Voćarstvo
Journal of Pomology

Naučni časopis
Scientific Journal

VOĆARSTVO
JOURNAL OF POMOLOGY

Naučno voćarsko društvo Srbije
Scientific Pomological Society of Serbia

Vol. 56 ∗ Br. 211–212 ∗ januar–jun 2022.
Vol. 56 ∗ No. 211–212 ∗ January–June 2022

Voćarstvo
Journal of Pomology

Naučni časopis
Scientific Journal

***IZDAVAČ* – PUBLISHER**

Naučno voćarsko društvo Srbije, Čačak
Scientific Pomological Society of Serbia, Čačak

U sufinansiranju časopisa učestvuju – *Publication is co-financed by*
Ministarstvo prosvete, nauke i tehnološkog razvoja RS – *Ministry of Education, Science and Technological Development of RS*
Institut za voćarstvo, Čačak – *Fruit Research Institute, Čačak*

Časopis izlazi tromesečno – *Published quarterly*
Godišnja pretplata – *Annual subscription*: fizička lica – *personal subscription* – 500 RSD;
Preduzeća i ustanove u Srbiji – *Serbian institutions* – 1.000 RSD; inostranstvo – *foreign countries* – 40 €;
ex-Yu republike – *ex-Yu republics* – 20 €
Tekući račun – *Current account*: 155-2670-51, Halkbanka, Čačak
Devizno plaćanje po instrukciji na zahtev/*Foreign currency payments should follow the istructions given on request*

Uredništvo i administracija – *Editorial board and administration*
Kralja Petra I br. 9, 32000 Čačak, Tel: 032/327-550, Fax: 032/321-391; E-mail: iglisic@institut-cacak.org

Tiraž – *Circulation*: 200

Štampa – *Printed by:* „Štamparija Svetlost“ d.o.o., Gvozdena Paunovića 208, 32000 Čačak

Časopis se citira u – *Cited in*: CAB international – Horticultural Abstract, Plant Breeding Abstract; Ulrich Periodicals Directory; Referativni Zhurnal; elektronska verzija u/*electonic version in*: digitalnom repozitorijumu NBS: www.nb.rs; *apstrakti na*/*abstracts on*: website: www.institut-cacak.org

SADRŽAJ

CONTENTS

Voćarstvo, 56, 211–212 (2022), 7–18
Journal of Pomology, 56, 211–212 (2022), 7–18

UDK: 634.10(497.11 centrala Srbija)
Originalni naučni rad
Original scientific paper

Preliminary results of *in situ* characterisation of autochthonous apple genotypes originated from the central and southwest Serbia region

Slađana Marić*, Ivana Glišić, Nebojša Milošević, Jelena Tomić, Mira Milinković, Milena Đorđević, Sanja Radičević

Fruit Research Institute, Čačak, Kralja Petra I/9, 32000 Čačak, Republic of Serbia
**E-mail: smaric@institut-cacak.org*

Received: 21 April 2022; Accepted: 10 May 2022

Abstract. The paper presents the main biological properties of 17 *in situ* old local apple cultivars and landraces grown in the regions of central and southwestern Serbia: 'Ilinjača' (Jezdina), 'Kraljica', 'Vidovača', 'Ilinjača' (Trnava), 'J-GM/1', 'Prancija', 'Strekinja', 'Lepocvetka', 'J-LuN/1', 'Prancija Slatka', 'Džumurka', 'Slatka Kadumana', 'Lubenjaja', 'J-ČaO/1', 'Senabija', 'Budimka' and 'Kolačara'. The following characteristics of these genotypes were assessed: flowering phenophase, harvest date, pomological properties (physical and chemical, including bioactive compounds) and disease susceptibility to scab [*Venturia inaequalis* (Cooke) Wint.] and fireblight [*Erwinia amylovora* (Burnill)]. The average flowering time was during the third decade of April, whilst the predominant harvest date was from mid-September to mid-October. The highest fruit weight was determined in 'Ilinjača' (Trnava), while the lowest was in 'Vidovača' (262.99 g and 29.23 g, resp.). The best fruit quality among the assessed genotypes, measured by the fruit chemical composition, was found in 'Senabija' (soluble solids content – 17.05%; total and invert sugars content – 12.70% and 9.66%, resp.). The cultivar 'Strekinja' and landrace 'J-ČaO/1' were characterised by the highest content of total phenols and anthocyanins, respectively. In terms of fruit attractiveness, 'Lepocvetka', 'J-ČaO/1', 'Senabija' and 'Budimka' could be singled out. All of the studied genotypes showed resistance to fireblight and a relatively narrow range of susceptibility to scab under field conditions. Overall, Serbian autochthonous apple genotypes appear to carry useful characteristics that could be important for current/future breeding work and commercial growing suitable for fresh consumption, industrial and domestic processing.

Key words: *Malus domestica* Borkh., indigenous genotypes, phenological properties, pomological properties, resistance

Introduction

Apple (*Malus domestica* Borkh.) is the main perennial fruit species of temperate climates of the world, with an annual production of more than 86 million tonnes in 2020 (FAOSTAT, 2022). In addition, apple is also one of the major fruit species in the Republic of Serbia, with average production of 445,705 tonnes (2016–2020) that in the same period reached the production of plum (474,740 tonnes) as the main fruit in the country. There are more than 10,000 described apple cultivars worldwide (Way et al., 1991), thousands of which are curated in national repositories, especially in Europe and the United States of America (Peace et al., 2019). Likewise, a large number of cultivars are also maintained by private institutes or associations, as well as active amateur networks. The number of apple cultivars is presumably underestimated because many local landraces have not been accurately documented. On the other hand, constrained number of cultivars dominated as parents in earlier breeding programmes i.e. 'Cox's Orange Pippin', 'Golden Delicious', 'Jonathan' and 'McIntosh' (Noiton & Alspach, 1996), as well as in modern breeding work within which 'Gala' and 'Fuji' appear as frequently used parental cultivars in recent years (de Albuquerque Jr. et al., 2011). Therefore, for development of new apple cultivars with a wider genetic base it is essential that breeders have access to a diverse array of genotypes ? mainly international cultivars, local cultivars, landraces and wild species. Bramel & Volk (2019) reported that local cultivars and landraces encompass genotypes that have historical, cultural, economic and heritage value. Marić et al. (2016a) also pointed that autochthonous genotypes carry useful traits and represent valuable germplasm for future apple breeding programmes as sources of new traits and local adaptation.

Apart from developing new cultivars, the assessment of genetic variability in autochthonous apple material is in the tradition of the Fruit Research Institute, Čačak (FRI). Within the past two decades, the work on collection and evaluation has been intensified by the institutions involved in maintenance of apple genetic resources in the Republic of Serbia (RS), aiming to reveal the richness and diversity in biological properties of the autochthonous genotypes (Mratinić, 2005; Mratinić & Fotirić Akšić, 2011; Marić et al., 2013, 2016a, 2016b; Korićanac et al., 2020). Although remarkable efforts have been made to conserve apple germplasm in the RS to date, it is essential to co-ordinate both genotypic and phenotypic characterisation in order to detect new sources of diversity. The genotypic characterisation of autochthonous apple local cultivars and landraces has been initiated at FRI through the study of genes involved in ethylene biosynthesis and perception, i.e. *ACS1*, *ACO1* and *ETR1* genes (Marić et al., 2005, 2007, 2021a, 2021b).

The FRI work on characterisation of autochthonous apple material has mainly been focused on genotypes that exist in its *ex situ* collection. Aiming to document, preserve and encourage the use of Serbian autochthonous material, it is indispensable to continue with collection and characterisation of the available apple accessions. Therefore, this work was undertaken primarily to study phenological (flowering phenophase and harvest date) and pomological (physical and chemical, including bioactive compounds) characteristics, and resistance to major causal agents of economically important diseases in seventeen *in situ* apple genotypes grown in different regions of central and southwestern Serbia.

Material and Methods

Plant material. Seventeen autochthonous apple genotypes (Tab. 1), corresponding to old cultivars or landraces of unknown origin, were analysed/sampled in individual growers' orchards during 2020/2021 in central and southwestern Serbia, i.e. the regions of Čačak (villages Jezdina and Ostra), Užice (village Trnava), Kraljevo (village Samaila), Lučani (village Negrišori), Gornji Milanovac (town) and Aranđelovac (village Progoreoci). The given name of a particular apple landrace ('J-GM/1', 'J-LuN/1' and 'J-ČaO/1') was based on geographical determinants (city, municipality and village) and number (related to the harvest date of the genotype in the specific region).

Phenological characteristics. The flowering phenophase was assessed according to Wertheim (1996), by monitoring the onset, full and end of flowering (10% fully open flowers, 80% fully open flowers and 90% worn flowers, resp.). The samples of 20 fruits in three replications per apple genotype were harvested randomly when the fruits reached eating conditions (seed maturity and separation of the fruit stalk and branch were also monitored).

Pomological characteristics. Standard methods [using technical scale Adventurer Pro AV812M (Ohaus Corporation, Switzerland) and digital caliper (Kronen, Germany)] were applied for the determination of the main physical characteristics – fruit weight (FW), height (FH) and width (WF). The fruit chemical composition, including bioactive compounds, was determined on the basis of the following parameters: soluble solids content (SSC) – using the portable refractometer (Hanna Instruments, Germany); total and invert sugars content (TS and IS, resp.) – according to the Luff-Schoorl method (Egan et al., 1981), expressed in %;

Tab. 1. Location and harvest date of the assessed autochthonous apple genotypes
Tab. 1. Lokacija i vreme berbe ispitivanih autohtonih genotipova jabuke

Locality *Lokalitet*	Genotype *Genotip*	Coordinates and altitude *Koordinate i nadmorska visina*	Harvest date *Vreme berbe*
Jezdina	'Ilinjača'	43°51'681"N; 20°18'254"E; 396 m	July 07th
Progoreoci	'Kraljica'	44°20'380"N; 20°24'814"E; 184 m	July 23rd
Jezdina	'Vidovača'	43°51'662"N; 20°18'311"E; 386 m	July 28th
Trnava	'Ilinjača'	43°57'476"N; 19°53'987"E; 532 m	August 19th
G. Milanovac	'J-GM/1'	44°01'193"N; 20°24'916"E; 197 m	August 20th
Jezdina	'Prancija'	43°51'649"N; 20°18'090"E; 383 m	August 21st
Progoreoci	'Strekinja'	44°20'412"N; 20°24'090"E; 203 m	August 26th
Samaila	'Lepocvetka'	43°46'010"N; 20°30'044"E; 266 m	September 11th
Negrišori	'J-LuN/1'	43°50'282"N; 20°10'581"E; 333 m	September 13th
Jezdina	'Prancija Slatka'	43°51'090"N; 20°17'992"E; 441 m	September 15th
Trnava	'Džumurka'	43°57'545"N; 19°53'981"E; 539 m	September 15th
Trnava	'Slatka Kadumana'	43°57'514"N; 19°53'993"E; 534 m	September 15th
Jezdina	'Lubenjaja'	43°51'140"N; 20°17'917"E; 446 m	September 17th
Ostra	'J-ČaO/1'	43°55'713"N; 20°29'679"E; 319 m	September 21st
Jezdina	'Senabija'	43°51'018"N; 20°18'154"E; 499 m	October 10th
Jezdina	'Budimka'	43°51'653"N; 20°18'200"E; 397 m	October 15th
Jezdina	'Kolačara'	43°51'640"N; 20°18'175"E; 401 m	October 18th

sucrose content (SUC) – calculated as the difference between the total and invert sugars, multiplied by coefficient of 0.95; total acids content (TA) – expressed in % malic acid (titration with 0.1 N NaOH in the presence of phenolphthalein as indicator); pH value of the fruit juice (pH) – using the CyberScan 510 pH meter (Eutech Instruments Pte Ltd, Singapore); total phenol content (TPC) – by the spectrophotometer (Jenway 6300, United Kingdom) according to the Folin–Ciocalteu method (Singleton & Rossi, 1965), using gallic acid as the standard Šexpressed as gallic acid equivalents per 100 g of fresh weight (mg GAE 100 g^{-1} FW)]; antioxidant activity (AA) using DPPH (2,2-diphenyl-1-picrylhydrazyl) assay reported by (expressed as % inhibition of the DPPH radical); total anthocyanin content (TAC) – by the pH differential method [expressed in mg of cyianidin-3-glucoside per 100 g of fresh weight (mg C3G 100 g^{-1} FW)].

The further sensorial fruit characteristics such as shape (FS), attractiveness (FA), ground colour (GC), over colour (OC), flesh colour (FC) and firmness (FF) were assessed according to the Apple Descriptors of the International Board for Plant Genetic Resources (IBPGR, 1982) and Apple (Fruit Varieties) – Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability (TG/14/9) of International Union for the Protection of New Varieties of Plants (UPOV, 2005).

Susceptibility to causal agents of the economically most important diseases under field conditions. The susceptibility to causal agents of scab [*Venturia inaequalis* (Cooke) Wint.] and fireblight [*Erwinia amylovora* (Burnill)] was determined in accordance with Apple Descriptors (IBPGR, 1982), on the scale from 1 to 9 (where 3 is low, 5 is medium and 7 is high susceptibility): 1 = 0–3%, 2 = 4–6%, 3 = 7–12%, 4 = 13–25%, 5 = 26–50%, 6 = 51–75%, 7 = 76–88%, 8 = 89–99%, 9 = 100% (the 1–9 scale corresponds to the Van der Zwet scale and the portion of the tree blighted).

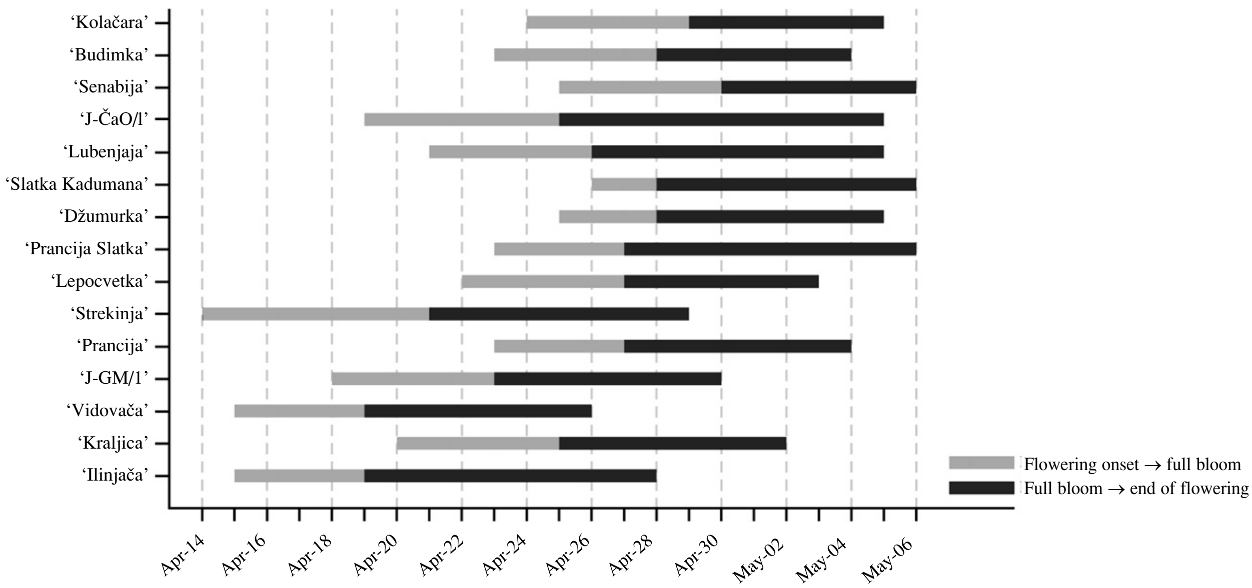
Statistical analysis. The analyses were performed using SPSS statistical software package, Version 8.0 for Windows (SPSS Inc., Chicago, IL). The one-way analysis of variance (ANOVA) was used for establishing the impact of genotype on the fruit physical parameters and bioactive compounds. In the cases when the *F* test was significant, testing of arithmetic means was performed using the test of Least Significant Differences (LSD test) for significance threshold of $P \leq 0.05$.

Results and Discussion

This study reports a phenotypic survey of important biological characteristics (phenological, pomological and susceptibility to major causal agents of important diseases under field conditions) in seventeen apple accessions encompassing local cultivars and landraces that are traditionally grown in the central and southwest Serbia.

Phenological characteristics. Flowering phenophase of the assessed apple genotypes is shown in Figure 1. The earliest onset of flowering was recorded in 'Strekinja' (April 14th) and the latest in 'Slatka Kadumana' (April 26th). Regarding full flowering, it appeared firstly in cultivars 'Ilinjača' (Jezdina) and 'Vidovača' (April 19th) and the latest in 'Senabija' (April 30th). Therefore, approximately 11-day difference in full flowering between the earliest and latest genotypes was noted [genotypes 'Ilinjača' (Trnava) and 'J-LuN/1' were excluded from the calculation, since no flowering occurred during the spring 2021]. Among the assessed local apple cultivars from southern Serbia, Mratinić & Fotirić Akšić (2011) stated a 16-day difference in full flowering. Flowering time as a very important apple characteristic has a great impact on choice of genotypes for growing in particular conditions and using as parents in future breeding programmes. The late flowering apples should be preferred due to their capacity to avoid the risk of crop loss caused by late spring frosts (Blažek et al., 2015), as well as to reduce the risk of fire blight spread (Aldwinkle et al., 1976).

Regarding the harvest date (Tab. 1), the genotypes were divided into groups from early ['Ilinjača' (Jezdina) – July 07th] to very late ('Senabija', 'Budimka' and 'Kolačara' – October 10th, 15th and 18th, resp.). Among the assessed genotypes, most of them are late and very late apples. Apple fruit is climacteric in nature, therefore its ripening is physiologically and biochemically governed by the enzymes whose activity is triggered and coordinated by ethylene. In the latest study, Marić et al. (2021b) reported the results of molecular characterisation of aforementioned seventeen accessions with respect to polymorphism of genes involved in ethylene biochemical pathway (*ACS1* and *ACO1* genes). The same authors pointed that



Flowering onset – full bloom/*početak cvetanja – puno cvetanje*
Full bloom – end of flowerin/*puno cvetanje – kraj cvetanja*

Fig. 1. Flowering phenophase of the assessed autochthonous apple genotypes
Sl. 1. Fenofaza cvetanja ispitivanih autohtonih genotipova jabuke

Tab. 2. Fruit physical characteristics of the assessed autochthonous apple genotypes
Tab. 2. Fizičke osobine ploda ispitivanih autohtonih genotipova jabuke

Genotype *Genotip*	Fruit weight/*Masa ploda* (g)	Fruit height/*Visina ploda* (mm)	Fruit width/*Širina ploda* (mm)
'Ilinjača' (Jezdina)	151.55 ± 8.54 d*	53.10 ± 3.55 g	52.25 ± 4.45 g
'Kraljica'	99.30 ± 3.80 fg	54.35 ± 1.97 g	68.32 ± 4.16 cde
'Vidovača'	29.23 ± 4.28 h	43.81 ± 2.31 h	41.04 ± 2.05 h
'Ilinjača' (Trnava)	262.99 ± 8.28 a	67.95 ± 3.01 ab	87.39 ± 4.36 a
'J-GM/1'	110.25 ± 4.34 ef	66.50 ± 3.53 bc	70.40 ± 1.58 bcd
'Prancija'	83.88 ± 5.63 g	52.82 ± 2.37 g	58.91 ± 1.12 fg
'Strekinja'	125.98 ± 14.27 e	58.43 ± 1.41 f	67.63 ± 2.84 de
'Lepocvetka'	109.43 ± 12.69 ef	60.85 ± 3.31 ef	66.50 ± 3.33 de
'J-LuN/1'	167.78 ± 5.84 d	63.76 ± 1.81 cd	75.02 ± 4.88 bc
'Prancija Slatka'	115.75 ± 5.42 ef	60.96 ± 0.66 ef	66.75 ± 1.51 de
'Džumurka'	159.61 ± 13.53 d	60.44 ± 1.44 ef	74.68 ± 1.99 bc
'Slatka Kadumana'	159.31 ± 15.42 d	65.98 ± 2.66 bcd	76.51 ± 2.83 bc
'Lubenjaja'	219.94 ± 16.18 b	71.63 ± 2.28 a	82.93 ± 2.74 a
'J-ČaO/1'	165.08 ± 1.57 d	62.02 ± 0.50 e	74.28 ± 2.23 bc
'Senabija'	92.32 ± 0.79 g	45.35 ± 0.96 h	62.18 ± 0.48 ef
'Budimka'	165.11 ± 6.55 d	62.26 ± 3.02 de	76.81 ± 0.90 b
'Kolačara'	193.16 ± 5.44 c	61.10 ± 0.49 e	85.64 ± 1.05 a

* The different lower-case letters assigned to columns show significant differences for ≤ 0.05 after applying LSD test / *Različita mala slova u kolonama označavaju značajne razlike na nivou ≤ 0.05 primenom LSD testa*

'J-LuN/1' and 'Kraljica' as heterozygous accessions for the *ACS1* gene (*ACS1-1/2*) may have an important position in future breeding programmes. The allelic constitutions of genes involved in ethylene biosynthesis and perception in autochthonous apple genotypes maintained in FRI *ex situ* collection were reported by Marić et al. (2005, 2007, 2021a). The authors also emphasised that new alleles might be revealed in the autochthonous material, citing that to date the allele *d* of *ETR1* gene (encoding ETR1 receptor) has been identified only in nine Serbian accessions, but not in economically important apple cultivars. Therefore, both *in situ* and *ex situ* autochthonous apple material could be considered as a collection of alleles, where each accession represents a unique combination of alleles.

Pomological characteristics. The studied apple genotypes differed significantly in terms of FW, FH and WF (Tab. 2) The FW varied from 29.23 g ('Vidovača') to 262.99 g ['Ilinjača' (Trnava)], and the genotypes were classified into groups from very small/small to large/very large according to UPOV (2005). The FH and WF were the highest in 'Lubenjaja' (71.63 mm) and 'Ilinjača' (Trnava) (87.39 mm) respectively, whilst the lowest values of both parameters were found in 'Vidovača' (43.81 mm and 41.04 mm, resp.); these characteristics were correlated with FW. The variability in FW, as one of the most important characteristics, was also found in autochthonous apple cultivars grown in southern Serbia (70.0 g to 193.3 g; Mratinić & Fotirić Akšić, 2011), Bosnia and Herzegovina [97.90 g to 276.18 g (Gaši et al., 2011); 90.01 g to 155.26 g (Salkić et al., 2017); 95.4 g to 168.8 g (Kulina et al., 2018)] and Turkey (49.5 g to 152.2 g; Pirlak et al., 2003). The FW of cultivars 'Budimka' and 'Senabija' were consistent with results from Gaši et al. (2011) and Salkić et al. (2017), respectively. In contrast, Mratinić & Fotirić Akšić (2011) reported lower value for 'Budimka' (86.67 g) and Gaši et al. (2011) higher value for 'Senabija' (160.10 g). However, Gaši et al. (2011) and Kulina et al. (2018) reported significantly higher FW for 'Lepocvetka' (208.12 and 158.3 g, resp.) in comparison with our result (109.43 g). Morphometrical characteristics of 'Budimka', 'Kraljica' and 'Strekinja' grown in FRI *ex situ* apple collection were stated by Marić et al. (2016a), whereas Korićanac et al. (2020) reported data for 'Kolačara' in *in situ* condition. Since numerous factors affect the main

Tab. 3. Fruit chemical composition of the assessed autochthonous apple cultivars
Tab. 3. Hemijski sastav ploda ispitivanih autohtonih genotipova jabuke

Genotype *Genotip*	Soluble solids content *Rastvorljive suve materije* (%)	Total sugars *Ukupni šećeri* (%)	Invert sugars *Invertni šećeri* (%)	Sucrose *Saharoza* (%)	Total acids *Ukupne kiseline* (%)	pH value of the fruit juice *pH vrednost soka ploda*
'Ilinjača' (Jezdina)	10.15	5.28	4.62	0.63	1.52	2.94
'Kraljica'	13.60	9.36	5.98	3.21	1.09	3.06
'Vidovača'	15.30	9.48	5.85	3.45	0.23	4.28
'Ilinjača' (Trnava)	10.90	8.16	5.66	2.38	0.70	3.29
'J-GM/1'	11.60	7.92	4.44	3.30	0.67	3.09
'Prancija'	12.70	8.64	6.54	2.00	0.33	4.14
'Strekinja'	11.60	7.32	6.10	1.16	0.91	3.13
'Lepocvetka'	12.95	9.33	5.85	3.31	0.15	4.00
'J-LuN/1'	11.15	8.16	5.10	2.91	0.61	3.16
'Prancija Slatka'	11.25	9.48	7.10	2.26	0.16	4.52
'Džumurka'	13.10	8.88	5.48	3.23	0.82	3.20
'Slatka Kadumana'	12.00	8.88	5.72	3.00	0.17	4.22
'Lubenjaja'	12.95	9.48	7.10	2.26	0.16	4.52
'J-ČaO/1'	9.90	6.48	5.42	1.03	1.42	3.27
'Senabija'	17.05	12.70	9.66	2.09	0.86	3.28
'Budimka'	14.10	9.95	6.10	3.66	0.54	3.54
'Kolačara'	12.00	8.16	5.35	2.67	0.64	3.38

physical characteristics, distinctions in the published results could be the consequence of different environmental conditions and applied cultural practices (*in situ* and *ex situ*).

The results of fruit chemical composition in the assessed autochthonous apple genotypes are shown in Table 3. The highest SSC, TS and IS were found in 'Senabija' (17.05%, 12.70% and 9.66%, resp.), whereas SUC was the highest in 'Budimka' (3.66%). The lowest SSC was defined in landrace 'J-ČaO/1' (9.90%), whilst the cultivar 'Ilinjača' (Jezdina) was characterised by the lowest content of TS (5.28%) and SUC (0.63%), as well as the highest content of TA (1.52%), accompanied by the lowest pH value of the fruit juice (2.94%). Slightly higher values for SSC in some autochthonous apple genotypes collected in southern (>16%, except for the cultivar 'Hadži Sinana' – 12.55%) and western (>15%) Serbia were reported by Mratinić & Fotirić Akšić (2011) and Korićanac et al. (2020), respectively. Kulina et al. (2018) also stated the higher value of SSC for 'Lepocvetka' (16.15%) in comparison with result obtained in our study for this cultivar (12.95%). Moreover, for the autochthonous genotypes grown in FRI *ex situ* apple collection, Marić et al. (2016a) found that 'Kraljica' and 'Strekinja' had higher SSC, whereas in 'Budimka' SSC was lower. Based on the fact that the balance between sugars and acids influences the eating quality and consumers' decision-making, genotypes 'Vidovača', 'Prancija', 'Lepocvetka', 'Prancija Slatka', 'Slatka Kadumana' and 'Lubenjaja' might be recommended for fresh consumption, while the other genotypes that have TS/TA lower than 20 are suitable for industrial and domestic processing.

According to Lattanzio (2003), phenolic compounds encompass natural secondary metabolites that determine colour, appearance, flavour and health-promoting properties of fruits. Apple as one of the most popular fruit species is available all year round, and can be considered as a major functional food resource that have beneficial effects on human health. Therefore, the assessment of TPC, AA and TAC in insufficiently documented Serbian autochthonous apple genotypes is very important in order to recognise them as a valuable source of health-promoting compounds. In our study, TPC, AA and TAC varied greatly among the studied autochthonous genotypes and the obtained results are shown in Table 4. The values for TPC ranged from 117.00 ('Prancija') to 337.50 ('Strekinja') mg GAE 100 g^{-1} FW. The cultivar 'Vidovača' was characterised by the highest AA (89.84%), whilst the lowest value of this parameter was observed in 'Džu-

Tab. 4. Content of bioactive compounds in the fruit of the assessed autochthonous apple cultivars
Tab. 4. Sadržaj bioaktivnih komponenti u plodu ispitivanih autohtonih genotipova jabuke

Genotype *Genotip*	Total phenol content *Ukupni fenoli* (mg GAE 100 g^{-1} FW)	Antioxidant activity *Antoksidativna aktivnost* (%)	Total anthocyanin content *Ukupni antocijani* (mg C3G 100 g^{-1} FW)
'Ilinjača' (Jezdina)	313.00 ± 9.00 ab*	86.92 ± 2.62 ab	0.63 ± 0.63 fg
'Kraljica'	297.00 ± 11.5 bc	80.42 ± 4.41 bc	2.09 ± 0.62 cde
'Vidovača'	253.50 ± 6.00 d	89.84 ± 0.89 a	5.43 ± 0.10 b
'Ilinjača' (Trnava)	155.50 ± 11.5 gh	63.71 ± 6.80 de	1.25 ± 0.83 defg
'J-GM/1'	151.50 ± 10.5 gh	55.92 ± 6.07 ef	2.71 ± 1.04 c
'Prancija'	117.00 ± 8.00 h	52.26 ± 4.40 ef	2.09 ± 1.25 cde
'Strekinja'	337.50 ± 8.5 a	89.25 ± 0.90 a	0.83 ± 0.83 efg
'Lepocvetka'	156.00 ± 8.25 gh	62.54 ± 4.43 de	0.83 ± 0.12 efg
'J-LuN/1'	206.00 ± 3.00 e	78.04 ± 4.52 bc	2.50 ± 1.25 cd
'Prancija Slatka'	148.50 ± 12.5 gh	64.88 ± 5.53 d	0.21 ± 0.32 g
'Džumurka'	132.00 ± 2.00 hi	48.68 ± 0.54 f	2.92 ± 1.25 c
'Slatka Kadumana'	136.50 ± 5.50 hi	63.40 ± 0.62 de	1.04 ± 0.21 efg
'Lubenjaja'	172.00 ± 10.00 fg	76.23 ± 12.57 c	0.42 ± 0.14 g
'J-ČaO/1'	288.00 ± 13.50 cd	86.68 ± 0.54 abc	11.27 ± 0.42 a
'Senabija'	193.00 ± 13.20 ef	68.37 ± 5.83 d	1.67 ± 1.68 cdef
'Budimka'	197.50 ± 12.5 ef	76.95 ± 6.54 c	0.63 ± 0.21 fg
'Kolačara'	202.00 ± 12.00 e	78.12 ± 6.77 bc	0.63 ± 0.13 fg

* The different lower-case letters assigned to columns show significant differences for ≤ 0.05 after applying LSD test/*Različita mala slova u kolonama označavaju značajne razlike na nivou ≤ 0.05 primenom LSD testa*

murka' (48.68%). The highest TAC was found in landrace 'J-ČaO/1' (11.27 mg C3G 100 g^{-1} FW), which was expected because of its red flesh as a distinguishing feature. The lowest value for TAC was identified in 'Prancija Slatka' (0.21 mg C3G 100 g^{-1} FW). In comparison with the result of TPC obtained for 'Kolačara' in our study, Korićanac et al. (2020) reported lower value of this parameter. Interestingly, the same authors also pointed out that autochthonous cultivars had significantly higher TPC compared to commercial ones. Similar results were stated by Djapo et al. (2016), who examined TPC in five autochthonous and two commercial cultivars. Additionally, Panzella et al. (2013) reported that traditional apple cultivars from Southern Italy could be considered as a rich source of phenols with superior antioxidant activity, since exhibited from two- to seven-fold higher phenol content, as well as from one and half- to four-fold hydrogen donor activity than widely consumed cultivars.

Sensorial characteristics. The quality of apple fruit is a complex phenomenon, conditioned by the appearance and the flavour (taste and aroma). Barrett et al. (2010) reported that consumers firstly evaluate the visual appearance and colour, followed by the taste, aroma and texture. Therefore, the fruit attractiveness defines the first consumers' opinion, but the flavour ensures their preference and a repeat purchase. The results of fruit sensorial characteristics in the assessed autochthonous apple genotypes are shown in Table 5. Based on fruit shape, the genotypes were divided into seven groups, from globose, flat, conical to ovate. Namely, the predominant fruit shapes in this study were flat (eight genotypes) and globose (three genotypes). The evaluated genotypes were mostly classified as intermediate (11 genotypes) in terms of fruit attractiveness. Good attractiveness was observed in 'Lepocvetka', 'J-ČaO/1', 'Senabija' and 'Budimka'. The predominant ground colour was whitish green (10 genotypes), whereas yellow green and green were observed in one and six genotypes, respectively. Orange (three genotypes), light red (one genotype), red (nine genotypes) and dark red (three genotypes) were determined over colours with stripes and flushed patterns; no over colour was observed in 'Džumurka'. Most of the assessed genotypes were non-russeting, viz. fine russet was observed on the fruit surface of 'Džumurka'. White flesh colour was predominant (13 genotypes), whilst on the basis of this characteristic

Tab. 5. Fruit sensorial characteristics of the assessed autochthonous apple genotypes
Tab. 5. Senzoričke karakteristike ploda ispitivanih autohtonih genotipova jabuke

Genotype *Genotip*	Fruit shape *Oblik ploda*	Fruit attractiveness *Atraktivnost ploda*	Ground colour *Osnovna boja pokožice*	Over colour *Dopunska boja pokožice*	Flesh colour *Boja mezokarpa*	Flesh firmness *Čvrstina mezokarpa*
'Ilinjača' (Jezdina)	globose-conical *okruglasto-koničan*	very poor *veoma loša*	whitish green *svetlozelena*	red *crvena*	white *bela*	soft mek
'Kraljica'	flat *spljošten*	intermediate *srednja*	whitish green/ *svetlozelena*	red *crvena*	yellowish *bledožuta*	medium *srednje čvrst*
'Vidovača'	conical *koničan*	intermediate *srednja*	green *zelena*	dark red *tamnocrvena*	white *bela*	soft *mek*
'Ilinjača' (Trnava)	flat *spljošten*	intermediate *srednja*	whitish green *svetlozelena*	orange *narandžasta*	white *bela*	medium *srednje čvrst*
'J-GM/1'	globose *okruglast*	intermediate *srednja*	whitish green *svetlozelena*	orange *narandžasta*	yellowish *bledožuta*	soft *mek*
'Prancija'	globose *okruglast*	intermediate *srednja*	whitish green *svetlozelena*	red *crvena*	white *bela*	firm *čvrst*
'Strekinja'	flat *spljošten*	intermediate *srednja*	green *zelena*	light red *svetlocrvena*	white *bela*	firm *čvrst*
'Lepocvetka'	long-conical *kupast*	good *dobra*	whitish green *svetlozelena*	red *crvena*	white *bela*	firm *čvrst*
'J-LuN/1'	flat *spljošten*	intermediate *srednja*	whitish green *svetlozelena*	orange *narandžasta*	white *bela*	firm *čvrst*
'Prancija Slatka'	flat *spljošten*	intermediate *srednja*	whitish green *svetlozelena*	red *crvena*	white *bela*	firm *čvrst*
'Džumurka'	flat *spljošten*	poor *loša*	green *zelena*	no over colour *bez dopunske boje*	white *bela*	firm *čvrst*
'Slatka Kadumana'	flat *spljošten*	intermediate *srednja*	green *zelena*	red *crvena*	yellowish *bledožuta*	firm *čvrst*
'Lubenjaja'	flat *spljošten*	intermediate *srednja*	green *zelena*	red *crvena*	white *bela*	firm *čvrst*
'J-ČaO/1'	ovate *duguljast*	good *dobra*	whitish green *svetlozelena*	dark red *tamnocrvena*	crvena *reddish*	firm *čvrst*
'Senabija'	short-globose- *conical/okruglasto-spljošten*	good *dobra*	green *zelena*	red *crvena*	white *bela*	firm *čvrst*
'Budimka'	ovate *duguljast*	good/ *dobra*	yellow green *žuto-zelena*	red *crvena*	white *bela*	firm *čvrst*
'Kolačara'	globose *okruglast*	intermediate *srednja*	whitish green *svetlozelena*	dark red *tamnocrvena*	white *bela*	medium *srednje čvrst*

the landrace 'J-ČaO/1' belongs to the red-fleshed apples. As for flesh firmness, the genotypes were classified into three groups: soft (three genotypes), medium (three genotypes) and firm (11 genotypes).

Susceptibility to causal agents of the economically most important diseases under field conditions. All of the assessed autochthonous old apple cultivars and landraces showed resistance to fireblight (rated 1 on the scale) and a relatively narrow range of susceptibility to scab under field conditions (Fig. 2). With regard to scab susceptibility, the genotypes can be classified into three groups, from 0–3% (1 on the scale) to 26–50% (5 on the scale). Fifteen genotypes showed resistance and low susceptibility to scab (ranging from 1 to 3 on the scale) under field conditions, whereas ‘Kraljica’, ‘Strekinja’, ‘Džumurka’, ‘J-ČaO/1’ and ‘Senabija’ displayed the best performance in terms of resistance to *Venturia inaequalis* (Cooke) Wint. Medium scab susceptibility was observed in two genotypes (ranging 5 on the scale), i.e. ‘J-GM/1’ and ‘Kolačara’. Field resistance to fireblight of autochthonous apple genotypes from FRI *ex situ* collection was reported by Marić et al. (2016a, 2016b). Our result for scab susceptibility of ‘Budimka’ was in agreement with those reported by Marić et al. (2016a), where the same authors stated medium scab susceptibility for ‘Kraljica’ and ‘Strekinja’ in *ex situ* condition.

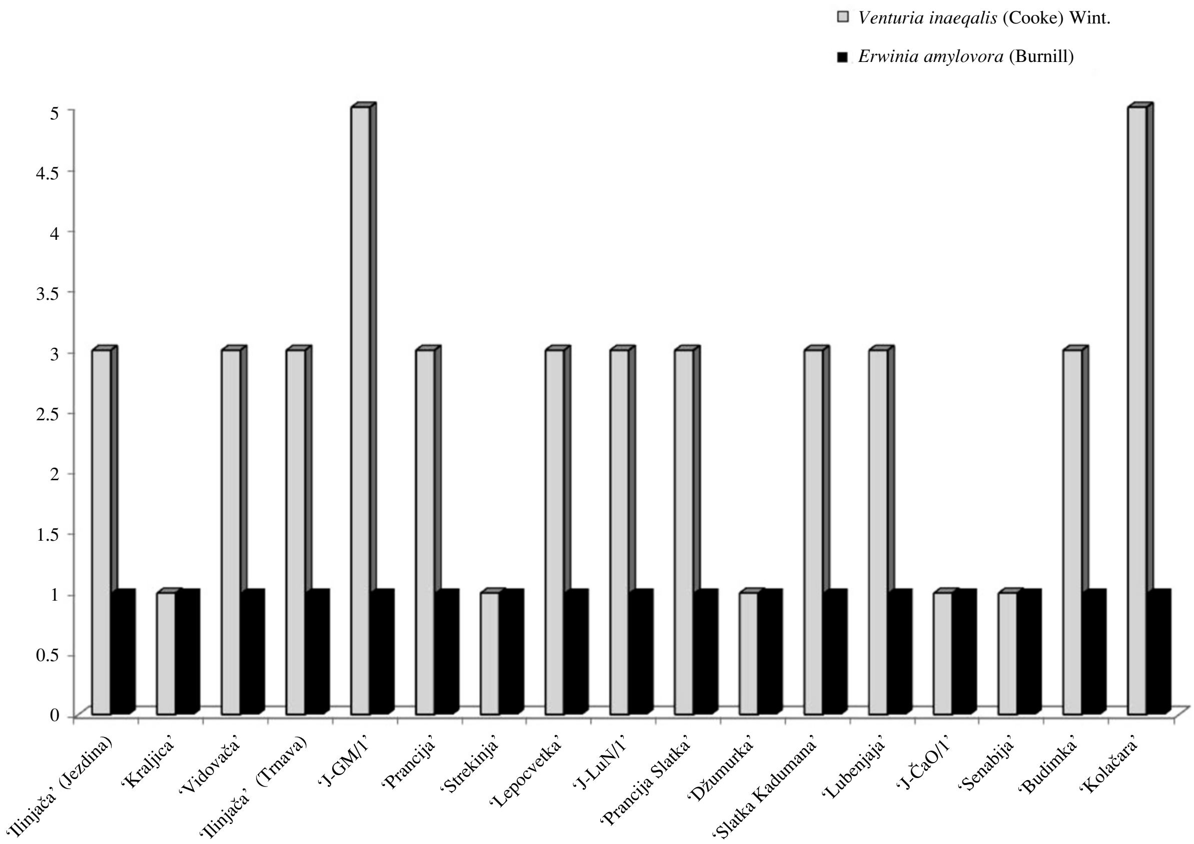


Fig. 2. Susceptibility of the assessed autochthonous apple genotypes to scab and fireblight under field conditions
Sl. 2. *Otpornost ispitivanih autohtonih genotipova jabuke na prouzrokovače čađave pegavosti lista i krastavosti plodova, kao i bakteriozne plamenjače u poljskim uslovima*

Conclusion

This study has revealed richness and diversity of the biological characteristics in the Serbian autochthonous apple material. Further studies should aim to continue research in the field of collection, genotypic and phenotypic characterisation, and utilization of these accessions for different purposes. Changing climatic conditions, new pest and disease pressures, and the fruit production with fewer chemical inputs to meet consumer demand will result in the need for well adapted local apple genotypes with higher levels of resistance to abiotic and biotic stresses. Meeting these challenges will depend on the genetic diversity of apple germplasm which will be available for the long-term use.

Acknowledgements

This research was funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contract number: 451-03-68/2022-14/200215).

References

Aldwinkle H.S., Way R.D., Livermore K.G., Preczewski J.L., Beer S.V. (1976): Fire blight in the Geneva apple collection. Fruit Varieties Journal, 30: 42–55.

Barrett D.M., Beaulieu J.C., Shewfelt R. (2010): Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: Desirable levels, instrumental and sensory measurement, and the effects of processing. Critical Reviews in Food Science and Nutrition, 50: 369–389.

Blažek J., Paprštein F., Køelinová J. (2015): Heritability of flowering time within apple progeny. Czech Journal of Genetics and Plant Breeding, 51(1): 23–28.

Bramel P.J., Volk G. (2019): A global strategy for the conservation and use of apple genetic resources. Global Crop Diversity Trust, Bonn.

de Albuquerque C.L., Denardi F., de Mesquita Dantas A.C., Nodari R.O. (2011): The self-incompatible RNase S-alleles of Brazilian apple cultivars. Euphytica, 181: 277–284.

Djapo M., Omanović-Mikličanin E., Velagić-Habul E., Gaši F., Grahić J. (2016): Phenolic composition of different fruit tissues of five autochthonous apple cultivars in Bosnia and Herzegovina. Works of the Faculty of Agriculture and Food Sciences, University of Sarajevo, 61(66/1): 118–122.

Egan H., Kirk R., Sawyer R. (1981): The Luff Schoorl method. Sugars and preserves. In: 'Pearson's Chemical Analysis of Foods', Churchill Livingstone, Edinburgh, pp. 152–153.

FAOSTAT (2022): Available online: https://www.fao.org/-faostat/en/#data/QCL.

Gaši F., Šimon S., Pojskić N., Kurtović M., Pejić I. (2011): Analysis of morphological variability in Bosnia and Herzegovina's autochthonous apple germplasm. Journal of Food Agriculture and Environment, 9: 444–448.

IBPGR (1982): Descriptor list for apple (*Malus*). ECSC, EEC, EAEC, Brussels and Luxembourg, and International Board of Plant Genetic Resources, Rome.

Korićanac A., Lukić M., Rilak B., Popović B., Mitrović O., Marić S. (2020): Evaluation of fruit quality of two autochthonous apple cultivars suitable for widespread production. Proceedings of Young Researches Conference 'YOURS 2020', Belgrade (Republic of Serbia), pp. 81–86.

Kulina M., Radović M., Životić B., Životić G. (2018): Fizičko-hemijske karakteristike ploda značajnijih autohtonih sorti jabuke sa područja Majevice. Zbornik radova XXIII savetovanja o biotehnologiji sa međunarodnim učešćem, Čačak (Republika Srbija), pp. 146–153.

Lattanzio V. (2003): Bioactive polyphenols: Their role in quality and storability of fruit and vegetables. Journal of Applied Botany, 77: 128–146.

Marić S., Bošković R., Tešović Ž., Lukić M. (2005): Genetical polymorphism of ACC synthase and ACC oxidase in autochthonous apple cultivars. Journal of Pomology, 39(150): 139–148.

Marić S., Bošković R., Lukić M. (2007): The polymorphism of *ETR1* gene in autochthonous apple cultivars. Genetika, 39(3): 387–394.

Marić S., Lukić M., Radičević S., Milošević N. (2013): Properties of some indigenous apple genotypes grown in region of Serbia. Acta Horticulturae, 981: 53–58.

Marić S., Lukić M., Radičević S., Đorđević M. (2016a): Biological properties of some autochthonous apple genotypes from the *ex situ* collection of Fruit Research Institute Čačak. Acta Horticulturae, 1139(1): 123–130.

Marić S., Lukić M., Radičević S., Mitrović O., Đorđević M. (2016b): Phenological and pomological traits of some indigenous apple genotypes from the *ex-situ* collection of Fruit Research Institute, Čačak (Republic of Serbia). Book of Proceedings of VII International Scientific Agriculture Symposium 'Agrosym 2016', Jahorina (Republic of Srpska, Bosnia and Herzegovina), pp. 255–260.

Marić S., Radičević S., Lukić M., Đorđević M., Glišić I. (2021a): Identification of *ACS1*, *ACO1* and *ETR1* alleles in some indigenous apple genotypes. Acta Horticulturae, 1308: 19–26.

Marić S., Glišić I., Milošević N., Radičević S., Đorđević M., Vujović T. (2021b): Characterisation of indigenous apple accessions with respect to polymorphism of *ACS1* and *ACO1* genes. Acta Agriculturae Serbica, 26(52): 151–157.

Mratinić E. (2005): Autohtone sorte jabuke u Srbiji i Crnoj Gori. Draganić, Beograd.

Mratinić E., Fotirić Akšić M. (2011): Evaluation of phenotypic diversity of apple (*Malus* sp.) germplasm through the principle component analysis. Genetika, 43(2): 331–340.

Noiton D.A.M., Alspach P.A. (1996): Founding clones, inbreeding, coancestry, and status number of modern apple cultivars, 121(5): 773–782.

Panzella L., Petriccione M., Rego P., Scortichini M., Napolitano A. (2013): A reappraisal of traditional apple cultivars from Southern Italy as a rich source of phenols with superior antioxidant activity. Food Chemistry, 140(4): 672–679.

Peace C.P., Bianco L., Troggio M., van de Weg E., Howard N.P., Cornille A., Durel C.E., Myles S., Migicovsky Z., Schaffer R.J., Costes E., Fazio G., Yamane H., van Nocker S., Gottschalk C., Costa F., Chagné D., Zhang X., Patocchi A., Gardiner S.E., Hardner C., Kumar S., Laurens F., Bucher E., Main D., Jung S., Vanderzande S. (2019): Apple whole genome sequences: recent advances and new prospects. Horticulture Research, 6: 59.

Pirlak L., Güleryüz M., Aslantas R., Esitken A. (2003): Promising native summer apple (*Malus domestica*) cultivars from north-eastern Anatolia, Turkey. New Zealand Journal of Crop and Horticultural Science, 31: 311–314.

Salkić B., Jovović Z., Salkić E., Salkić A. (2017): Pomological characteristics of the most represented autochthonous apple cultivars from the area of northeast Bosnia. Technologica Acta, 10(2): 29–33.

Sánchez-Moreno C., Larrauri J.A., Saura-Calixto F. (1998): A procedure to measure the antiradical efficiency of polyphenols. Journal of the Science of Food and Agriculture, 76(2): 270–276.

Singleton V.L., Rossi J.A. (1965): Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture, 16(3): 144–158.

UPOV (2005): Guidelines for the conduct of tests for distinctness, uniformity and stability. Apple (Fruit Varieties) UPOV Code: MALUS_DOM (*Malus domestica* Borkh.). Technical Guideline TG/14/9, Geneva.

Way R.D., Aldwinckle H.S., Lamb R.C., Rejman A., Sansavini S., Shen T., Watkins R., Westwood M.N., Yoshida Y. (1991): Apples (*Malus*). Acta Horticulturae, 290: 3–46.

Wertheim S.J. (1996): Methods for cross pollination and flowering assessment and their interpretation. Acta Horticulturae, 423: 237–241.

CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

634.1/.8

VOĆARSTVO : naučni časopis = Journal of Pomology : scientific journal / editor in chief Ivana Glišić. - Vol. 39, no. 149 (2005)- . - Čačak : Scientific Pomological Society of Serbia, 2005- (Čačak : Štamparija Svetlost). - 26 cm

Tromesečno. - Stvarni naslov od br. 201 (2018) Journal of Pomology.
Tekst na srp. i engl. jeziku. -
Je nastavak: Jugoslovensko voćarstvo = ISSN 0350-2155
ISSN 1820-5054 = Voćarstvo
COBISS.SR-ID 120509708