

WILD PEAR (*Pyrus pyraster* (L.) Burgsd.) FRUIT AND SEED MORPHOLOGY DEPENDING ON FRUIT SIZE

MORFOLOGIJA PLODA I SJEMENA DIVLJE KRUŠKE (*Pyrus pyraster* (L.) Burgsd.) U OVISNOSTI O VELIČINI PLODA

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SUMMARY

The current study aims to evaluate the effects of fruit size of wild pear (*Pyrus pyraster* (L.) Burgsd.) on morphological fruit and seed traits. Wild pear fruit was collected from 10 trees in the area of Žumberačko gorje in the fall of 2022. The fruit was randomly collected from the ground and divided into three groups according to their weight (small (<10 g), medium (10 – 15 g) and large (>15 g)). Fruit size had a significant effect on the following morphological traits: fruit weight, fruit length, fruit width, the number of filled seeds, the weight of fresh seeds per fruit, the weight of 1 fresh seed and the weight of air-dried seed, while no significant difference was found for fruit shape index, the number of empty seeds, the weight of 1 air dried seed and the share of seed dry matter. For all the aforementioned traits where the difference was significant, large fruit had significantly highest values, while in most cases (with the exception of the weight of 1 fresh seed), medium fruit had significantly higher values than small fruit. Comparing the correlation coefficients between different fruit size groups, it is evident that higher fruit size traits had a significant effect on the number of filled seeds in medium and large wild pear fruit only. In addition, it is visible that fruit weight and width, and not fruit length, had of the largest impact on the number of filled seeds. The principal component analysis revealed 3 significant principal components with eigenvalues greater than 1, which explained 75.88% of the total variability. It was shown that large fruit distinguish themselves from small and partly between medium by F1 axis. F1 was mainly influenced by fruit weight, fruit length, fruit width, the number of filled seeds, the weight of fresh seeds per fruit and the weight of air-dried seed per fruit. Based on the results obtained from this study, it can be concluded that for nursery production of wild pear seedlings bigger fruit should be used due to the higher number of filled seeds.

KEY WORDS: *Pyrus pyraster*, fruit, seed, morphology, multivariate analysis, nursery

INTRODUCTION

UVOD

The genus *Pyrus* belongs to the family Rosaceae, subtribe *Pyrinae*, and contains at least 22 widely recognized primary species, all indigenous to Asia, Europe, and the mountainous area of North America (Bennici et al., 2018). Recently, in the face of global climate changes, more attention has been paid in many European countries to rare woody species that can adapt to dry climatic conditions, and one of

these is the wild pear (Drvodelić et al., 2012). In addition, in many European countries the wild pear is in the focus of interest of landscape designers and foresters, as this species has an aesthetic impact on the landscape, a good growth rate and provides valuable wood (Paganová, 2009).

The wild pear is widespread through the Europe. In north Europe it reaches the Baltic sea in Poland, Lithuania and northern Germany, in west Europe it reaches the Atlantic Ocean in France and occupies the southern parts of the Uni-

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ted Kingdom, in south Europe it occupies most parts of Italy and Greece, but not the islands (with the exception of Sardinia) and Iberian Peninsula, and to the east partly it occupies Latvia, Belarus, Ukraine, Russia and Caucasus mountains and eastern Black sea shore (EUFORGEN, 2023). It is mostly found on the forest edges, in hedges on farmland or in very extreme locations where stronger competitors do not survive (Kleinschmit et al., 1998). In Slovakia, the wild pear is one of the rare woody plants and is often found in the scattered vegetation of the landscape, but also on forest edges, especially in warm oak-tree communities (Paganová, 2009). In Serbia, only a small population of wild pear has remained (Mikić et al., 2009), which indicates its threatened existence. According to EUFORGEN (2023), the wild pear is extremely light-demanding and has low competitive abilities. It has high morphological heterogeneity, which may be due to the effect of balancing selection caused by a self-incompatibility mechanism (Wolko et al., 2015) or due to the hybridization between *P. communis* and native *P. pyraeaster*, e.g. the gene flow from cultivars (Wagner and Büttner, 2019). Moreover, due to its economic insignificance and inconspicuous appearance, in combination with present-day intensive forest and agricultural management systems, a further decrease of this species is expected (Reim et al., 2017).

Wild pear trees grow slowly, but under very favourable habitat conditions they grow up to 20 m tall and reach a diameter of 0.5 m (Drvodelić et al., 2012). The species' tolerance to drought can be attributed to its tap roots (Mikić et al., 2009). It has astringent fruit, with many stone cells that make it difficult to separate the seeds (Cerović et al., 2015). Its fruits are rarely suitable for consumption, and are usually dried or processed into brandy (Šebek, 2019) or marmalade and jam (Drvodelić et al., 2012). However, they are excellent food for wild animals, such as deer, roe deer etc. (Drvodelić et al., 2012). Its seeds may be used for generative propagation. It is known that wild pear seedlings are used as rootstock, and even today they are preferred on calcareous, poor sandy soils, where Fe-chlorosis is a serious problem (Cerović et al., 2015; Šebek 2019, Bennici et al., 2018 according to Continella et al., 2006; Condello et al., 2009; Mišić, 1984). Seedlings can also be used for afforestation since its wood is highly valued on the market, and because it has high ecological importance, being part of natural threatened ecosystems (Camerano et al., 2013; Drvodelić et al., 2012; Kleinschmit et al., 1998). Moreover, it can be used as a very valuable breeding material (Mikić et al., 2009). The seeds of the wild pear are separated from the fleshy aril immediately after the collection in autumn. Sowing takes place in early spring after stratification for three to four months at a temperature of 3–5°C. Due to the extended time of planting in the field, climate changes and minor shocks due to transplanting seedlings, it is best to grow them in multi-containers made of solid plastic.

Due to its heterogeneity, there is great variability in fruit morphology. Therefore, the current study aims to evaluate the effects of fruit size of wild pear (*Pyrus pyraeaster* (L.) Burgsd.) on the morphological and physiological traits of its fruit and seed, as well to determine the variability of the studied traits in agroecological conditions of Žumberačko gorje, Croatia. Moreover, this study presents a continuation of two previous, similar studies (Drvodelić et al., 2018, 2015).

MATERIALS AND METHODS

MATERIJALI I METODE

Initially, this study was designed to last for three consecutive years, from 2021 to 2023, on 10 wild pear trees (*Pyrus pyraeaster* (L.) Burgsd.) in the Žumberačko gorje area (45°50'33.10"N; 15°35'08.65"E). However, due to frost damage and the fact that the wild pear is prone to alternative bearing, the fruit was collected only in the fall of 2022. One hundred and fifty fruits were randomly collected from the ground and divided into three groups according to their weight (small (<10 g), medium (10–15 g) and large (>15 g)). Consequently, the small, medium and large fruit consisted of 24, 37 and 89 fruit per sample, respectively.

All analyses were conducted at the Laboratory of Forest Seed and Nursery Production of the Institute of Ecology and Silviculture of the University of Zagreb, Faculty of Forestry and Wood Technology (Figures 1 and 2). Fruit length and width (mm) were measured with a digital scrolling scale (Sylvac Pro) with an accuracy of 0.01 mm. Fruit width was measured at the widest part of the fruit. For each fruit, two opposite lengths and widths were measured, from which the average values were calculated. Fruit weight (g) was measured using a digital analytical balance (Kern Pls, Kern&Sohn GmbH, Germany) with an accuracy of 0.01 g. Then all fruits were submitted to the manual seed extraction process with small knife. At the same time, the number of filled and empty seeds per each fruit was recorded. The weight of the full fresh seed per fruit (g) was recorded on a RADWAG balance (Model AS 220.3Y, S/N: 565960, Max 220 g, Min 10 mg, d=0.1 mg, Bracka, Poland), while the weight of 1 fresh seed was calculated as the ratio between the weight of the full fresh seed per fruit and the number of full seeds per fruit. Afterwards, all seeds were placed on the sterilised surface at room temperature to reduce their moisture content to 8–14%, which took several days. The weight of full air-dried seeds per fruit was then measured using the aforementioned balance and the weight of 1-air dried seed was calculated as the ratio between the weight of full air-dried seed per fruit and the number of full seeds per fruit. The share of seed dry matter was calculated as a difference in % between fresh and air-dried seed mass.

Data was statistically analysed using XLSTAT add-on for Microsoft Office 2016 by ANOVA and Tukey's HSD test ($P < 0.05$). Pearson's correlation analysis was also performed in the same software. Prior to principal components



Figure 1. Fruit of the wild pear (left) and transverse and longitudinal section through the fruit (right)

Slika 1. Plodovi divlje kruške (lijevo) i poprečni i uzdužni presjek ploda (desno)



Figure 2. Wild pear seeds

Slika 2. Sjeme divlje kruške

analysis (PCA), Kaiser-Meyer-Olkin measure of sampling adequacy was used to examine if it was correct to perform PCA and gave a value of 0.56, which was acceptable (Kaiser, 1974) for continuation to the PCA analysis

RESULTS REZULTATI

According to the ANOVA, fruit size had a significant effect on the following morphological wild pear traits: fruit weight, fruit length, fruit width, the number of filled seeds, the weight of fresh seeds per fruit, the weight of 1 fresh seed and the weight of air-dried seeds per fruit. However, for fruit shape index, the number of empty seeds, the weight of 1 air dried seed and the share of seed dry matter no significant difference was recorded (Table 1). Large fruit had significantly the highest and small fruit significantly the lowest values of fruit weight, fruit length, fruit width, the

Table 1. Morphological and physiological traits of wild pear (*Pyrus pyraster* (L.) Burgsd.) fruit (mean \pm SD)

Tablica 1. Morfološka i fiziološka svojstva ploda divlje kruške (*Pyrus pyraster* (L.) Burgsd.) (srednja vrijednost \pm SD)

Trait Svojstvo	Small fruit Mali plodovi	Medium fruit Srednje veliki plodovi	Large fruit Veliki plodovi	P
Fruit weight (g) / Masa ploda (g)	8.99 \pm 1.14 a	12.26 \pm 1.58 b	18.79 \pm 2.59c	<0.0001
Fruit length (mm) / Duljina ploda (mm)	20.46 \pm 1.52 a	22.70 \pm 1.57 b	26.03 \pm 1.89 c	<0.0001
Fruit width (mm) / Širina ploda (mm)	23.91 \pm 1.68 a	27.32 \pm 1.72 b	31.26 \pm 1.92 c	<0.0001
Fruit shape index / Indeks oblika ploda	0.86 \pm 0.064	0.83 \pm 0.056	0.83 \pm 0.045	0.100
Number of filled seeds (pcs) / Broj punih sjemenki (kom)	1.16 \pm 1.08 a	2.35 \pm 1.30 b	3.51 \pm 1.83 c	<0,0001
Number of empty seeds (pcs) / Broj praznih sjemenki (kom)	1.54 \pm 1.02	1.54 \pm 1.45	1.12 \pm 1.28	0.152
Weight of fresh seeds per fruit (g) / Masa svježeg sjemena po plodu (g)	0.07 \pm 0.04 a	0.14 \pm 0.06 b	0.23 \pm 0.10 c	<0,0001
Weight of 1 fresh seed (g) / Masa jedne svježe sjemenke (g)	0.05 \pm 0.02 a	0.06 \pm 0.02 a	0.07 \pm 0.03 b	0.007
Weight of air-dried seeds per fruit (g) / Masa sjemena sušenog na zraku po plodu (g)	0.05 \pm 0.02a	0.09 \pm 0.04 b	0.15 \pm 0.06 c	<0,0001
Weight of 1 air-dried seed (g) / Masa jedne sjemenke sušene na zraku (g)	0.03 \pm 0.01	0.03 \pm 0.01	0.04 \pm 0.02	0.083
Share of seed dry matter (%) / Udio suhe tvari sjemena (%)	61.31 \pm 21.34	65.15 \pm 6.61	60.21 \pm 13.12	0.284

Note: Values with the same letter are not significant according to Tukey's HSD test at $P < 0.05$ level

Bilješka: vrijednosti obilježene istim slovima nisu značajne prema Tukeyjevom HSD testu pri $P < 0,05$

Table 2. Correlation coefficients for the morphological and physiological traits evaluated on all wild pear (*Pyrus pyraster* (L.) Burgsd.) fruit
Tablica 2. Korelacijski koeficijenti za morfološka i fiziološka svojstva svih plodova divlje kruške (*Pyrus pyraster* (L.) Burgsd.)

Variables Varijable	Fruit weight (g) Masa ploda (g)	Fruit length (mm) Duljina ploda (mm)	Fruit width (mm) Širina ploda (mm)	Fruit shape index Indeks oblika ploda	Number of filled seeds (pcs) Broj punih sjemenki (kom)	Number of empty seeds (pcs) Broj praznih sjemenki (kom)	Weight of fresh seeds per fruit (g) Masa svježeg sjemena po plodu (g)	Weight of 1 fresh seed (g) Masa jedne svježe sjemenke (g)	Weight of air-dried seeds per fruit (g) Masa sjemena sušenog na zraku po plodu (g)	Weight of 1 air-dried seed (g) Masa jedne sjemenke sušene na zraku (g)	Share of seed dry matter (%) Udio suhe tvari sjemena (%)
Fruit weight (g) / Masa ploda (g)	0.87	0.93	-0.15	0.51	-0.17	0.61	0.31	0.62	0.31	-0.20	
Fruit length (mm) / Duljina ploda (mm)		0.87	0.23	0.37	-0.10	0.43	0.26	0.50	0.26	-0.15	
Fruit width (mm) / Širina ploda (mm)			-0.28	0.54	-0.10	0.61	0.25	0.67	0.31	-0.11	
Fruit shape index / Indeks oblika ploda				-0.30	0.02	-0.32	0.04	-0.29	-0.08	-0.10	
Number of filled seeds (pcs) / Broj punih sjemenki (kom)						-0.33	0.83	-0.29	0.83	-0.18	0.05
Number of empty seeds (pcs) / Broj praznih sjemenki (kom)							-0.19	0.21	-0.29	-0.06	-0.24
Weight of fresh seeds per fruit (g) / Masa svježeg sjemena po plodu (g)								0.25	0.98	0.26	-0.12
Weight of 1 fresh seed (g) / Masa jedne svježe sjemenke (g)									0.36	0.93	-0.12
Weight of air-dried seeds per fruit (g) / Masa sjemena sušenog na zraku po plodu (g)										0.35	0.03
Weight of 1 air-dried seed (g) / Masa jedne sjemenke sušene na zraku (g)											0.25
Share of seed dry matter (%) / Udio suhe tvari sjemena (%)											0.25

*All bold values present significant correlations at $P < 0.05$

*Sve podebljane vrijednosti predstavljaju značajnu korelaciju pri $P < 0.05$

number of filled seeds, the weight of fresh seeds per fruit and the weight of air-dried seeds per fruit (Table 1). The weight of 1 fresh seed was significantly higher in large fruit in contrast to that in small and medium fruit, where no significant difference was recorded (Table 1).

In all samples significant and very high positive correlation was recorded between fruit weight and fruit width ($r = 0.93$). Significant and high positive correlations were recorded between fruit weight and fruit length ($r = 0.87$) and between fruit length and fruit width ($r = 0.87$). Significant and moderate positive correlations were recorded between fruit weight and the weight of air-dried seeds per fruit ($r = 0.62$); between the weight of fresh seeds per fruit ($r = 0.61$) or the number of filled seeds ($r = 0.51$); between fruit length and the weight of air-dried seeds per fruit ($r = 0.50$) and between fruit width and the weight of air-dried seeds per fruit ($r = 0.67$), the weight of fresh seeds per fruit ($r = 0.61$) or the number of filled seeds ($r = 0.54$) (Table 2).

In small wild pear fruit significant and high positive correlations were recorded between the weight of fresh seeds per fruit and the weight of air-dried seeds per fruit ($r = 0.88$); between the number of empty seeds and the weight of 1 fresh seed ($r = 0.83$); between fruit weight and fruit width ($r = 0.73$) and between the weight of 1 fresh seed and the weight of 1 air-dried seed ($r = 0.73$). Significant, positive and moderate correlations were recorded between fruit weight and fruit length ($r = 0.52$); between fruit length and

fruit shape index ($r = 0.53$); between the number of filled seeds and the weight of fresh seeds per fruit ($r = 0.66$) and between the weight of air-dried seeds per fruit ($r = 0.66$); between the weight of fresh seeds per fruit and the weight of 1 fresh seed ($r = 0.55$). Significant, negative and high correlation was observed between the number of empty seeds and the share of seed dry matter ($r = -0.79$). Significant, negative and moderate correlations were observed between the number of filled seeds and the number of empty seeds ($r = -0.58$) and significant, negative and low correlation was observed between fruit width and fruit shape index ($r = -0.49$) (Table 3).

In medium wild pear fruit significant and very high positive correlations were recorded between the number of filled seeds and the weight of air-dried seeds per fruit ($r = 0.91$), between the weight of fresh seeds per fruit and the weight of air-dried seeds per fruit ($r = 0.99$) and between the weight of 1 fresh seed and the weight of 1 air-dried seed ($r = 0.90$). Significant and high positive correlations were recorded between the number of filled seeds and the weight of fresh seeds per fruit ($r = 0.80$) and between fruit weight and fruit length ($r = 0.73$). Significant, positive and moderate correlations were recorded between fruit length and fruit width ($r = 0.50$) or fruit shape index ($r = 0.58$); between fruit width and the weight of 1 air-dried seed ($r = 0.57$) and between the weight of 1 air-dried seed and the share of seed dry matter ($r = 0.51$) (Table 4).

Table 3. Correlation coefficients for the morphological and physiological traits evaluated on small wild pear (*Pyrus pyraeaster* (L.) Burgsd.) fruit
Tablica 3. Korelacijski koeficijenti za morfološka i fiziološka svojstva malih plodova divlje kruške (*Pyrus pyraeaster* (L.) Burgsd.)

Variables Varijable	Fruit weight (g) Masa ploda (g)	Fruit length (mm) Duljina ploda (mm)	Fruit width (mm) Širina ploda (mm)	Fruit shape index Indeks oblika ploda	Number of filled seeds (pcs) Broj punih sjemenki (kom)	Number of empty seeds (pcs) Broj praznih sjemenki (kom)	Weight of fresh seeds per fruit (g) Masa svježeg sjemena po plodu (g)	Weight of 1 fresh seed (g) Masa jedne svježe sjemenke (g)	Weight of air-dried seeds per fruit (g) Masa sjemena sušenog na zraku po plodu (g)	Weight of 1 air-dried seed (g) Masa jedne sjemenke sušene na zraku (g)	Share of seed dry matter (%) Udio suhe tvari sjemena (%)	
Fruit weight (g) / Masa ploda (g)		0.52	0.73	-0.22	-0.39	0.23	-0.16	0.09	-0.25	0.55	-0.17	
Fruit length (mm) / Duljina ploda (mm)				0.49	0.53	-0.21	0.23	-0.12	0.04	-0.07	0.33	-0.27
Fruit width (mm) / Širina ploda (mm)					-0.49	-0.11	0.06	-0.21	-0.10	-0.41	0.20	0.05
Fruit shape index / Indeks oblika ploda						-0.08	0.15	0.06	0.12	0.42	0.09	-0.34
Number of filled seeds (pcs) / Broj punih sjemenki (kom)							-0.58	0.66	-0.34	0.66	-0.46	0.33
Number of empty seeds (pcs) / Broj praznih sjemenki (kom)								0.04	0.83	-0.01	0.34	-0.79
Weight of fresh seeds per fruit (g) / Masa svježeg sjemena po plodu (g)									0.55	0.88	0.20	-0.38
Weight of 1 fresh seed (g) / Masa jedne svježe sjemenke (g)										0.41	0.73	-0.54
Weight of air-dried seeds per fruit (g) / Masa sjemena sušenog na zraku po plodu (g)											0.32	-0.23
Weight of 1 air-dried seed (g) / Masa jedne sjemenke sušene na zraku (g)												0.16
Share of seed dry matter (%) / Udio suhe tvari sjemena (%)												

*All bold values present significant correlations at $P < 0.05$

*Sve podebljane vrijednosti predstavljaju značajnu korelaciju pri $P < 0.05$

Table 4. Correlation coefficients for the morphological and physiological traits evaluated on medium wild pear (*Pyrus pyraeaster* (L.) Burgsd.) fruit
Tablica 4. Korelacijski koeficijenti za morfološka i fiziološka svojstva srednje velikih plodova divlje kruške (*Pyrus pyraeaster* (L.) Burgsd.)

Variables Varijable	Fruit weight (g) Masa ploda (g)	Fruit length (mm) Duljina ploda (mm)	Fruit width (mm) Širina ploda (mm)	Fruit shape index Indeks oblika ploda	Number of filled seeds (pcs) Broj punih sjemenki (kom)	Number of empty seeds (pcs) Broj praznih sjemenki (kom)	Weight of fresh seeds per fruit (g) Masa svježeg sjemena po plodu (g)	Weight of 1 fresh seed (g) Masa jedne svježe sjemenke (g)	Weight of air-dried seeds per fruit (g) Masa sjemena sušenog na zraku po plodu (g)	Weight of 1 air-dried seed (g) Masa jedne sjemenke sušene na zraku (g)	Share of seed dry matter (%) Udio suhe tvari sjemena (%)	
Fruit weight (g) / Masa ploda (g)		0.41	0.73	-0.25	0.40	-0.02	0.38	0.15	0.44	0.44	0.00	
Fruit length (mm) / Duljina ploda (mm)				0.50	0.58	0.07	-0.12	0.11	0.19	0.27	0.44	
Fruit width (mm) / Širina ploda (mm)					-0.42	0.43	0.39	0.05	0.57	0.46	0.26	
Fruit shape index / Indeks oblika ploda						-0.30	-0.22	-0.23	0.16	-0.26	-0.06	0.26
Number of filled seeds (pcs) / Broj punih sjemenki (kom)							-0.10	0.80	-0.20	0.91	0.12	0.12
Number of empty seeds (pcs) / Broj praznih sjemenki (kom)								0.19	0.43	-0.20	0.12	0.17
Weight of fresh seeds per fruit (g) / Masa svježeg sjemena po plodu (g)									0.43	0.99	0.43	0.12
Weight of 1 fresh seed (g) / Masa jedne svježe sjemenke (g)										0.42	0.90	0.10
Weight of air-dried seeds per fruit (g) / Masa sjemena sušenog na zraku po plodu (g)											0.47	0.25
Weight of 1 air-dried seed (g) / Masa jedne sjemenke sušene na zraku (g)												0.51
Share of seed dry matter (%) / Udio suhe tvari sjemena (%)												

*All bold values present significant correlations at $P < 0.05$

*Sve podebljane vrijednosti predstavljaju značajnu korelaciju pri $P < 0.05$

Table 5. Correlation coefficients for the morphological and physiological traits evaluated on large wild pear (*Pyrus pyraeaster* (L.) Burgsd.) fruit
Tablica 5. Korelacijski koeficijenti za morfološka i fiziološka svojstva velikih plodova divlje kruške (*Pyrus pyraeaster* (L.) Burgsd.)

Variables Varijable	Fruit weight (g) / Masa ploda (g)	Fruit length (mm) / Duljina ploda (mm)	Fruit width (mm) / Širina ploda (mm)	Fruit shape index Indeks oblika ploda	Number of filled seeds (pcs) Broj punih sjemenki (kom)	Number of empty seeds (pcs) Broj praznih sjemenki (kom)	Weight of fresh seeds per fruit (g) Masa svježeg sjemena po plodu (g)	Weight of 1 fresh seed (g) Masa jedne svježe sjemenke (g)	Weight of air-dried seeds per fruit (g) Masa sjemena sušenog na zraku po plodu (g)	Weight of 1 air-dried seed (g) Masa jedne sjemenke sušene na zraku (g)	Share of seed dry matter (%) Udio suhe tvari sjemena (%)
Fruit weight (g) / Masa ploda (g)	0.69	0.83	-0.02	0.21	-0.11	0.29	0.17	0.23	0.22	-0.30	
Fruit length (mm) / Duljina ploda (mm)		0.69	0.55	0.00	0.06	-0.04	0.07	0.04	0.10	-0.18	
Fruit width (mm) / Širina ploda (mm)			-0.22	0.28	-0.01	0.33	0.09	0.43	0.21	-0.15	
Fruit shape index / Indeks oblika ploda				-0.33	0.08	-0.42	0.01	-0.41	-0.09	-0.07	
Number of filled seeds (pcs) / Broj punih sjemenki (kom)						-0.34	0.80	-0.50	0.74	-0.40	0.09
Number of empty seeds (pcs) / Broj praznih sjemenki (kom)							-0.25	0.17	-0.15	-0.03	-0.31
Weight of fresh seeds per fruit (g) / Masa svježeg sjemena po plodu (g)								0.07	0.98	0.13	-0.06
Weight of 1 fresh seed (g) / Masa jedne svježe sjemenke (g)									0.23	0.93	-0.02
Weight of air-dried seeds per fruit (g) / Masa sjemena sušenog na zraku po plodu (g)										0.25	0.29
Weight of 1 air-dried seed (g) / Masa jedne sjemenke sušene na zraku (g)											0.34
Share of seed dry matter (%) / Udio suhe tvari sjemena (%)											

*All bold values present significant correlations at $P < 0.05$

*Sve podebljane vrijednosti predstavljaju značajnu korelaciju pri $P < 0.05$

For large wild pear fruit significant and very high positive correlations were recorded between the weight of fresh seeds per fruit and the weight of air-dried seeds per fruit ($r = 0.98$) and between the weight of 1 fresh seed and the weight of 1 air dried seed ($r = 0.93$). Significant and high positive correlations were recorded between fruit weight and fruit width ($r = 0.83$); between the number of

filled seeds and the weight of fresh seeds per fruit ($r=0.80$) and between the number of filled seeds and the weight of 1 air-dried seed per fruit ($r = 0.74$). Significant, positive and moderate correlations were recorded between fruit weight and fruit length ($r = 0.69$); between fruit length and fruit width ($r = 0.69$) or fruit shape index ($r=0.55$) (Table 5).

Table 6. PCA factor loadings and squared cosines of the variables for the morphological and physiological traits of wild pear (*Pyrus pyraeaster* (L.) Burgsd.) fruit
Table 6. Faktorska opterećenja i kosinus kvadrata u analizi glavnih komponenti za morfološka i fiziološka svojstva plodova divlje kruške (*Pyrus pyraeaster* (L.) Burgsd.)

Variables Varijable	Factor loadings			Squared cosines of the variables		
	PC1	PC2	PC3	PC1	PC2	PC3
Fruit weight (g) / Masa ploda (g)	0.89	0.05	0.32	0.79	0.00	0.10
Fruit length (mm) / Duljina ploda (mm)	0.77	0.06	0.58	0.60	0.00	0.33
Fruit width (mm) / Širina ploda (mm)	0.90	0.00	0.21	0.82	0.00	0.04
Fruit shape index / Indeks oblika ploda	-0.21	0.11	0.74	0.04	0.01	0.54
Number of filled seeds (pcs) / Broj punih sjemenki (kom)	0.68	-0.66	-0.13	0.46	0.43	0.02
Number of empty seeds (pcs) / Broj praznih sjemenki (kom)	-0.34	0.22	0.21	0.12	0.05	0.05
Weight of fresh seeds per fruit (g) / Masa svježeg sjemena po plodu (g)	0.90	-0.20	-0.23	0.81	0.04	0.05
Weight of 1 fresh seed (g) / Masa jedne svježe sjemenke (g)	0.51	0.82	-0.15	0.26	0.67	0.02
Weight of air-dried seeds per fruit (g) / Masa sjemena sušenog na zraku po plodu (g)	0.89	-0.19	-0.29	0.79	0.03	0.08
Weight of 1 air-dried seed (g) / Masa jedne sjemenke sušene na zraku (g)	0.48	0.84	-0.22	0.23	0.70	0.05
Share of seed dry matter (%) / Udio suhe tvari sjemena (%)	-0.11	0.14	-0.41	0.01	0.02	0.17
Eigenvalue / Svojtvene vrijednost				4.92	1.96	1.46
Variability (%) / Varijabilnost (%)				44.73	17.84	13.31
Cumulative % / Kumulativno (%)				44.73	62.57	75.88

*All bold values present significant correlations at $P < 0.05$

*Sve podebljane vrijednosti predstavljaju značajnu korelaciju pri $P < 0.05$

PCA revealed 3 significant principal components having eigenvalues higher than 1, which explained 75.88% of the total variability. Higher factor loading and squared cosine values of the variables meant that there is a tighter association with the same principal component. Factor 1 (F1) described 44.73% of the total variability and included fruit weight, fruit length, fruit width, the number of filled seeds, the weight of fresh seeds per fruit and the weight of air dried seeds. Factor 2 (F2) described 17.84% of the total variability and included the weight of 1 fresh seed and the weight of 1 air dried seed. Factor 3 (F3) described 13.31% of the total variability and fruit shape index was the only trait associated with this factor (Table 6).

Figure 3 shows that large wild pear fruit differ from small wild pear fruit and partly from medium wild pear fruit by F1 axis. F2 and F3 axes did not produce a clear separation (data not shown for F3 axis).

DISCUSSION RASPRAVA

In the north western part of Bosnia and Herzegovina, Zavišić et al.(2018) reported that the fruit weight of *Pyrus communis* var. *pyraeaster* in 2012 and 2013 was 11.82 and 9.64 g (respectively) for Banja Luka locality, 13.61 and 14.74 g (respectively) for Manjača locality, 11.05 and 11.30 g (respectively) for Potkozarje locality and 11.96 and 13.49 g (respectively) for Kozara locality. In Montenegro, in the area of Polimlje, Šebek (2019) reported that the average three-year *Pyrus pyraeaster* fruit weight of 11 studied genotypes ranged from 7.95 to 27.06 g. In this study (Table 1) variations in fruit weight are in accordance with the available literature data.

Paganova (2009) reported that in Slovakia *Pyrus pyraeaster* subsp. *pyraeaster* and *Pyrus pyraeaster* subsp. *achras* mean fruit

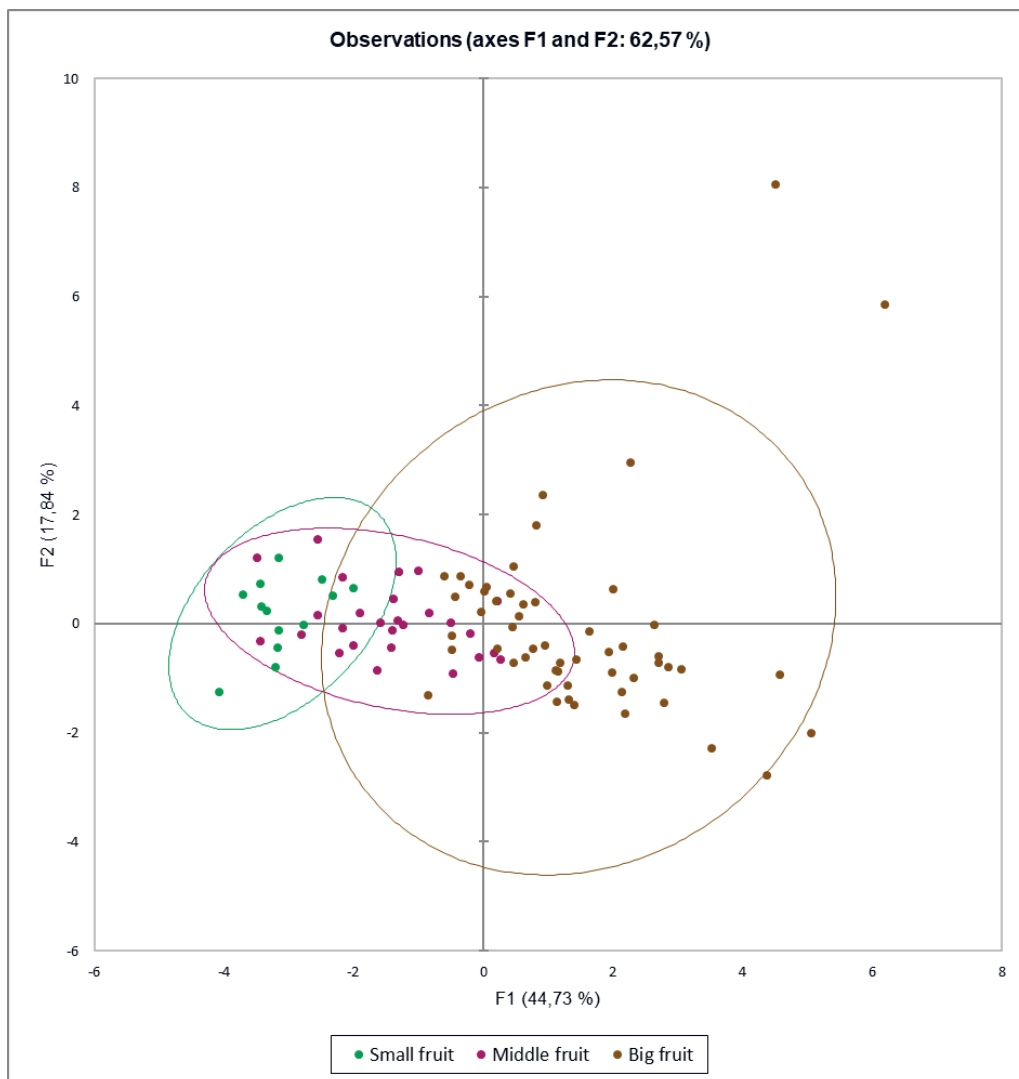


Figure 3. Canonical plot for a principal component analyses in relation to PC1 and PC2 with respect to wild pear fruit size (*Pyrus pyraeaster* (L.) Burgsd.) fruit

Slika 3. Grafički prikaz uzorka u odnosu na PC1 i PC2 s obzirom na veličinu ploda divlje kruške (*Pyrus pyraeaster* (L.) Burgsd.). Legenda: mali plodovi (zeleno boja), srednje veliki plodovi (tamno roza boja), veliki plodovi (smeđa boja)

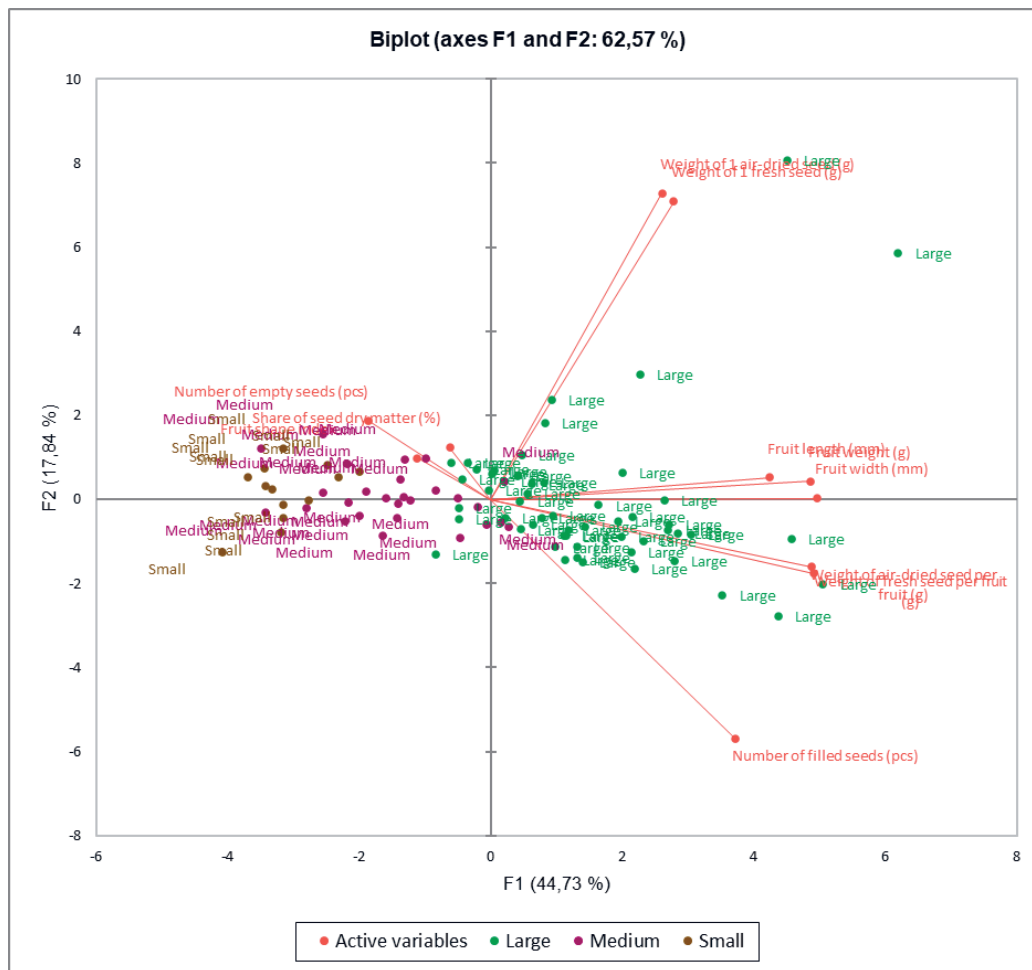


Figure 4. Biplot, in relation to PC1 and PC2, for principal component analyses of the morphological and physiological traits evaluated on large, medium and small wild pear (*Pyrus pyraeaster* (L.) Burgsd.) fruit

Slika 4. Grafički prikaz, u odnosu na PC1 i PC2 analize glavnih komponenti morfoloških i fizioloških svojstava dobivenih na malim, srednje velikim i velikim plodovima divlje kruške (*Pyrus pyraeaster* (L.) Burgsd.).

Legenda: aktivne varijable (crvena boja), mali plodovi (smeđa boja) srednje veliki plodovi (tamno roza boja), veliki plodovi (zelena boja)

length was 24.50 and 28.14 mm (respectively). In the north-western part of Bosnia and Herzegovina, Zavišić et al. (2018) reported that fruit weight of *Pyrus communis* var. *pyraeaster* in 2012 and 2013 was 24.80 and 22.50 mm (respectively) for Banja Luka locality, 25.00 and 25.00 mm (respectively) for Manjača locality, 25.30 and 25.00 mm (respectively) for Potkozarje locality and 24.60 and 25.10 mm (respectively) for Kozara locality. Fruit length per locality ranged from 20.20 to 27.00 mm for Banja Luka locality, 34.70 to 19.00 for Manjača locality, 20.30 to 30.00 for Potkozarje locality, 30.80 to 20.70 for Kozara locality (Zavišić et al., 2018). In Montenegro, in the Polimlje area, Šebek (2019) reported that the average three-year *Pyrus pyraeaster* fruit length of 11 studied genotypes varied from 20.12 to 36.21 mm. In this study (Table 1) variations in fruit length are higher than in aforementioned available literature data, although the average values are in agreement with previously reported data.

Paganova (2009) reported that in Slovakia *Pyrus pyraeaster* subsp. *pyraeaster* and *Pyrus pyraeaster* subsp. *achras* mean fruit

maximum diameter was 26.43 and 25.89 mm (respectively). Zavišić et al. (2018) reported that *Pyrus communis* var. *pyraeaster* fruit maximum diameter in 2012 and 2013 was 27.20 and 25.60 mm (respectively) for Banja Luka locality, 28.50 and 29.40 mm (respectively) for Manjača locality, 26.80 and 28.20 mm (respectively) for Potkozarje locality and 26.80 and 25.10 mm (respectively) for Kozara locality. The maximum fruit diameter per locality was between 24.70 and 29.40 mm for Banja Luka locality, between 32.90 and 23.80 mm for Manjača locality, between 24.70 and 28.30 mm for Potkozarje, and between 35.10 and 19.90 mm for Kozara (Zavišić et al., 2018). In Germany, Wagner and Büttner (2019) reported that the mean fruit width of *Pyrus pyraeaster* was 24.2 mm. In Montenegro, in the area of Polimlje, Šebek (2019) reported that average three-year *Pyrus pyraeaster* fruit width of 11 studied genotypes varied from 12.31 to 30.06 mm. In this study (Table 1), variations in fruit width are in accordance with available literature data. It is also evident that bigger fruit have higher values of fruit width.

In their study, Paganova (2009) reported that in Slovakia *Pyrus pyraeaster* subsp. *pyraeaster* and *Pyrus pyraeaster* subsp. *achras* fruit length to diameter ratio was 0.93 and 1.09 (respectively). In Germany, Wagner and Büttner (2019) reported that the fruit length to width ratio of *Pyrus pyraeaster* was 0.93. Zavišić et al. (2018) reported that *Pyrus communis* var. *pyraeaster* fruit length to diameter ratio in 2012 and 2013 was 0.92 and 0.88 (respectively) for Banja Luka locality, 0.88 and 0.85 (respectively) for Manjača locality, 0.90 and 0.90 (respectively) for Potkozarje locality and 0.93 and 0.90 (respectively) for Kozara locality. Per locality, fruit length to diameter ratio ranged from 0.81 to 1.02 for Banja Luka locality, from 0.75 to 1.13 for Manjača locality, from 0.82 to 1.08 for Potkozarje locality, from 0.84 to 1.18 for Kozara locality (Zavišić et al., 2018). In this study, the average fruit shape index for small, medium and large fruit were 0.86 ± 0.064 , 0.83 ± 0.056 and 0.83 ± 0.045 (respectively), while minimum and maximum fruit shape index of all fruit were 0.74 and 1.02 (data not shown). Such results are a little bit lower than in the available literature. When ratio is greater than 1 it means that the fruit is elongated, pear-shaped (Misimović et al., 2012). In this study (Table 1), almost all fruit had values below 1, indicating their squat shape (Brewer et al., 2006). Since there was no significant difference in fruit shape ratio between different fruit sizes, wild pear fruit does not change shape with size.

In Montenegro, in the area of Polimlje, Šebek (2019) reported that the average three-year mass of 100 dry seeds of 11 studied genotypes of *Pyrus pyraeaster* ranged from 2.66 g to 3.73 g. In this study (Table 1), variations in air-dried seed mass are higher in our study than in the available literature data, although the average values are in agreement with the previously reported data.

When the correlation coefficients of all wild pear fruits were analysed, fruit weight and width showed a significant moderate and fruit length a significant small positive correlation with the number of filled seeds (Table 2). This indicates that wild pear fruit with higher values for the size traits have a higher number of filled seeds. However, when correlation coefficients with regard to fruit size thresholds were examined, in small wild pear fruit no such significant correlations were observed. Meanwhile in medium and large wild pear fruit there was low, but significant and positive correlation between fruit weight or length and the number of filled seeds (Tables 4 and 5). The aforementioned indicates that bigger fruits are associated with more filled seeds. In addition, in all wild pear fruit, fruit width had higher correlation with the number of filled seeds than fruit length (Table 2). This is even more clearly visible in correlations with regard to fruit size groups, where fruit length did not achieve significant correlation with the number of filled seeds in any fruit size group (Tables 3, 4 and 5).

Therefore, it is clear that fruit weight and width have impact on the number of filled seeds. In addition, only small wild pear fruit had significant and high positive correlation between the number of empty seeds and the weight of 1 fresh seed, and negative with the share of seed dry matter. Positive significant correlations in all cases between the number of filled seed and the weight of air-dried seeds per fruit is logical, since a higher number of filled seeds means a higher number of filled seed per fruit and thus a higher seed weight per fruit.

PCA analysis discrimination between large and small, and partly between medium wild pear fruit, by F1 axis, means that traits that mostly influenced F1 (fruit weight, fruit length, fruit width, the number of filled seeds, the weight of fresh seeds per fruit and the weight of air dried seed per fruit) are most important for majority of distinguishing between the aforementioned fruit classes (Figure 3). The correlations between the selected variables and factors are also shown in the biplot (Figure 4). According to the biplot, fruit length, fruit width, fruit weight, the weight of air-dried seeds per fruit and the weight of fresh seeds per fruit are positively correlated. It can be seen that there is a negative relationship between these variables and the number of empty seeds, the total dry matter and the fruit shape index.

CONCLUSIONS ZAKLJUČCI

According to the results obtained from this study, it can be concluded that for nursery production of wild pear seedlings bigger fruit should be used due to their higher number of filled seeds. In addition, when collecting wild pear fruit for seed extraction, more emphasis must be given to fruit weight and width then length, since they have higher effect on the number of full seeds. In future work focus will be put on seed germination rate and seedling quality from different fruit size groups.

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SAŽETAK

Cilj istraživanja je utvrditi utjecaj veličine ploda divlje kruške (*Pyrus pyraeaster* (L.) Burgsd.) na morfološka svojstva ploda i sjemena. Plodovi divlje kruške uzrokovani su nasumično s 10 stabla na području Žumberačkog gorja u jesen 2022. godine. Navedeni plodovi podijeljeni su u tri grupe prema njihovoj masi (mali (< 10 g), srednje veliki (10–15 g) i veliki (> 15 g)). Veličina ploda imala je statistički značajan utjecaj na sljedeća morfološka svojstva: masu ploda, duljinu ploda, širinu ploda, broj punih sjemenki, masu svježeg sjemena po plodu, masu jedne svježije sjemenke i masu sjemenke sušene na zraku po plodu, dok za indeks oblika ploda, broj šturih sjemenki, masu jedne sjemenke sušene na zraku i udio suhe tvari nije zabilježena značajna razlika. Za sva navedena svojstva za koja je zabilježena značajna razlika, veliki plodovi imali su značajno najviše vrijednosti, dok su u većini slučajeva (s iznimkom mase jedne svježije sjemenke) srednje veliki plodovi imali značajno veće vrijednosti od malih plodova. Pri usporedbi korelacijskih koeficijenta s različitim grupama veličine, vidljivo je da je veća veličina ploda značajno utjecala na broj punih sjemenki samo u srednje velikim i velikim plodovima. Također, vidljivo je da od parametara veličine ploda, masa i širina ploda imaju ključni utjecaj na broj punih sjemenki, za razliku od duljine ploda. Provedena analiza glavnih komponenti rezultirala je s dvije funkcije koje su imale veće svojstvene vrijednosti od 1 i koje su objasnile 75,88 % ukupne varijabilnosti. Veliki plodovi razlikuju se u odnosu na male i djelomično u odnosu na srednje velike po F1 osi. F1 os uglavnom je pod utjecajem mase ploda, duljine ploda, širine ploda, broja punih sjemenki, mase svježeg sjemena po plodu i mase sjemenke sušene na zraku po plodu. Na temelju rezultata koji su dobiveni u ovom istraživanju može se zaključiti da za rasadničarsku proizvodnju sadnica divlje kruške veći plodovi trebaju imati prednost zbog većeg broja punih sjemenki.

KLJUČNE RIJEČI: *Pyrus pyraeaster*, plod, sjeme, morfološka analiza glavnih komponenti, rasadničarstvo