major factors influencing fruit acidity and SSC.

The SSC/TA ratio or ripening index plays an important role in consumer acceptance and can be a tool for fruit taste evaluation, i.e., perception of sweetness and flavour (Alavoine et al., 1988). Consumers worldwide complain about hard (unripe), non-sweet, poorly-flavored apricots in markets, as they desire sweet, ripe fruit (Moreau-Rio, 2006). In the present study, RI varied significantly between cultivars (Table 6). The highest value was observed in 'Hungarian Best' and the lowest in 'Precoce de Tirynthe'. In addition, good and statistically similar SSC/TA ratios were found in 'Farbaly', 'Ketch Pshar', 'Fardao' and 'Roxana'. 'Candela', 'Betinka', 'Čačansko Zlato', 'Wonder Cot', 'Orange Red', 'Tsunami', and 'Aurora' also had similar SSC/TA ratios to each other. Our SSC/TA ratio values were lower, for the same cultivars, than the results obtained by Davarynejad et al. (2010) and higher in most cases than those of Caliscan et al. (2012), Tarantino et al. (2017) and Miodragović et al. (2019). Some authors noted that SSC values higher than 13°Brix were positively related with an increased SSC/TA ratio, improving the fruit eating quality and, thus, consumer acceptance (Bassi and Audergon, 2006; Ruiz and Egea, 2008). In the present study, six cultivars ('Goldrich', 'Spring Blush', 'Wonder Cot', 'Tsunami', 'Aurora' and 'Precoce de Tirynthe') did not meet these criteria, primarily due to high TA values. In addition, Kader (1999) reported that fruits with an SSC/TA ratio between 10 and 15 had a well-balanced eating quality, while fruits with a lower ratio were too acidic, and apricots with the highest SSC/TA ratio had the lowest acidity and consistent SSC values.

3.4. Pearson's correlation matrix among variables

Data in Figure 2 revealed that TCSA negatively correlated with YE, as previously reported (Hernández et al., 2010). This relationship clearly showed that trees that produced proportionally more, i.e., had higher yield efficiencies, grew less. It can be said that in young apricot trees, vigor is inversely related to early bearing efficiency. TCSA positively correlated with SSC and TA. These data underline the important relationships between apricot tree adaptability and development and the major factors of fruit quality. Yield per tree correlated strongly with cumulative yield and moderately with YE, whereas cumulative yield correlated with YE. These results concur with data of Hernández et al. (2010).

Fruit physical traits (fruit and stone weight, fruit linear dimensions and geometric mean diameter) were significantly correlated. These relationships had also been described earlier by Biondi et al. (1991). It has been reported that fruits with higher weight induced higher stone weight and fruit size (Milosevic and Milosevic, 2013). Therefore, all three parameters can be used to predict each other, as previously reported by Ruiz and Egea (2008). Fruit weight also correlated with flesh/stone ratio, fruit shape index, soluble solids, and acidity, but relationships were not significant, which is in agreement with previous study (Badenes et al., 1998). Flesh/stone ratio was positively correlated with fruit length, that is, fruits with larger size had better ratios (Milosevic and Milosevic, 2013). All fruit dimensions and size significantly correlated with each other.

In particular, SSC showed a positive correlation to SSC/TA ratio, which indicates the tendency that apricots with higher SSC have better eating quality (Milosevic and Milosevic, 2013). The TA was negatively correlated with SSC/TA ratio, whereas no significant relationship with SSC was found, as previously reported (Hernández et al., 2010; Milosevic and Milosevic, 2013).

3.5. Principal component analysis (PCA)

Of the total variance among cultivars, 88% was explained by the first five components (Table 7). PC1 consisted of yield, cumulative yield, fruit weight, stone weight, length, width, thickness, and geometric mean diameter comprised about 38.3% of total variance. PC2, which represented yield efficiency, SSC and ripening index constituted 19.8%

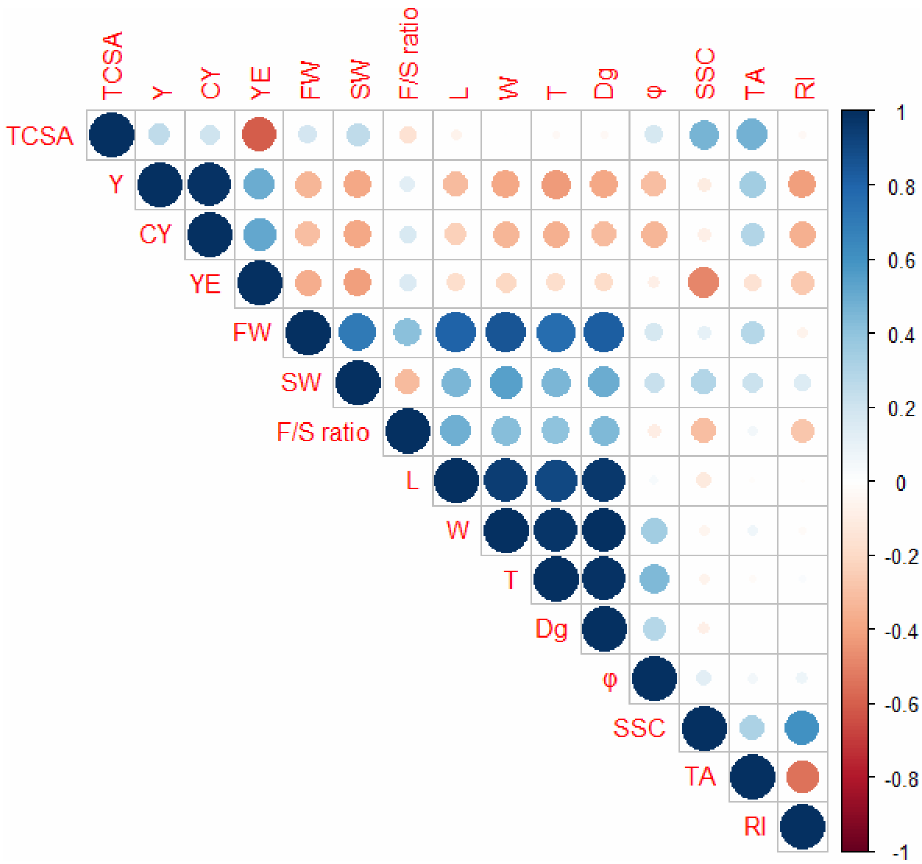

Figure 2. Pearson's rank correlation matrix among the set of 15 studied variables of apricot cultivars evaluated. For abbreviations see Section 'Materials and methods'.

of total variance, while PC3 included TCSA and total acids which accounted for 16.2% of total variance. Table 8 shows the correlation between the original variables and the first three principal components.

As observed in PCA (Figure 3), the first three components represented 74.3% of total variance (38.3%, 22.1% and 19.8%, respectively). These values were much higher than those reported by Ruiz and Egea (2008) and Milosevic and Milosevic (2013) but lower than those of Perez-Gonzales (1992). These discrepancies among different authors can be attributed to number of genotypes and variables used.

4. Conclusion

The study of newly introduced and traditional apricot genotypes grown under the same conditions shows a great variability. Since that study included commercial cultivars, the range of variation observed was wider than expected. Variation was observed for properties related to phenology, tree growth, productivity, and fruit quality. One of the most important findings of this study is that among 19 commercial cultivars evaluated, most had very high SSC and other critical fruit quality attributes, whereas only 6 had fruit weight ≥50 g. This could suggest that most of the cultivars possess a relatively small genetic fruit size, especially 'Zerdelija' and/or 'Ketch Pshar'. However, the genetic potential of many cultivars for fruit size and productivity may have been limited by the acidic, shallow, and heavy soil, absence of irrigation and probably inadequate fertilization management. We believe that a more aggressive orchard management program may be required for apricots grown in this soil type, especially

Table 7. Eigenvalues, variance %, and cumulative % of first four factors contributing to 81.82% of total variance.

Component (PC)	Eigenvalues	Variance (%)	Cumulative variance (%)
1	5.75	38.32	38.32
2	2.96	19.76	58.08
3	2.43	16.23	74.31
4	1.13	7.51	81.82
5	0.97	6.44	88.26

Table 8. Loading factor of variables in the first four principal components (PCs).

Variable	PC1	PC2	PC3	PC4	PC5
TCSA	0.0571	–0.3186	0.8128	–0.0409	0.0811
Y	–0.5892	0.5158	0.5106	–0.1600	0.2391
CY	–0.5448	0.5416	0.4673	–0.2481	0.2765
YE	–0.4131	0.6385	–0.3153	0.1260	0.3489
FW	0.8874	0.1209	0.2789	–0.0799	–0.1403
SW	0.6506	–0.3486	0.2812	0.1278	–0.1331
FR	0.3105	0.6911	–0.0205	–0.3036	0.0016
L	0.8860	0.3345	–0.0231	–0.2435	–0.0430
W	0.9578	0.2445	0.0282	–0.0039	0.1020
T	0.9337	0.2187	–0.0617	0.0371	0.2223
Dg	0.9450	0.2707	–0.0207	–0.0662	0.0999
φ	0.3676	–0.2163	0.0148	0.6305	0.6033
SSC	0.0755	–0.6880	0.4282	–0.3500	0.2816
TA	0.0326	0.1211	0.8518	0.2422	–0.1411
RI	0.1147	–0.6742	–0.3514	–0.5131	0.3641

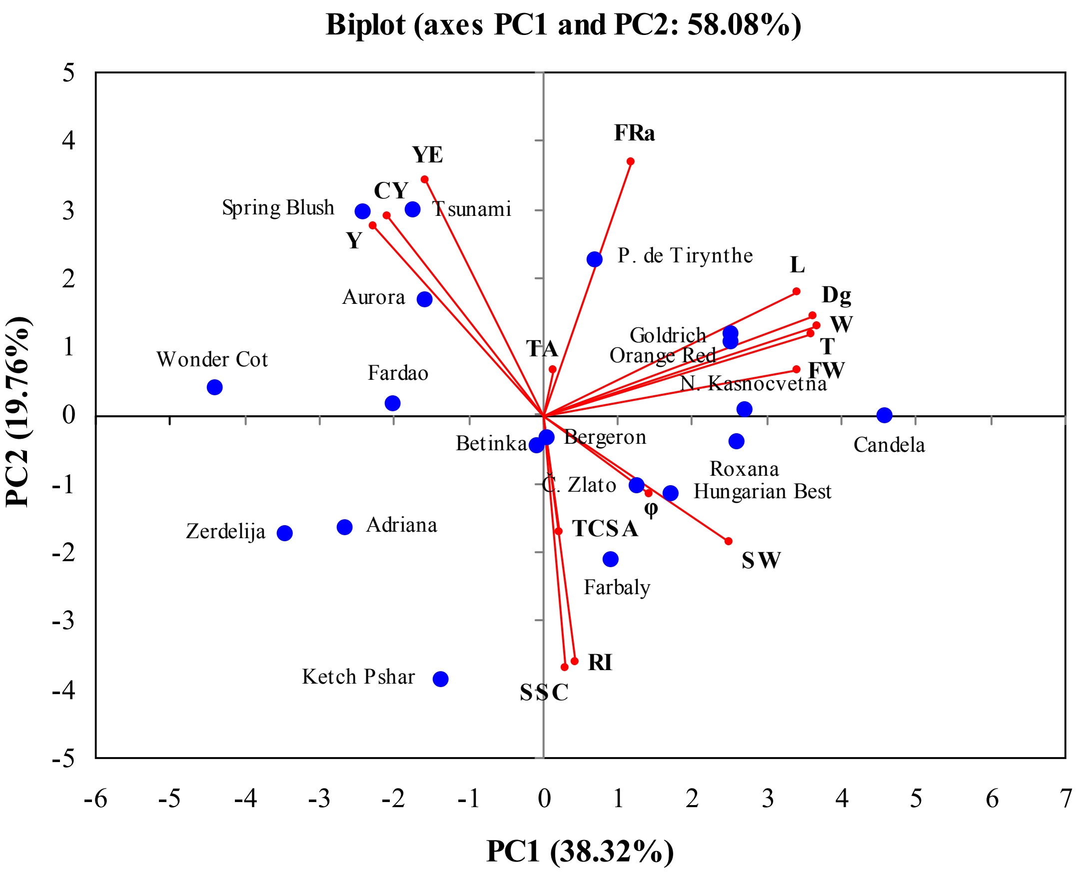

Figure 3. Segregation of 19 newly introduced and traditional apricot cultivars originating from different genetic origins according to their agronomic and fruit quality properties determined by principal component analysis (PCA).

fertilization with organic fertilizers, liming and irrigation. However, before summarizing the performance of any cultivar, a high number of years of observation are needed, and very often this estimation cannot be generalized and applied due to various environmental conditions.

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