Phenotypic diversity of autochthonous European (*Prunus domestica* L.) and Damson (*Prunus insititia* L.) plum accessions based on multivariate analysis

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Abstract

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Forty-three European (*Prunus domestica* L.) and twelve Damson (*P. insititia* L.) plum accessions originating from different and important growing regions in former Yugoslavia were studied to assess the overall degree of polymorphism, detect similarities among accessions and assess important agronomic, fruit quality and sensorial traits. Twenty variables were scored and subjected to multivariate analysis. Results showed a considerable phenotypic diversity among plum germplasm. A high correlation was found among some evaluated variables. Principal component analysis (PCA) revealed that traits related to fruit weight, yield and soluble solids content accounted for a large proportion of the observed variability. Accessions Bela Požegača, Crvena Ranka Bardaklija, Mudara, Požegača, Car Dušan, Julka, Turgonja and Crna Petrovka cvs are recommended for fresh consumption, while Požegača, Korajka, Bosanka and Bilska Rana cvs are recommended for drying. Most of accessions can be used for processing, particularly into plum brandy, whereas some can be used as rootstocks.

Keywords: correlation; fruit quality; germplasm; segregation, yield

In former Yugoslavia, the plum tree was the most spread species, because of the good climate conditions, the fruit value (energetic, nourishing, dietetic etc.) and was further considered a traditional species (Mratinic 2000). In this area, plums have high economic, social and supply importance. The numerous positive traits of these cultivars should make it interesting for plantation in other countries of the Balkan Peninsula. Autochthonous or local (primitive, folk) plum cultivars (accessions) grown in Serbia, Bosnia and Herzegovina, Macedonia and Montenegro belong to *P. domestica* L. and *P. insititia* L. and concentrate between latitude 41°03' and 44°40'N, although some isolated accessions exist and grow in other areas of the former Yugoslavia such as Croatia and Slovenia (Milošević et al. 2010). Plum accessions are numerous and well-adapted to agro-ecological conditions. The first selection from a diverse gene pool was conducted by local growers in order to obtain certain desirable traits. Despite its importance, little is known about plum phenotypic diversity. Data available are limited to an earlier work by Paunovic and Paunovic (1994) suggesting the existence of 92 autochthonous cultivars and noting a high variability in the main morphological, pomological and technological traits. The heterogeneity of the cultivated population can create problems in their usage, so efforts have been made to identify accessions with desirable properties.

Phenotypic variation of plums in former Yugoslavia was traditionally assessed using morphological characterization (Jovancevic 1977; Paunovic, Paunovic 1994; Mratinic 2000). Due to the plum species and/or cultivars, as well as the various types of propagation (both by suckers and by seeds) employed, plum populations are highly heterogeneous (Ercisli 2004) and show environmentally dependent morpho-anatomical traits. All above factors create a necessity for a detailed description and evaluation of plum accessions belonging to *P. domestica* and *P. insititia* originating in former Yugoslavia. Because of characterization highly influenced by environmental factors or developmental stage of plants, multivariate analysis must be used to determine phenotypic diversity (Hend et al. 2009).

The objective of this study is to describe the variability in 55 plum accessions from the collection, determine the correlation among the traits used to describe the collection and identify the most useful variables to discriminate among accessions.

MATERIAL AND METHODS

Plant material and measurements

The analysis involved forty-three autochthonous plum cultivars or accessions belonging to *P. domestica* L. and twelve accessions originating from *P. insititia* L. They involved *in situ* identification, marking and observation of accessions in Serbia, Bosnia and Herzegovina, Macedonia and Montenegro (Table 1). After gathering autochthonous plum cultivars from different regions of the above countries, a collection of 55 accessions was formed. The collection orchard was planted in 1998 at Prislonica near Cacak (Western Serbia). All accessions grafted on Myrobalan seedlings used as a material in this study during three consecutive years (2007 to 2009) were planted at distance 5 × 3 m and trained as open vase, under non-irrigated cultural practices. The study was based on 20 traits, describing agronomic (3), fruit quality (12) and sensorial (5) traits of plum accessions (Table 2). These are reported as part of IBPGR (1984) standard descriptors for the plum. Parameters related to the fruit were measured, calculated and visually estimated at harvest stage (full maturity). The samples of 50 fruits per tree were harvested randomly. All measurements were performed using digital caliper, precision weighing balance and digital measuring tape (Table 2).

Statistical analysis

Data of agronomic, fruit quality and sensorial traits were subjected to analysis of means; upper and lower decision limits were plotted and used to show differences between the mean value for each accessions and the grand mean. SYSTAT procedures (Systat Software Inc., Richmond, USA) were used to perform correlations (Pearson correlation coefficients at $P \leq 0.05$) among average values of agronomic, fruit quality and sensorial traits. Principal component analysis (PCA) was performed to investigate the relationship between agronomic, fruit quality and sensorial attributes and any possible accession groupings based on similar properties by using an XLSTAT procedure of computer statistical package (XLSTAT 7.5, Addinsoft, USA).

RESULTS AND DISCUSSION

Evaluation of agronomic, fruit quality and sensorial traits

Mean values of agronomic, fruit quality and sensorial traits studied are reported in Table 3. Data show very large variability among accessions for all traits. Flowering date (FD) of evaluated accessions showed a high range (37 days), while the differences for harvest date (HD) were higher (76 days). Thus, the differences for the FD and HD observed among the accessions were somehow expected. Harvest date ranged from mid July to the end of September, depending on cultivars (García-Mariño et al. 2008), and a genetically programmed process (de Dios et al. 2006), and considered as a quantitative trait in *Prunus* species (Vargas, Romero 2001; Dirlewanger et al. 2004). Also, both traits depend on environmental conditions (temperature, altitude etc.) and may change every year (Liverani et al. 2010). Due to the interaction between environment and genotype, it is very important to evaluate preliminarily the FD and HD performance of all accessions in the areas in which they will be cultivated (Koskela et al. 2010).

Plum accessions with different fruit weight (FW) and stone weight (SW), fruit dimensions and sphe-

Table 1. Name, code and origin (location) of autochthonous plum accessions

Accession (local name)	Accessions code	Location			
		city – village	latitude	longitude	altitude (m)
Arapka	ARP	Cacak – Ridjage	43°53'N	20°10'E	340
Bela požegača	BPZ	Cacak – Pakovraće	43°52'N	20°19'E	380
Belošljiva	BEL	Cacak – Miokovci	43°55'N	20°23'E	340
Cerovački piskavac[1]	CPI	Cacak – Trnava	43°53'N	20°20'E	480
Crnošljiva	CRN	Cacak – Ridjage	43°53'N	20°10'E	320
Crvena ranka*	CRB	Cacak – Trnava	43°53'N	20°20'E	480
Crvena ranka**	CRD	Cacak – Trnava	43°53'N	20°20'E	480
Čokešinka	COK	Cacak – Banjica	43°51'N	20°18'E	350
Kapavac	KAP	Cacak – Lipnica	43°51'N	20°17'E	360
Marićevka	MAR	Cacak – Gornja Gorevnica	43°56'N	20°24'E	400
Metlaš	MET	Cacak – Trnava	43°53'N	20°20'E	480
Mudara	MUD	Cacak – Banjica	43°51'N	20°18'E	450
Obični piskavac	OPI	Cacak – Trnava	43°53'N	20°20'E	480
Petrovača	PET	Cacak – Viljuša	43°52'N	20°19'E	320
Požegača	POZ	Cacak – Prislonica	43°56'N	20°27'E	400
Trnovača[1]	TRN	Cacak – Viljuša	43°52'N	20°19'E	295
Turgulja[1]	TUR	Cacak – Ridjage	43°53'N	20°10'E	560
Moravka[1]	MOR	Petrovac – Kladurovo	44°12'N	21°47'E	340
Crnica[1]	CRI	Petrovac – Kladurovo	44°12'N	21°47'E	340
Plaovača	PLA	Osečina	44°22'N	19°30'E	345
Volujevača[1]	VOL	Osečina – Lopatanj	44°21'N	19°36'E	370
Gorka bula	GBU	Osečina	44°24'N	19°30'E	345
Bjelica	BJL	Plav – Vojno Selo	42°59'N	19°94'E	930
Bjelošljiva	BJS	Bijelo Polje – Loznica	43°02'N	19°45'E	620
Car Dušan	CDU	Bijelo Polje – Lješnica	42°55'N	19°55'E	620
Durgulja[1]	DUR	Pljevlja – Mrzovići	43°19'N	19°22'E	800
Mednica	MED	Bijelo Polje – Krokočevo	43°06'N	19°72'E	670
Mudovalj[1]	MUV	Plav – Dobra Voda	42°59'N	19°94'E	920
Piskavica[1]	PIS	Berane – Dolac	42°50'N	19°51'E	730
Šarica	SAR	Plav – Vojno Selo	42°59'N	19°94'E	910
Trnošljiva[1]	TRS	Bijelo Polje – Bistrica	43°19'N	19°22'E	700
Turgonja[1]	TUR	Podgorica – Golubovci	42°23'N	19°25'E	10
Dronga[1]	DRO	Plav – Vojno Selo	42°59'N	19°94'E	920
Magareška crna šljiva	MCS	Skopje – Ljubanci	42°01'N	21°29'E	510
Beluvra	BEV	Prilep – Vitolište	41°11'N	21°50'E	790
Trnošljiva-M[1]	TRA	Bitolj – Trnovo	41°03'N	21°15'E	990
Magareška	MAG	Prilep – Topolčani	41°14'N	21°26'E	600
Crna petrovka	CPT	Ohrid – Leskoec	41°09'N	20°51'E	730
Panadjurka	PAN	Struga – Priskupština	41°20'N	20°37'E	690
Zimna	ZIM	Debar – Gorenci	41°30'N	20°34'E	700

Table 1 to be continued

Accession (local name)	Accessions code	Location			
		city – village	latitude	longitude	altitude (m)
Modra šljiva	MSI	Makedonski Brod – Drenovo	41°28'N	21°15'E	900
Gurgutka	GUR	Makedonski Brod – Drenovo	41°28'N	21°15'E	870
Banska šljiva	BAS	Berovo	41°43'N	22°52'E	870
Korajka	KOR	Lopare – Koraj	44°40'N	18°15'E	110
Bosanka	BOS	Lopare – Koraj	44°40'N	18°15'E	110
Bilska rana	BIR	Sarajevo	43°50'N	18°20'E	565
Julka	JUL	Lopare – Koraj	44°40'N	18°15'E	110
Dobojska rana	DRA	Sarajevo	43°50'N	18°20'E	565
Banjalučka bjelica	BAB	Sarajevo	43°50'N	18°20'E	565
Sitnica	SIT	Sarajevo	43°50'N	18°20'E	565
Slatkulja	SLA	Sarajevo	43°50'N	18°20'E	565
Miškovačka rana	MIR	Sarajevo	43°50'N	18°20'E	565
Kaurka	KAU	Sarajevo	43°50'N	18°20'E	565
Ružica	RUZ	Sarajevo	43°50'N	18°20'E	565
Podsedlinka	POD	Lopare – Čelić	44°40'N	18°15'E	100

[1]accessions belong to *Prunus insititia* L.; *Crvena ranka var. Bardaklija; **Crvena ranka var. Derosavka

ricity, main sensorial traits and chemical composition are presented in Table 3. The highest FW and fruit dimensions were observed in 'CPT' and the lowest in 'TRA'. According to Mratinic (2000), fruit weight of autochthonous plum cultivars in a broader region of South-Western Serbia and Šumadija fell within a range of 6.20–28.00 g with 50% of the cultivars having fruit weight of 15.0 g. The accessions in our study were classified as being extremely small in terms of fruit size, whereas the fruits of 'MUD' and 'CPT' were the only ones classified as being very small and small, respectively (IBPGR 1984). In general, accessions belonging to *P. domestica* had a larger fruit when compared with accession belonging to *P. insititia* (Mratinic 2000; Milošević et al. 2010; Milošević, Milošević 2011). Moreover, properties of the stones of *Prunus* taxa are the most stable ones (Woldring 2000), and their dimensions are very useful for the identification of *P. domestica*, *P. insititia* and *P. spinosa* (Behre 1978). Global shape of plum fruit (sphericity) was characterized by calculating fruit height/suture diameter (H/SD) and fruit height/cheek diameter (H/CD) ratio, respectively (Wert et al. 2007). Most of accessions showed ratios very close to 1.0, which means that some fruits were almost rounded to ovate. In plums, round shapes without protruding tips are preferred by consumers (Crisosto et al. 2007). For most of the accessions, skin was not cracked.

Yield per tree varied from 8.9 ('BAS') to 132.9 kg ('MCS') and showed very big differences among accessions, which is in agreement with a previous study of local plum cultivars (Paunovic, Paunovic 1994; Mratinic 2000). The observed variability supports the quantitative genetic control of yield previously reported in *Rosaceae* fruit crops (Dirlewanger et al. 2004).

Regarding soluble solids content (SS) and titratable acidity (TA), high variability was observed because both are cultivar-dependent traits (Table 3). An important phenotypic diversity regarding these traits was reported previously by other authors (Jovancevic 1977; Mratinic 2000). In the present study, SS ranged from 10.3°Brix in 'TRA' to 19.5°Brix in 'POZ', whereas TA varied between 0.6% ('POZ', 'KOR', 'BOS') and 2.1% ('BEL'). Generally, accessions belonging to *P. domestica* had the higher values of SS than accessions from *P. insititia*, while accessions from *P. insititia* had higher TA values when compared with accessions belong to *P. domestica*, as previously reported (García-Mariño et al. 2008). In our study, 47 accessions or 85.45% showed SS and TA values higher than 12°Brix and 1%, respectively. The SS content is a very important quality attribute, influencing nota-

Table 2. Agronomic, fruit quality and sensorial traits of plum accessions

Evaluated variables	Unit	Abbreviations
A. Agronomic values		
1. Flowering date was the date when 90% flowers were open	date	FD
2. Harvest date was the date when fruits have full maturity stage	date	HD
3. Yield was determined for each tree accession by ACS System Electronic Scale (Zhejiang, China)	kg/tree	Y
B. Fruit quality traits		
4. Fruit weight were measured by scale Tehnica ET-1111 (Iskra, Slovenia)	g	FW
5. Stone weight were measure by scale Tehnica ET-1111 (Iskra, Slovenia)	g	SW
6. Fruit height were measured by caliper Starrett 727 (Athol, USA)	cm	H
7. Suture diameter were measured by caliper Starrett 727 (Athol, USA)	cm	SD
8. Cheek diameter were measured by caliper Starrett 727 (Athol, USA)	cm	CD
9. H/SD was estimated as fruit height/suture diameter ratio	ratio	H/SD
10. H/CD was estimated as fruit height/cheek diameter ratio	ratio	H/CD
11. Suture deformation index was estimated as SD/CD ratio	ratio	SDI
12. Fruit size: 1=extremely small, 2=very small, 3=small, 4=small/medium, 5=medium, 6=medium/large, 7=large, 8=very large, 9=extremely large		FS
13. Soluble solids content was determined by hand refractometer Milwaukee MR 200 (ATC, USA)	°Brix	SS
14. Titratable acidity was measured by neutralization to pH 7.0 with 0.1N NaOH	%	TA
15. Ripening index was estimated as soluble solids/titratable acidity ratio	ratio	RI
C. Sensorial values		
16. Skin ground colour: 1=green, 2=light green, 3=light yellow, 4=yellow, 5=deep yellow		SG
17. Over skin colour: 0=white yellow, 1=pink, 2=red, 3=red violet, 4=violet, 5=dark violet, 6=blue, 7=mahagony, 8=dark blue, 9=black		OC
18. Skin cracking susceptibility: 0=no cracking, 1=extremely low, 3=low, 5=medium, 7=high, 9=extremely high		SC
19. Flesh colour: 1=green, 2=light green, 3=yellow-green, 4=light yellow, 5=yellow, 6=amber, 7=light orange, 8=orange, 9=red		FC
20. Eating quality was determined by a panel of five experts and ranking from 1=extremely poor, 3=poor, 5=fair, 7=good to 9=excellent		EQ

bly the sweet taste (Crisosto et al. 2007), while TA was the best predictor of acid taste and overall flavour. The SS/TA ratio or ripening index (RI) has an important role in consumer acceptance of some plum cultivars (Crisosto et al. 2007; Vangdal et al. 2007). In our study, RI ranged from 5.4 ('TRA') to 32.5 ('POZ') (Table 3). Considering the findings of Robertson et al. (1992) who reported that RI in European plums of high quality should be between 12 and 24 units, it can be concluded that only 9 accessions are within the limits of this study.

There was larger variability among accessions concerning the skin ground color (SG), over skin color (OC), flesh color (FC) and eating quality (EQ) (Table 3). The SG in most of the accessions was light green (26); the OC was dark blue in most accessions (13). Thirty two accessions had a yellow green FC. Regarding EQ, sixteen accessions had a poor, thirteen had a fair and good, seven had an excellent, three had extremely poor, two had a fair/good, and only one had an extremely poor/poor. An important phenotypic diversity regarding plum sensorial traits was reported previously by Milošević et al. (2010).

Examined germplasm of autochthonous plum cultivars consists of accessions that can be recommended for fresh consumption, processing or rootstocks production. Based on the fruit size (FS), chemical and sensorial properties, 'BPZ', 'CRB', 'MUD', 'POZ', 'CDU', 'JUL', 'TUR' and 'CPT' are recommended for fresh consumption, while 'POZ', 'KOR', 'BOS' and 'BIR' are recommended for drying. Almost all the fruits can be processed, particularly into plum brandy, while some accessions can

Table 3. Mean values of 20 agronomic, fruit quality and sensorial traits in 55 autochthonous plum accessions during 2007–2009

Accession	FD	HD	FW	H	SD	CD	H/SD	H/CD	SDI	FS	SW	Y	SC	SS	TA	RI	SG	OC	FC	EQ
ARP	08.04	17.08	16.3	36.6	24.2	24.1	1.51	1.52	1.00	1	0.67	54.3	0	12.9	1.6	8.1	2	7	3	3
BPZ	13.04	11.09	22.6	41.0	30.3	28.8	1.35	1.42	1.05	1	0.56	39.7	0	18.1	0.7	30.2	3	0	3	9
BEL	01.04	05.08	14.0	20.0	25.0	26.0	0.80	0.77	0.96	1	0.93	98.3	0	15.8	2.1	7.5	3	0	3	3
CPI	07.04	14.08	19.7	37.2	29.7	27.3	1.25	1.36	1.09	1	0.38	107.4	0	13.7	1.3	10.5	3	5	2	3
CRN	02.04	08.08	13.8	32.4	24.2	24.2	1.34	1.34	1.00	1	0.56	73.1	0	11.1	1.6	6.9	2	7	3	3
CRB	02.04	04.08	22.8	41.4	30.4	30.0	1.36	1.38	1.01	1	0.76	77.4	0	14.5	1.1	13.2	3	3	3	5
CRD	01.04	04.08	17.5	34.2	27.3	26.9	1.25	1.27	1.01	1	0.56	64.3	0	15.5	1.3	11.9	3	3	3	5
COK	01.04	13.08	19.7	37.1	28.9	28.4	1.28	1.31	1.02	1	0.74	49.8	0	13.4	1.3	10.3	3	7	3	5
KAP	06.04	29.07	11.1	29.8	24.8	23.6	1.20	1.26	1.05	1	0.43	126.4	0	11.5	1.7	6.8	2	8	3	5
MAR	06.04	10.08	15.8	32.7	27.3	27.1	1.20	1.21	1.01	1	0.83	46.3	3	12.1	1.3	9.3	2	6	3	5
MET	04.04	11.08	17.4	32.5	28.5	25.3	1.14	1.28	1.13	1	0.66	69.1	0	13.3	1.3	10.2	3	3	3	3
MUD	05.04	06.08	36.6	40.3	49.7	39.0	0.81	1.03	1.27	2	1.95	34.3	5	10.9	1.7	6.4	3	3	2	3
OPI	07.04	20.08	14.4	32.6	26.3	25.6	1.24	1.27	1.03	1	0.62	54.3	0	12.9	1.4	9.2	2	6	3	3
PET	30.03	12.07	12.1	26.0	23.0	25.1	1.13	1.03	0.92	1	1.12	89.9	5	12.9	1.0	12.9	2	5	3	3
POZ	13.04	06.09	23.4	43.0	32.0	30.2	1.34	1.42	1.06	1	0.67	66.6	0	19.5	0.6	32.5	2	7	3	9
TRN	28.03	26.09	6.8	21.3	21.0	21.4	1.01	0.99	0.98	1	0.14	67.9	0	12.2	1.3	9.4	1	7	2	1
TRG	06.04	21.08	20.9	35.0	28.0	29.0	1.25	1.21	0.96	1	1.56	34.9	3	10.4	1.8	5.8	2	9	3	3
MOR	03.04	24.08	11.5	39.3	22.8	22.1	1.72	1.78	1.03	1	0.53	80.1	0	12.3	1.6	7.7	2	5	7	7
CRI	31.03	13.08	6.2	26.1	21.3	17.9	1.22	1.46	1.19	1	0.31	76.9	0	11.2	1.6	7.0	3	4	5	6
PLA	27.03	11.08	27.6	40.0	34.4	34.7	1.16	1.15	0.99	1	1.25	56.8	0	13.4	1.3	10.3	2	6	5	7
VOL	26.03	13.08	8.5	26.3	24.0	24.9	1.09	1.06	0.96	1	0.66	50.1	0	14.9	1.2	12.4	3	5	4	3
GBU	25.03	15.09	8.2	30.8	21.6	21.5	1.42	1.43	1.00	1	0.58	112.2	3	11.8	1.7	6.9	1	0	4	1
BJL	04.04	14.08	14.1	30.8	26.7	26.9	1.15	1.14	0.99	1	0.95	32.6	0	13.9	1.3	10.7	2	1	3	7
BJS	20.03	17.08	13.0	31.5	27.4	24.8	1.15	1.27	1.10	1	0.91	69.7	0	13.6	1.4	9.7	2	0	3	7
CDU	05.04	12.09	19.8	37.6	29.3	30.4	1.28	1.24	0.96	1	1.04	57.1	0	16.9	1.0	16.9	2	6	2	9
DUR	03.04	18.09	14.2	34.6	26.0	26.1	1.33	1.32	1.00	1	0.89	49.3	5	14.0	1.4	10.3	5	5	3	9
MED	26.04	25.08	14.1	31.6	26.4	26.8	1.20	1.18	0.98	1	0.70	44.5	0	12.3	1.3	9.5	3	3	2	5
MUV	23.04	14.07	22.8	36.4	33.1	33.3	1.10	1.09	0.99	1	1.33	36.9	5	11.4	1.8	6.3	2	3	2	5
PIS	08.04	21.07	10.2	32.1	24.0	23.0	1.34	1.39	1.04	1	0.55	61.8	0	12.9	1.1	11.7	2	8	1	2
SAR	20.04	24.08	14.9	33.8	27.5	26.6	1.23	1.27	1.03	1	0.95	35.8	0	15.4	1.6	9.6	3	3	3	3

Table 3 to be continued

Accession	FD	HD	FW	H	SD	CD	H/SD	H/CD	SDI	FS	SW	Y	SC	SS	TA	RI	SG	OC	FC	EQ
TRS	03.04	10.09	7.30	21.9	22.7	23.0	0.96	0.95	0.99	1	0.78	57.1	0	12.1	1.2	10.1	2	3	4	3
TUR	29.03	11.08	29.1	39.8	34.5	34.8	1.15	1.14	0.99	1	1.33	50.1	0	11.9	1.6	7.4	2	0	3	5
DRO	20.04	28.08	22.8	37.1	32.0	32.0	1.16	1.16	1.00	1	1.01	39.8	0	13.4	1.4	9.5	2	8	4	7
MCS	05.04	23.08	8.9	30.9	22.0	20.1	1.40	1.54	1.09	1	0.62	132.9	0	13.6	1.5	0.1	2	5	6	5
BEV	15.04	25.08	16.4	35.0	25.7	27.2	1.36	1.29	0.94	1	0.97	24.1	3	13.3	1.7	7.8	3	6	4	5
TRA	11.04	04.09	3.5	16.9	16.8	16.8	1.00	1.00	1.00	1	0.39	8.9	0	10.3	1.9	5.4	2	8	3	1
MAG	08.04	14.08	33.6	39.8	34.5	37.5	1.15	1.06	0.92	1	1.47	69.4	0	12.9	1.8	7.2	4	6	6	3
CPT	06.04	17.07	45.2	45.6	38.7	38.4	1.18	1.19	1.01	3	1.72	11.9	5	13.4	1.2	11.2	3	9	3	6
PAN	12.04	08.09	8.9	29.8	21.1	21.8	1.41	1.37	0.97	1	0.57	112.8	0	13.9	1.4	9.9	2	6	4	5
ZIM	04.04	14.09	9.8	32.3	21.5	21.8	1.50	1.48	0.99	1	0.59	90.2	5	14.1	1.2	11.7	2	6	3	7
MSI	26.04	07.09	7.3	28.4	19.0	24.1	1.49	1.18	0.79	1	0.52	89.1	0	15.8	1.4	11.3	2	8	5	7
GUR	09.04	17.09	12.4	30.5	24.7	24.7	1.23	1.23	1.00	1	0.85	35.6	5	12.9	1.5	8.6	2	6	3	3
BAS	16.04	20.09	9.3	29.9	22.2	20.3	1.35	1.47	1.09	1	0.69	8.9	0	16.9	1.2	14.1	4	6	4	9
KOR	05.04	02.09	24.0	42.5	26.3	32.0	1.61	1.33	0.82	1	0.85	47.8	1	18.9	0.6	31.5	3	8	5	9
BOS	11.04	07.09	22.5	38.7	28.5	29.8	1.36	1.30	0.96	1	0.78	41.3	3	19.1	0.6	31.8	3	8	5	9
BIR	08.04	05.08	16.3	33.1	28.4	29.7	1.16	1.11	0.96	1	0.69	56.8	3	17.9	0.9	19.9	1	8	3	7
JUL	05.04	15.07	26.3	40.4	32.7	32.3	1.23	1.25	1.01	1	1.14	34.6	5	13.0	1.2	10.8	2	5	3	7
DRA	31.03	05.08	15.9	32.2	28.2	28.9	1.14	1.11	0.97	1	0.82	49.9	3	13.4	1.3	10.3	1	8	3	7
BAB	30.03	19.08	11.3	28.8	24.1	26.2	1.19	1.10	0.92	1	0.73	39.2	0	13.9	1.5	9.3	4	0	5	3
SIT	02.04	25.07	12.4	29.4	26.0	25.4	1.13	1.16	1.02	1	0.78	30.4	0	12.8	1.2	10.7	1	8	3	3
SLA	08.04	17.08	16.3	36.2	26.9	27.5	1.34	1.32	0.98	1	1.16	33.3	5	16.1	1.1	14.6	1	8	3	7
MIR	07.04	22.08	13.2	32.0	25.1	26.6	1.27	1.20	0.94	1	0.85	56.1	5	16.4	1.1	14.9	1	8	3	7
KAU	12.04	16.08	14.0	32.7	26.4	26.8	1.24	1.24	0.98	1	0.72	43.9	3	15.8	0.9	17.5	1	8	3	7
RUZ	02.04	14.08	14.2	31.1	28.1	32.0	1.11	0.97	0.88	1	0.94	22.2	5	14.1	1.3	10.8	3	3	3	5
POD	06.04	22.08	16.5	36.7	27.1	28.9	1.35	1.27	0.94	1	1.11	51.5	5	16.2	1.5	10.8	2	3	3	5

For abbreviations see Table 1 and 2

Table 4. Pearson's correlation matrix among different agronomic, fruit quality and sensorial variables in autochthonous plum accessions

Variable	FD	HD	FW	H	SD	CD	H/SD	H/CD	SDI	FS	SW	Y	SC	SS	TA	RI	SG	OC	FC	EQ
FD	1																			
HD	0.09	1																		
FW	–0.16	–0.19	1																	
H	–0.21	–0.06	0.81*	1																
SD	–0.12	–0.15	0.91*	0.70*	1															
CD	–0.08	–0.19	0.92*	0.73*	0.90*	1														
H/SD	–0.13	0.12	–0.13	0.43*	–0.34*	–0.23	1													
H/CD	–0.17	0.20	–0.10	0.41*	–0.20	–0.32*	0.85*	1												
SDI	–0.10	0.09	0.10	0.07	0.32*	–0.10	–0.24	0.29*	1											
FS	–0.12	–0.03	0.61*	0.33*	0.54*	0.45*	–0.21	–0.11	0.24	1										
SW	–0.07	–0.04	0.75*	0.48*	0.76*	0.79*	–0.31*	–0.34*	–0.01	0.52*	1									
Y	0.01	–0.04	–0.31*	–0.17	–0.31*	–0.36*	0.22	0.26	0.07	–0.25	–0.41*	1								
SA	–0.14	–0.15	0.26	0.28*	0.19	0.34*	0.16	–0.06	–0.31*	0.22	0.39*	–0.25	1							
SS	–0.12	–0.27*	0.10	0.29*	0.01	0.16	0.31*	0.14	–0.30*	–0.12	–0.10	–0.07	0.20	1						
TA	0.06	0.23	–0.13	–0.34*	–0.06	–0.15	–0.29*	–0.20	0.15	0.02	0.16	0.14	–0.25	–0.71*	1					
RI	–0.06	–0.36*	0.21	0.38*	0.11	0.23	0.28*	0.14	–0.22	–0.06	–0.10	–0.18	0.29*	0.83*	–0.86*	1				
SG	–0.09	–0.08	0.24	0.17	0.18	0.17	–0.01	0.02	0.10	0.14	0.13	–0.16	–0.05	0.10	0.09	0.04	1			
OC	–0.17	0.10	0.04	0.09	–0.10	–0.01	0.24	0.12	–0.21	0.12	–0.05	–0.13	0.21	0.08	–0.24	0.16	–0.30*	1		
FC	0.12	–0.01	–0.07	0.05	–0.22	–0.11	0.39*	0.28*	–0.20	–0.12	–0.08	0.21	–0.05	0.10	0.07	0.00	0.19	0.01	1	
EQ	–0.06	–0.14	0.23	0.48*	0.16	0.24	0.41*	0.33*	–0.11	–0.01	0.08	–0.15	0.26	0.65*	–0.58*	0.61	0.10	0.14	0.21	1

For abbreviations see Table 2; The asterisk indicates significant correlation at the 0.05 probability level

Table 5. Eigenvalues and proportion of total variability, eigenvectors of the first three principal components (PC), and component scores for 55 plum accessions

Variable	Eigen vectors			Accession	Component scores		
	PC1	PC2	PC3		PC1	PC2	PC3
Flower date	–0.077	–0.143	–0.379	ARP	–1.225	0.017	0.126
Harvest date	–0.206	–0.031	–0.233	BPZ	4.011	–0.253	1.659
Yield (kg/tree)	–0.130	–0.403	0.159	BEL	–1.470	–0.210	0.942
Fruit weight (g)	0.159	0.575	–0.042	CPI	–0.860	–0.805	2.288
Stone weight (g)	0.014	0.624	–0.231	CRN	–1.537	–0.395	0.822
SDI	–0.164	0.140	0.560	CRB	0.834	0.211	1.491
Soluble solids (°Brix)	0.473	–0.130	0.024	CRD	0.614	–0.319	1.508
Titratable acidity (%)	–0.466	0.101	–0.160	COK	0.072	0.476	0.688
Ripening index	0.502	–0.066	0.110	KAP	–2.265	–1.653	0.512
Over skin colour	0.137	–0.015	–0.215	MAR	–0.326	0.421	0.506
Flesh colour	0.035	–0.210	–0.557	MET	–0.872	0.070	2.059
Eating quality	0.412	0.010	–0.114	MUD	–1.852	5.106	2.277
				OPI	–1.092	–0.228	0.532
				PET	–0.176	–0.677	–0.712
				POZ	4.881	–0.488	1.463
				TRN	–1.901	–2.108	0.133
				TRG	–1.924	2.416	–1.293
				MOR	–1.100	–1.563	–1.487
				CRI	–2.035	–1.921	0.242
				PLA	0.512	1.082	–1.874
				VOL	–0.030	–1.309	–0.778
				GBU	–2.912	–1.884	0.038
				BJL	0.249	0.604	0.501
				BJS	–0.746	–0.073	0.846
				CDU	2.527	0.601	0.639
				DUR	0.453	0.290	0.136
				MED	–1.029	–0.144	–0.177
				MUV	–1.624	2.108	–0.439
				PIS	–0.787	–0.528	1.734
				SAR	–1.076	0.393	–0.271
				TRS	–0.764	–0.666	0.519
				TUR	–1.159	2.025	–0.671
				DRO	–0.123	0.806	–1.725
				MCS	–2.078	–2.121	–0.289
				BEV	–0.971	0.593	–1.820
				TRA	–2.436	–0.501	0.234
				MAG	–0.963	1.890	–2.462
				CPT	1.172	4.528	–0.881
				PAN	–0.367	–1.955	0.106

Table 5 to be continued

Variable	Eigen vectors			Accession	Component scores		
	PC1	PC2	PC3		PC1	PC2	PC3
				ZIM	0.402	–1.288	0.760
				MSI	1.037	–2.685	–2.578
				GUR	–1.087	0.282	0.017
				BAS	1.472	–0.350	–0.237
				KOR	5.602	–0.495	–1.226
				BOS	5.162	–0.508	–0.560
				BIR	2.996	–0.637	0.553
				JUL	0.579	1.831	0.112
				DRA	0.520	–0.159	–0.822
				BAB	–1.162	–0.955	–1.872
				SIT	–0.612	0.217	0.214
				SLA	1.633	0.772	–0.363
				MIR	1.486	–0.452	–0.425
				KAU	1.966	–0.482	0.027
				RUZ	0.349	0.535	–0.355
				POD	0.031	0.541	–0.368
				Eigenvalue	3.470	2.067	1.244
				Variance (%)	28.915	17.227	10.363
				Cumulative (%)	28.915	46.142	56.504

For accessions code and measured variables see Table 1 and 2

be used for rootstock (Paunovic 1988; Milošević et al. 2010). Moreover, *P. insititia* is mainly used as a rootstock for stone fruit trees, mainly plums and apricots because *P. insititia* belongs to *Prunus* subgenus that shares a common gene pool with other subgenera; it is able to act successfully as a rootstock or can be used for local consumption (fresh or dried) or plum brandy production (Vivero et al. 2001). However, Nenadović-Mratinić et al. (2007) conducted that Crveni piskavac cv. (*P. insititia*) was not suitable as a raw material for the production of high-quality brandies – neither alone, nor in a combination with Crvena ranka cv. (*P. domestica*).

Correlations among evaluated variables

Table 4 shows the correlation matrix between the variables studied. Flower date was not correlated with all variables. On the other hand, HD negatively correlated with SS content and with RI in a way that late harvested accessions generally had lower SS and RI values than the early ones. In our study, late harvested cultivars in more cases belong to *P. insititia*, which had a low SS content and high acidity. For this reason, RI had low values, as was previously found for different local plum cultivars (Nenadović-Mratinić et al. 2007). In addition, there is a close relationship between HD and fruit quality attributes such as SS content and RI values; therefore, valuable information regarding fruit quality is given by these parameters (García-Mariño et al. 2008). Also, it was reported that cultivars from *P. insititia* have a lower capacity to accumulate sugar compared to cultivars from *P. domestica*. This result concurs with the findings of Nenadović-Mratinić et al. (2007).

The FW was positively correlated with fruit height (H) or suture diameter (SD), cheek diameter (CD), FS and SW, therefore, these parameters can be used to predict each other (Okut, Akca 1995). On the other hand, FW negatively correlated with yield (Y) (Table 4). It indicated that higher yield induced lower fruit size, which is in agreement with previous work (Sestraş et al. 2007). Our results

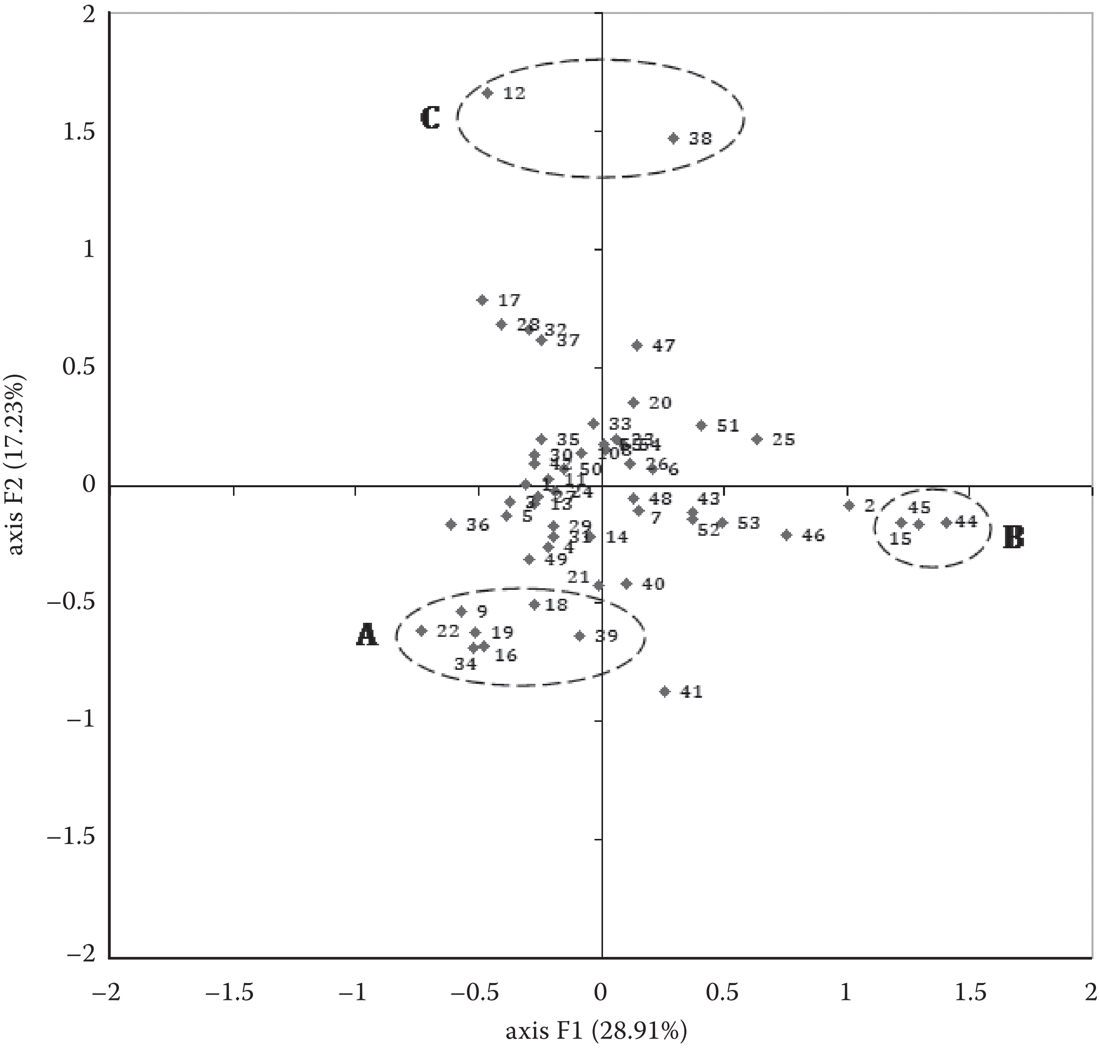

Fig. 1. Graphic representation of 55 plum accessions according to the plan generated by 1–2 axes of principal component analysis (see Table 2 for accessions series numbers). PC1 (28.91%) is plotted on the *x*-axis and PC2 (17.23%) on the *y*-axis with the vectors representing the loadings of evaluated data along with the principal component scores

show a very high correlation between FW and fruit diameter; therefore, both parameters can be used to predict each other. This relationship was also detected in other *Prunus* spp. (Demirsoy, Demirsoy 2004; Ruiz, Egea 2008). The H significantly correlated with other fruit dimensions and their ratios, skin cracking susceptibility (SC), SS, RI and EQ, and negatively correlated with TA, which means that larger plum fruit generally have better chemical and sensorial traits, than smaller fruits (Table 4). The FS positively correlated to SW, as previously described by Hend et al. (2009). Significant positive correlation was observed between SS and RI or EQ, whereas negative correlations between SS and TA were found, and were somewhat expected (Daza et al. 2008). On the one hand, these positions confirm a negative correlation between TA and RI or EQ, and the other positive correlation between RI and EQ. The correlation matrix also revealed a low negative correlation between SG and OC, as previously reported (Daza et al. 2008).

PCA analysis

PCA model was performed to provide an easy visualization of the complete data set in a reduced dimensional plot, it was used previously to establish genetic relationships among cultivars and to study correlations among agronomic and fruit quality traits within plum (Crisosto et al. 2007; Hend et al. 2009).

The results from the PCA in our study showed that more than 80% of the variability observed was explained by the first six components (data not shown). The first three principal components accounted for 28.91, 17.23 and 10.36%, respectively, of the total variations among plum accessions based on the twelve agronomic, fruit quality and sensorial traits (Table 5). Correlation between the original variables and the first three principal components is explained in Table 5: PC1 represents variables related to fruit quality traits (SS, RI, EQ and TA); PC2 explains variables associated with fruit size parameters and yield (FW, SW and Y); while PC3 represents variables related to flowering and harvest date (FD and HD), over skin and flesh colour (OC and FC) and suture deformation index (SDI). Correlations between characteristics revealed by this method may correspond to a genetic linkage between loci of controlling traits or a pleiotropic effect (Iezzoni, Pritts 1991).

Principal component analysis is aimed at identifying properties that differentiate among the accessions, indicating which variables are most related to important agronomic, fruit quality and sensorial traits, accounting for a large proportion of the observed variability. Fig. 1 represents PC1 and PC2 plotted on a bidimensional plane. Component scores for the evaluated accessions are shown in Table 5. Three groups of associated accessions were segregated. Group A is composed of accessions with the lowest negative PC1 and PC2 values. Accessions such as 'KAP', 'TRN', 'MOR', 'CRN', 'GBU', 'MCS' and 'PAN' characterized with the highest yield belong to this group. Group B includes three accessions with the highest positive PC1 values ('POZ', 'KOR' and 'BOS'). This group is distinguished with the best chemical composition and eating quality of fruits. Group C is comprised of accessions with the highest positive PC2 values that correspond to the highest fruit and stone weight ('MUD' and 'CPU').

CONCLUSIONS

The multivariate analysis was found useful for detection of phenotypic differences among the plum accessions studied. The results of the present work may also help breeders in selecting the most diverse accessions with similar agronomic, fruit quality and sensorial characteristics to begin crossing and breeding programs. This may result in increased plum growing for fruit production for fresh consumption, drying, processing and rootstock.

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