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FRUIT AND SEED MORPHOLOGICAL TRAITS AND DURATION EFFECT OF SULFURIC ACID SEED SCARIFICATION ON SOME *Crataegus* Tourn. ex L. SPECIES

MORFOLOŠKE OSOBINE PLODOVA I SJEMENA I TRAJANJE UČINKA SKARIFIKACIJE SJEMENA SUMPORNOM KISELINOM NA NEKE VRSTE IZ RODA *Crataegus* Tourn. ex L.

Damir DRVODELIĆ[1]*, Milan ORŠANIĆ[1], Ela ŠPANJOL[1], Marko VUKOVIĆ[2], Tomislav JEMRIĆ[2]

SUMMARY

Hawthorn species (*Crataegus* Tourn. *ex* L.) are widely known for their medical, ecological, and economic benefits. The main issue of this study was to define the morphological characteristics of fruits and seeds as well as the impact of sulfuric acid (96% concentration) scarification with different time duration on seeds of three different hawthorn species (*C. crus-galli*, *C. monogyna*, *C. laevigata*). Statically significant differences were reported for all measured fruit and seed morphological traits. The highest values of fruit weight, length and width were recorded for *C. crus-galli*, while the lowest for *C. monogyna*. Different sulfuric acid (96% concentration) scarification treatments were used for *C. cruss-galli* (150 and 210 min), *C. laevigata*, and *C. cruss-galli* (45, 75 and 105 min) seeds. Only significant differences were found in contrast to the control. Thickness of the tiniest part of the seed coat was significantly reduced in *C. crus-gallic* and *C. laevigata* scarified seeds in contrast to the control. Thickness of the thickest part of the seed coat was significantly reduced only in *C. crus-galli* seeds scarified for 210 min in contrast to the control. Therefore, optimal duration of scarification treatment for *C. crus-galli* seeds should be 210 min. The results obtained in this study will contribute to a better knowledge of morphometric characteristics and the pre-sowing treatment of seeds of some *Crataegus* species which can be utilized in nursery production.

KEY WORDS: scarification, double dormancy of seeds, seeds, *Crataegus monogyna, Crataegus laevigata, Crataegus crus-galli*

INTRODUCTION
UVOD

Hawthorn (*Crataegus* Tourn. *ex* L.) is present worldwide with about 280 species. The most common species are *Crataegus monogyna* Jacq., *Crataegus laevigata* (Poir.), *Crataegus mexicana* Moc. & Sessé ex DC. and *Crataegus douglasii* Lindl., grown in Europe, North Africa, West Asia and North America (Nazhand et al., 2020). *C. monogyna, C. laevigata,* and *C. crus-galli* are the main hawthorn species in Croatian agroecological conditions. People have known the benefits of using hawthorn's berries for centuries (Nazhand et al., 2020; Chang et al., 2005; Chang et al., 2002; Daliu et al., 2018; Martinelli et al., 2021).

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C. monogyna commonly grows in temperate deciduous forests (Fichtner and Wissemann, 2021). It prefers sunny and semi-shade exposition, either in forests or at forest edges and in thickets (Fichtner and Wissemann, 2021). It inhabits almost all parts of Europe with the exception of the northern and eastern margins (Tutin et al., 1981). Its fruit are pomes; in Croatia, they are ripe in October. They are subglobose or ellipsoidal, generally bright red to deep red, shiny and glabrous (Idžojtić, 2019). *C. laevigata* grows in a moderately cold climate area (Fichtner and Wissemann, 2021). The best conditions for it to thrive are loamy or heavy clay soils in the shade of forests and it is distributed mainly in western and central Europe (Christensen, 1984). Its fruits are pomes which are globose to ellipsoidal, generally red, shiny and glabrous. They mature in September and October. *C. crus-galli* grows in cold climate areas, on average to moderately moist soils with good drainage in sunny habitats. It is distributed in the eastern part of North America and in central and western Europe. The fruit are pomes that are globose or broadly ovoid, dull red and glabrous, maturing from September to October. Their core is stony, 1-seeded, embedded in flesh, except in the uppermost part (Idžojtić, 2019). In general, the mature seeds have a seed coat which protects the endosperm, and within the endosperm the immersed embryo is present. Embryo consists of: plumula, radicle and cotyledons (Pelc and Ptak, 2014). *C. laevigata* and *C. monogyna* are widely spread throughout the world and hence have a major ecological and economic value. Both in China and Europe, hawthorn fruit is consumed not only for medicinal purposes but also as foodstuff (e.g., canned fruit, jam, jelly, beverages and wine) (Chang et al., 2002 according to Leung and Foster, 1996).

In the temperate zone, plants often develop dormant seeds and buds. All species of genus *Crataegus* have seeds with dormant embryos (Fichtner and Wissemann, 2021; Dickinson, 1985). Seeds of the *Crataegus* species exhibit both endogenous (related to immature embryos) and exogenous (related to seed coat properties) dormancy, which is then called double dormancy (Drvodelić et al., 2018). This can regulate the germination and dormancy of a seed. Scarification is necessary for thinning the seed coat and releasing exogenous dormancy, that is, chemical scarification increases the permeability of water and gas to the seed through the corrosion of the seed coat (Olmez et al., 2007). Ultimately, it influences faster and more uniform germination. Scarification can be carried out on pre-dried seeds with sulfuric acid treatment (from 30 min up to 4 hours) (St Johns, 1983).

The main issue of this study was to determine morphological characteristics of fruits and seeds as well as the impact of treatment with sulfuric acid (96% concentration) scarification with different time duration on seeds of three different hawthorn species (*C. crus-galli*, *C. monogyna*, *C. laevigata*).

MATERIALS AND METHODS
MATERIJALI I METODE

The fruits of three species of the genus *Crataegus* (Figure 1) were harvested from a wild population in October 2021 in Croatia, Zagreb, at the following coordinates: *C. laevigata* at 45°49'19.08' N, 16°1'5.08" E; *C. monogyna* at 45°49'18.13' N, 16°1'43.63' E; *C. crus-galli at 45°47'44'* N, 15°57'53' E. To ensure heterogeneity of the samples, around 3500 fruit in total have been collected from 20 different plants per each species. All analyses were conducted at the Laboratory of Forest Seed and Nursery Production of the Faculty of Forestry and Wood Technology, University of Zagreb, Department of Ecology and Silviculture.

Fruit morphological parameters were measured on 30 fruits per species. Fruit length and width (mm) were measured with a digital scrolling scale (Sylvac Pro) with an accuracy of 0.01 mm. For each fruit, two opposite lengths and widths were measured. Fruit weight was measured using a digital analytical balance (Kern Pls, Kern&Sohn GmbH, Germany) with an accuracy of 0.01 g.

Subsequently, all fruits were submitted to the seed extraction process, and each seed was manually extracted from the fruit. During that process, on the basis of 100 fruit per species, the number of seeds per each fruit was determined. Afterwards, all seeds were placed on the sterilised surface

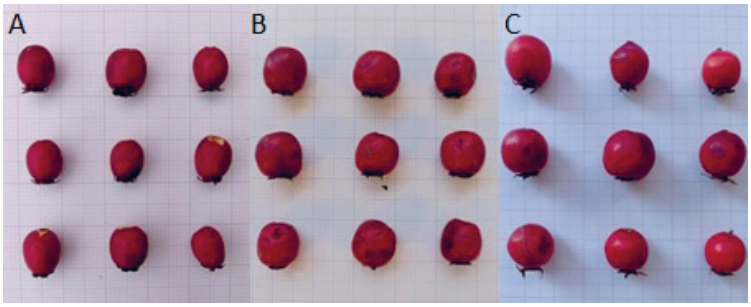

Figure 1: Fruit of *C. monogyna* (A), *C. laevigata* (B) and *C. crus-galli* (C)
Slika 1: Plodovi vrsta *C. monogyna* (A), *C. laevigata* (B) i *C. crus-galli* (C)

Figure 2: The process of reducing moisture content (8-14%) of hawthorn seeds at room temperature
Slika 2: Proces smanjenja sadržaja vlage (8-14 %) u sjemenu glogova pri sobnoj temperaturi

at room temperature to reduce their moisture content to 8-14%, which took several days (Figure 2, 3).

The weight of 1000 air-dried seeds was measured for each species according to ISTA rules (ISTA International Rules for Seed Testing, 2016) (8 measurements of 100 seeds per species) using a digital analytical balance (Kern PLS 4200-2F) with an accuracy of 0.01 g. The weight of each seed was randomly measured on 30 seeds per species using a digital analytical balance (Radwag AS R1 PLUS Analytical Balances, Polandwith an accuracy of ± 0.1 mg). Subsequently, 100 randomly selected seeds per species were scanned for morphological measurements using the Epson scanner, Epson perfection V700 Photo (model: STD4800). The data were then analysed using WinSEEDLE 2011 software (Regent Instruments, Canada). In the mentioned software 23 morphological parameters per each seed were analysed.

In the second part of the study, the aforementioned seeds were subjected to the sulfuric acid (96% concentration) scarification process. Treatments were distinguished by the duration of the scarification process (immersion time), for *C. laevigata* and *C. monogyna* species of 45, 75 and 105 min, while for *C. crus-galli* species the duration was 150 and 210 min. Random sampling (800 seeds per treatment) in three repetitions were made per species. The duration of scarification treatment for *C. crus-galli* was prolonged due to the greater thickness of the seed coat. Subsequently, the thickest and thinnest part of the walls of 10 seeds per treatment of each species was measured by cross-sectioning the seeds with a knife and a hammer. The aforementioned measurements were performed using a digital microscope (Dino-Lite Pro, Dino-Lite, The Netherlands) and the data were analysed using software (DinoCapture 2.0., Dino-Lite, The Netherlands).

Data were statistically analysed using SAS statistical software ver. 9.4 (SAS Institute, NC) by ANOVA and Tukey's HSD test ($P < 0.05$).

RESULTS
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According to ANOVA, species had a significant effect on all morphological and biological properties of fruits and

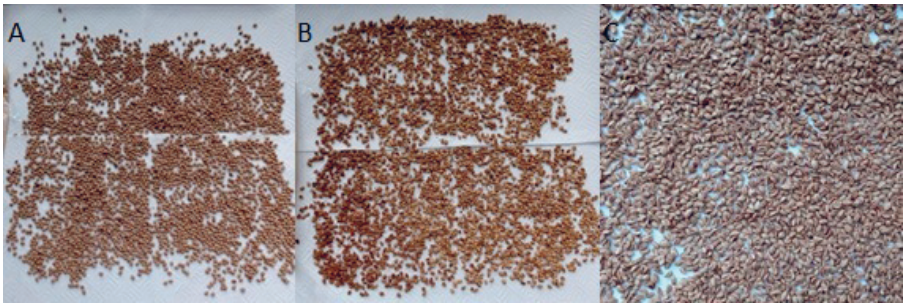

Figure 3: Seeds of *C. monogyna* (A), *C. laevigata* (B) and *C. cruss–galli* (C)
Slika 3: Sjeme *C. Monogyna* (A), *C. laevigata* (B) i *C. cruss–galli* (C)

seeds of some species of *Crataegus* Tourn. *ex* L., with the exception of the horizontal and vertical position of the seed (Tables 1, 2 and 3). According to the Tukey HSD test, all three species differ significantly between each other for most traits with the exception of fruit shape index, seed weight, seed curvature and horizontal and vertical position of the seed (Tables 1, 2 and 3). Since *Crataegus* species are mainly propagated generatively, it is important to contribute to further understanding pomological and morphological properties of fruits and seeds. The significantly highest fruit weight, length, and width were exhibited by fruit of *C. crus-galli*, and the lowest by those of *C. monogyna* (Table 1). The fruit shape index was significantly the smallest in the fruit of *C. monogyna*, while between the other two species no significant differences were recorded, meaning that *C. monogyna* has a more elliptical fruit shape compared to the other two species (Table 1). Significantly highest seed number and weight of 1000 seeds had *C. crus-galli* fruit, while the lowest *C. monogyna* and *C. laevigata* (respectively) (Table 1). The seed weight was significantly higher in the fruit of *C. crus-galli*, while no significant differences were recorded between two other species.

Significantly the highest projected seed area, the straight and curved length and width had *C. crus-galli* fruit, while the lowest was recorded for *C. monogyna* (Table 2). The curvature of the seeds was significantly highest in the *C. crus-galli* fruit and the ratio of seed length/width in the *C. laevigata* fruit, while between the other two species for both traits, no significant differences were recorded (Table 2).

Significantly the highest volume and surface area of the seed circle, the surface area of the ellipse, the surface area of the triangle and the projected circumference had the fruit of *C. crus-galli,* while the lowest values were recorded for *C. monogyna* (Table 3). The projected circumference coefficient was highest in the *C. monogyna* fruit, while it was the lowest in the *C. crus-galli* fruit (Table 3)

According to ANOVA, treatment had a significant effect on the thinnest and thickest coat part of the *C. crus-galli* seeds as well as on the thinnest and thickest coat part of the *C. laevigata* seeds (Table 4).

According to Tukey's HSD test, the thinnest part of the *C. crus-galli* seeds was significantly reduced in both treatments (scarification 150 and 210 min) compared to the control, while no significant differences were recorded between treatments (Table 4). Although, according to ANOVA, treatment had a significant effect on the thickest part of the *C. crus-galli* seeds, according to Tukey's HSD test, no signifi-

Table 1: Morphological properties of fruits and seeds of three species of the genus *Crataegus*
Tablica 1: Morfološka svojstva plodova i sjemena tri vrste roda *Crataegus*

Species Vrsta	FW (g) MP (g)	FL (mm) DP (mm)	FW (mm) ŠP (mm)	FSI IOP	SN (pcs) BS (kom)	ISW (g) MPS (g)	W1000S (g) M1000S (g)
C. crus-gali L.	1.27 ± 0.27a	14.70 ± 0.92a	13.44 ± 1.07a	1.10 ± 0.07b	2.50 ± 0.52a	0.09 ± 0.02a	87.46 ± 1.04a
C. laevigata (Poir.) DC.	0.54 ± 0.09b	10.70 ± 0.57b	9.84 ± 0.67b	1.09 ± 0.06b	2.25 ± 0.52b	0.04 ± 0.01b	37.35 ± 0.64b
C. monogyna Jacq.	0.28 ± 0.04c	9.05 ± 0.47c	7.46 ± 0.44c	1.22 ± 0.08a	1.00 ± 0.00c	0.05 ± 0.01b	47.43 ± 1.22c
				ANOVA			
Species – Vrsta	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***

[1] Results are expressed as mean ± SD, with the exception of ANOVA, where they present the P value / Rezultati su izraženi kao srednje vrijednosti ± SD s izuzetkom ANOVE gdje predstavljaju P vrijednosti; [2] Means followed by different letters within columns are significantly different (Tukey's HSD test; P <0.05) / Srednje vrijednosti kojima je pridruženo različito slovo unutar stupca se signifikantno razlikuju (Tukey's HSD test; P <0.05); [3]*** significant at P ″ 0.001 / ***signifikantno pri P ″ 0.001; [4] Abbrevations / Kratice: FW/MP – fruit weight/masa ploda, FL / DP – fruit length / duljna ploda, FW / ŠP – fruit width / širina ploda, FSI / IOP – fruit shape index / indeks oblika ploda, SN / BS – seed number in individual fruit / broj sjemenki u pojedinačnom plodu; ISW / MPS – individual seed weight / masa pojedinačnog sjemena, W1000S / M1000S – weight of 1000 seeds / masa 1000 sjemenki

Table 2: Morphological seed properties of three species of the genus *Crataegus*
Tablica 2: Morfološka svojstva sjemena tri vrste roda *Crataegus*

Species Vrsta	PA (mm²) PP (mm²)	SL (mm) RD (mm)	CL (mm) ZD (mm)	SW (mm) RD (mm)	CW (mm) ZŠ (mm)	C (mm) Z (mm)	L-W D-Š
C. crus-gali L.	31.59 ± 4.73a	8.20 ± 0.53a	8.32 ± 0.56a	5.20 ± 0.63a	5.17 ± 0.63a	0.05 ± 0.04a	0.64 ± 0.07a
C. laevigata (Poir.) DC.	18.86 ± 3.13b	6.00 ± 0.39b	6.09 ± 0.39b	4.16 ± 0.53b	4.13 ± 0.53b	0.03 ± 0.02b	0.69 ± 0.07b
C. monogyna Jacq.	16.32 ± 1.92c	5.50 ± 0.32c	5.56 ± 0.32c	3.95 ± 0.31c	3.93 ± 0.31c	0.03 ± 0.02b	0.72 ± 0.04c
				ANOVA			
Species – Vrsta	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***	<.0001***

[1] Results are expressed as mean ± SD, with the exception of ANOVA, where they present the P value / Rezultati su izraženi kao srednje vrijednosti ± SD s izuzetkom ANOVE gdje predstavljaju P vrijednosti; [2] Means followed by different letters within columns are significantly different (Tukey's HSD test; P <0.05) / Srednje vrijednosti kojima je pridruženo različito slovo unutar stupca se signifikantno razlikuju (Tukey's HSD test; P <0.05); [3]*** significant at P ″0.001 / ***signifikantno pri P ″0.001; [4] Abbrevations / Kratice: PA/PP – projected area / projicirana površina, SL / RD – straight length / ravna duljina, CL / ZD – curved length / zakrivljena duljina, SW / RD – straight width / ravna duljina, CW / ZŠ – curved width / zakrivljena širina, C / Z – curvature / zakrivljenost, L-W / D-Š – ratio of length and width / omjer duljine i širine

Table 3: Morphological seed properties of three species of the genus *Crataegus*
Tablica 3: Morfološka svojstva sjemena tri vrste roda *Crataegus*

Species Vrsta	CV (mm^2) VK (mm^2)	CS (mm^2) PK (mm^2)	ES (mm^2) PE (mm^2)	TS (mm^2) PT (mm^2)	HP (mm) HP (mm)	VP (mm) VP (mm)	PC (mm) PO (mm)	CPC KPO
C. crus-gali L.	107.27 ± 28.19a	99.53 ± 15.02a	70.38 ± 10.62a	63.36 ± 9.56a	80.51 ± 37.45a	125.84 ± 48.80a	22.00 ± 1.46a	0.82 ± 0.05a
C. laevigata (Poir.) DC.	52.10 ± 14.84b	59.72 ± 9.86b	42.23 ± 6.97b	38.02 ± 6.28b	81.10 ± 33.41a	122.25 ± 47.28a	16.78 ± 1.33b	0.84 ± 0.04b
C. monogyna Jacq.	42.87 ± 8.55c	51.54 ± 6.31c	36.45 ± 4.46c	32.81 ± 4.02c	78.88 ± 35.98a	120.89 ± 50.01a	15.36 ± 1.00c	0.87 ± 0.04c
				ANOVA				
Species – Vrsta	<.0001***	<.0001***	<.0001***	<.0001***	0.90n.s.	0.76n.s.	<.0001***	<.0001***

[1] Results are expressed as mean ± SD, with the exception of ANOVA, where they present the P value / Rezultati su izraženi kao srednje vrijednosti ± SD s izuzetkom ANOVE gdje predstavljaju P vrijednosti; [2] Means followed by different letters within columns are significantly different (Tukey's HSD test; P <0.05) / Srednje vrijednosti kojima je pridruženo različito slovo unutar stupca se signifikantno razlikuju(Tukey's HSD test; P <0.05); [3]n.s., *, ***non significant or significant at P ″0.05 or P ″0.001 (respectively) / n.s., *, ***nesignifikantno ili signifikantno pri P″0.05 ili P″0.001 (respektivno); [4] Abbrevations / Kratice: CV/VK- circle volume / volumen kruga, CS / PK – circle surface / površina kruga, ES / PE – elipse surface / površina elipse, TS / PT – triangle surface / površina trokuta, HP / HP – horizontal position / horizontalna pozicija, VP / VP- vertical position / vertikalna pozicija, PC / PO-projected circumference / projicirani opseg, CPC / KPO - coefficient of projected circumference / koeficijent projiciranog opsega

cant differences were recorded (Table 4). Scarification of seeds with sulfuric acid for 150 min led to an average reduction of the thinnest part of the seed coat by 0.23 mm and the thickest by 0.39 mm. The scarification of the seeds for 210 min led to an average reduction of the thinnest part of the seed coat by 0.19 mm and the thickest by 0.62 mm.

Table 4: Influence of the duration of scarification with sulfuric acid on coating thickness of three species of the genus *Crataegus*
Tablica 4: Utjecaj trajanja skarifikacije sumpornom kiselinom na debljinu sjemene ljuske tri vrste roda *Crataegus*

Species Vrsta	Treatment Tretman	Thinnest coat part (mm) Najtanji dio sjemene ljuske (mm)	Thickest coat part (mm) Najdeblji dio sjemene ljuske (mm)
C. crus-gali L.	Control Kontrola	0.62 ± 0.23a	2.42 ± 0.48a
	Scarification 150 min Skarifikacija 150 min	0.39 ± 0.10b	2.03 ± 0.38ab
	Scarification 210 min Skarifikacija 210 min	0.43 ± 0.14b	1.80 ± 0.38b
	ANOVA		
	Treatment Tretman	0.011*	0.01**
C. laevigata (Poir.) DC.	Control Kontrola	0.35 ± 0.10a	1.57 ± 0.15a
	Scarification 45 min Skarifikacija 45 min	0.19 ± 0.05b	1.33 ± 0.21a
	Scarification 75 min Skarifikacija 75 min	0.15±0.02b	1.40 ± 0.24a
	Scarification 105 min Skarifikacija 105min	0.16 ± 0.05b	1.41 ± 0.26a
	ANOVA		
	Treatment Tretman	<.0001***	0.10n.s.
C. monogyna Jacq.	Control Kontrola	0.48 ± 0.10a	1.19 ± 0.18a
	Scarification 45 min Skarifikacija 45 min	0.38 ± 0.18a	1.22 ± 0.18a
	Scarification 75 min Skarifikacija 75 min	0.33 ± 0.16a	1.28 ± 0.27a
	Scarification 105 min Skarifikacija 105 min	0.37 ± 0.13a	1.32 ± 0.17a
	ANOVA		
	Treatment Tretman	0.14n.s.	0.47n.s.

[1] Results are expressed as mean ± SD, with the exception of ANOVA, where they present the P value / Rezultati su izraženi kao srednje vrijednosti ± SD s izuzetkom ANOVE gdje predstavljaju P vrijednosti; [2] Means followed by different letters within columns are significantly different (Tukey's HSD test; P <0.05) / Srednje vrijednosti kojima je pridruženo različito slovo unutar stupca se signifikantno razlikuju (Tukey's HSD test; P <0.05); [3]n.s., *, **, ***non significant or significant at P ″0.05, P ″0.01 or P ″0.001 (respectively) / n.s., *, **, ***nesignifikantno ili signifikantno pri P ″0.05, P ″0.01 ili P ″0.001 (respektivno

According to Tukey's HSD test, the thinnest part of the *C. laevigata* seeds was significantly reduced in three treatments (scarification 45, 75 and 105 min) compared to the control, while no significant differences were recorded between the treatments (Table 4). Although no significant differences were recorded for the part of the thickest seed coat, according to the average values, a trend is evident in which all treatments reduced the part of the thickest seed coat of the seed compared to the control.

DISCUSSION
RASPRAVA

The importance of this study was to contribute to a better knowledge of morphometric characteristics and presowing treatment of seeds of some *Crataegus* species, which can be utilized in nursery production in order to increase and improve the results of seedling production in the nurseries.

According to Idžojtić (2019), *C. crus-galli* fruit are 8–12 mm long and 9 mm wide, *C. laevigata* fruit are 10–14 mm long and 8–12 mm wide and those of *C. monogyna* are 8–10 mm long and 7–9 mm wide. These results are notably different from the results obtained in this study (Table 1). Furthermore, the mentioned publication (Idžojtić, 2019) states that the weight of 1000 air dried seeds of *C. monogyna* is 66 g, which is also different from the results obtained in this study (Table 1). The reason for aforementioned may be due to tree maturity, agro-ecological conditions and genetic expression. In their study, Khadivi et al. (2019) stated that the average fruit length of *C. monogyna* was 8.29 – 15.14 mm and width 7.22 - 13.44 mm. Gundogdu et al. (2014) measured 13.12 mm and 12.55 mm, while Gokturk et al. (2017) measured 7.78 mm and 5.35 mm, respectively. Gundogdu et al. (2014) also reported that the average fruit weight of *C. monogyna* is 1.35 g and the average seed weight 0.29 g. Kheloufi et al. (2019) recorded that the average seed weight of *C. monogyna* was 0.25 ± 0.04 g, while Gokturk et al. (2017) determined 13.79 g for 100 seeds. The aforementioned results differ in comparison with those obtained in this study (as well as between each other), which is probably due to the agroecological conditions and hereditary factors.

In their publication, Khadivi et al. (2019) reported that *C. monogyna* fruit were mainly determined as elliptical, circular and medium-elliptical (41%, 30% and 29%, respectively). Moreover, in the research by Dvirna et al. (2021), the fruit shape index of *C. monogyna* was stated to be widely short- ellipsoidal to ovoid or rounded, while of *C. laevigata* it was spherical (short–ellipsoidal). These results are in agreement with this study (Table 1). The significance of the results obtained shows a large variability of fruits and seeds of species of the genus *Crataegus*. In regard to other studied morphological seed properties of three species of the genus *Crataegus* (Table 2 and 3), there is, up to our knowledge, exceptional deficiency of available literature data for comparison.

The hawthorn genus (*Crataegus* L.) has poor seed germination due to stony endocarp and embryo dormancy (Ahmadloo et al., 2016). Hence, to lessen the rigidity of the endocarp, chemical scarification of the seed endocarp has been employed on the hawthorns (Mohammed, 2023). Therefore, in this study, the duration effect of sulfuric acid (concentration 96%) seed scarification was tested (Table 4). Only significant differences were found in contrast to the control. Thickness of the tiniest part of the seed coat was significantly reduced in *C. crus-gallic* and *C. laevigata* scarified seeds in contrast to the control. Although scarification of the *C. monogyna* seeds did not significantly reduce thickness of the tiniest part of the seed coat, there is an evident trend, based on average values, that scarification treatments reduced it. Thickness of the thickest part of the seed coat was significantly reduced only in *C. crus-galli* seeds scarified for 210 min in contrast to the control. In other cases, no significant differences were recorded, but the same trend based on average values is evident for the seeds of *C. laevigata*. Therefore, optimal duration of scarification treatment for *C. crus-galli* seeds should be 210 min, while for other two species no clear conclusion can be made. Gokturk et al. (2017) reported that sulfuric acid scarification rate, measured as change in seed diameter and length, varied between *Cataergus* species. Those results are in agreement with this study. Up to our knowledge, there is scarcity of studies that evaluates the impact of scarification treatment on the thinnest and thickest part of the seed coat of the aforementioned species. For this reason, it is highly suggested that further research studies be conducted.

CONCLUSIONS
ZAKLJUČCI

The morphological properties of the fruits and seeds of *Crataegus* sp. are highly variable, which can be influenced by different habitat, habitus, genetic inheritance, exposition toward the solar radiation, maturity of the trees, microclimate of the area (the amount of rain or drought) etc. Optimal duration of scarification treatment for *C. crus-galli* seeds should be 210 min. However, for other two species no clear conclusion can be made, which emphasizes the need for further studies on this topic.

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SAŽETAK

Vrste gloga (*Crataegus* Tourn. ex L.) su znane po njihovim pozitivnim medicinskim, ekološkim i ekonomskim svojstvima. Glavni cilj ovog istraživanja bio je definirati morfološke karakteristike ploda i sjemena te utjecaj skarifikacije sumpornom kiselinom (96%-tna koncentracija) različitog trajanja na sjeme tri vrste gloga (*C. crus-galli*, *C. monogyna*, *C. laevigata*). Utvrđene su statistički značajne razlike za sva mjerena morfološka svojstva ploda i sjemena. Najveću masu, duljinu i širinu ploda imala je *C. crus-galli*, a najmanju *C. monogyna*. Različita duljina trajanja skarifikacije sumpornom kiselinom (96%-tna koncentracija) primijenjena je na sjemenu *C. cruss-galli* (150 i 210 min), *C. laevigata* i *C. cruss-galli* (45, 75 i 105 min). Značajne razlike zabilježene su samo u odnosu na kontrolu. Debljina najtanjeg dijela sjemene ljuske bila je značajno smanjena u skarificiranom sjemenu *C. crus-galli* i *C. laevigata* za razliku od kontrole. Debljina najdebljeg dijela sjemene ljuske bila je značajno smanjena samo kod sjemena *C. crus-galli* skarificiranom 210 minuta u odnosu na kontrolu. Shodno navedenome optimalno trajanje skarifikacije sjemena *C. crus-galli* trebalo bi biti 210 min. Rezultati dobiveni u ovom istraživanju doprinijet će boljem poznavanju morfologije i predsjetvenog tretmana sjemena nekih *Crataegus* vrsta koje se mogu koristiti u rasadničarskoj proizvodnji.

KLJUČNE RIJEČI: skarifikacija, dvostruka dormantnost sjemena, sjeme, *Crataegus monogyna, Crataegus laevigata, Crataegus crus-galli*