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Variability of morphological and biological characteristics of Wild Service Tree (*Sorbus torminalis* (L.) Crantz) fruits and seeds from different altitudes

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Abstract

Aims and objectives of research: *The study aimed to research the influence of altitude on dimensions, i.e. the shape of Wild Service tree fruits (Sorbus torminalis (L.) Crantz). We also wanted to test the variability of major biological characteristics of fruits and seed, the elements of seed quality and their relations.*

Materials and Methods: *In September 2003 we gathered fruits from 24 Wild Service Trees of different ages and positions in the stand structure on three sites (Medvednica, Psunj and Južni Dilj) situated at different altitudes. The altitude of each tree was determined with the GPSmap 60CSx device, after which dendrometric measurements were carried out and fruits were collected. We measured fruit length (FL) and width (FW) and calculated their index (FL/FW). The mass of each fruit was weighed on the laboratory scales Sartorius and the number of fruits per kilo was calculated. The seeds were manually extracted from the fruits and the number of filled (sound) seeds per fruit was counted in line with the ISTA rules. In order to break the double seed dormancy we applied the stratification in accordance with the ISTA rules. For the statistical analysis of the data we used ANOVA, LSD test, correlation analysis and canonical discriminant multivariate analysis with the locality as a grouping variable. All statistical analyses were performed using STATISTICA 8.0 program package.*

Results: *We obtained a positive and strong correlation between fruit length and altitude (R=0.67), i.e. between fruit shape index and altitude (R=0.71), which means that the higher the altitude of the population of the Wild Service Tree in the Republic of Croatia, the longer the fruits. At higher altitudes the Wild Service Tree seed shows a larger degree of dormancy and requires somewhat longer period of stratification.*

Conclusion: *The observed differences between the three studied locations might be attributed to changed climatic and soil conditions.*

INTRODUCTION

The genus *Sorbus* L. (*Rosacee: Maloideae*) encompasses around 250 species distributed in the northern hemisphere of which 91 are native to Europe *(1)*. According to Warburg and Kárpáti *(2)* there are only 19 species growing in Europe while the latest multivariate research of the genus *Sorbus* distinguishes between 12 species only *(3)*. Most of the European species from the genus *Sorbus* (70 out of 91) are of hybrid origin *(3)*.

The Wild Service Tree (*Sorbus torminalis* (L.) Crantz) is a deciduous species which reaches the height of up to 30 meters. It has a round dense crown and a straight trunk whose DBH ranges from 50 to 70 (even up to 100) cm. Its root system first has a taproot and later is heart-shaped *(4)*.

The Wild Service Tree is native to western, central and southern Europe, northern Africa, the Crimea, Asia Minor, Caucasus and Transcaucasia. It grows at altitudes of up to 900 meters. According to Kausch *(5)* the north--western edge of its distribution area starts on the British Isles where it reaches up to 54 degrees of the northern latitude. It does not grow in the lowlands of the Netherlands, in the north-western parts of Germany and on the peninsula of Jutland. It is distributed in Asia Minor, the Balkan peninsula (except for the southern parts of Greece), on the territory of Italy and the Iberian peninsula with some isolated populations seen in the north-eastern part of Africa while it is most frequently found in France.

In Croatia it grows in mosaic pattern communities, i.e. as solitary trees or in small groups, mixed with other species, mostly in thermophilic forest communities of the Downy and Sessile oak and on sunny positions. It is rarely seen in the Mediterranean zone of Croatia *(6)*. According to Matić and Vukelić *(7)* it can be more frequently found in the sub-Mediterranean zone, especially in its wetter and colder parts. It quite frequently occurs on higher positions of the Mediterranean mountainous belt (altitudes of up to 700 meters) in the community with Downy oak and European Hop-hornbeam (*Ostryo--Quercetum pubescentis* Ht. 1938). This community occurs as an extrazonal type in continental Croatia and as a rule thrives on rendzic leptosol, limestone and dolomite on exposed and warm positions.

Matić and Vukelić *(7)* describe the Wild Service Tree as a pioneer and a postpioneer species with broad ecological valency. The authors see it as a side species contributing to biological diversity, stability of the stand, support to the main tree species and improvement of the soil quality. It is a semiskiophilic species and, when young, is quite tolerant to shade but later requires plenty of light. It ranges between thermophilic and mesophilic species which tolerates drought, cold and late spring frosts.

The Wild Service Tree flowers in May and June and begins yielding at the age of 25 to 30. The variations in flowering between the populations depend on the micro climate while the fruits ripen in October. In the northern parts of its distribution area the fruits of the Wild Service Tree mature about a month later than in the center *(8)* while the fruits on the shaded trees do not fully ripen even during warm and sunny years *(9)*.

The fruits of the Wild Service tree are counter ovoid to globose, brown with white spots, 14–18 mm long, and 8–15 mm wide, edible and come in corymbs of 5–10. The fruit pericarp comprises a membrane exocarp (skin), pulp (flesh) and endocarp (core). The fruits which ripen in September and October contain up to four elongated, dark brown seeds up to 7 mm long. They are dispersed by animals (zoohoria), mostly birds. According to Bednorz *(10)* and many other sources Wild Service Tree fruits contain between 2 and 4 seeds. When researching the sub family *Maloideae* Rocher *et al. (11)* found out that only 25 to 50% of the gynoeciums in a fruit develop into mature seeds. Aldasoro *et al. (3)* point out that the characteristics of Wild Service Tree fruits and seeds are influenced by the way the seeds are dispersed in nature (fruits are eaten and dispersed by birds and mammals), which can significantly reduce the phylogenetic difference. According to McAllister *(12)* certain fruit characteristics, such as its size, are strongly influenced by site factors. The variability of Wild Service Tree fruits in size and shape is a well-known fact. Kárpáti *(13)* gives a list of seven different fruit shapes: *typus, sphaerocarpa, pisifera, macrocarpa, microcarpa, dolichocarpa and pomoida*.

Idžojtić *et al. (14)* write about the variability of a species as the basis for successful adaptation to changing conditions of the environment during its long life cycle, which in the long run is important for the survival of the species, i.e. variability ensures adaptability of populations to changes in the environment over generations. Negative factors that undermine the variability of the Wild Service Tree are: excessive commercial exploitation, narrow genetic base of small populations, failure of natural regeneration, competition from other species, inadequate silvicultural practices and uncontrolled seed transfer *(15)*.

The genetic variability of the Wild Service Tree on the basis of polymorphysms of enzymes was mainly researched in France *(16)* while the study of variability on the basis of morphological characteristics of leaves and fruits was conducted in Croatia *(14)*.

The aim of this paper was to research the influence of altitude on dimensions, i.e. the shape of Wild Service tree fruits (*Sorbus torminalis* (L.) Crantz).

RESEARCH AREA

In September 2003 fruits were collected from 24 Wild Service Trees at three sites in the Republic of Croatia with different average altitudes: Medvednica *(9),* Psunj *(6),* and Južni Dilj *(9)*. The selection criteria were a minimum distance of 50 meters between the trees and well--developed fruits. The selected trees had different diameters and positions in the stand structure. The Wild Service Trees on Medvednica grow at an average altitude of 499±34 m, on Južni Dilj at 272±52 m and on Psunj at 226±21m. The altitude of the trees on Medvednica is by 227 meters higher compared to Južni Dilj and 73 meters compared to Psunj. The lowest average height difference of 46 meters was measured the trees on Psunj and Južni Dilj.

MATERIALS AND METHODS

Each tree on the selected localities was recorded with GPSmap 60CSx which was also used to determine altitudes. The fruit yield was graded on the scale of good,

partial, poor and none. The device Vertex III was used to measure the total height and height to the crown for each tree while DBH ($d_{1.30}$) was measured with a calliper.

The fruits were picked from different parts of the crown with the scissors with a telescopic handle. The morphometric analysis of the fruits was performed immediately upon picking in the Laboratory for Seed Testing of the Department of Ecology and Silviculture, University of Zagreb. For the purpose of the analysis of fruits, a random sample of 30 fruits was taken from each tree. A digital caliper (in mm and two decimals) was used for measuring fruit length (FL) and fruit width (FW). On the basis of the obtained measures, the FL/FW index was calculated. The mass of each fruit was weighed on the laboratory scales Sartorius with the precision of 0.01 g. The number of Wild Service Tree fruits in 1 kilo was also calculated. The seeds were extracted manually and with a knife from the pulp and the number of filled (sound) seeds in each fruit was counted. The same method was applied for extracting seeds from the rest of the fruits, the seeds were thoroughly washed in water and left to dry at room temperature till they reached constant mass. The absolute seed weight was determined in accordance with the ISTA Rules *(17)*.

To break the double dormancy of the seed, we applied the stratification process from the ISTA Rules on Testing Seed Germination of Trees and Shrubs from the Genus *Sorbus* L. *(18)*. On 11 December 2003, the seed was mixed with sterile alluvial and wet sand and left to stratify. The stratification temperature was 3 °C. During the stratification, humidity and aeration of the seed were checked four times in order to determine the number of germinated seeds. The criterion for the determination of seed germination was the appearance of a radicle visible with naked eye.

The data of tree, fruit and seed characteristics was analyzed by ANOVA and, when the effect of location was significant at $P \leq 0.05$, LSD test at $P \leq 0.05$ level. The correlation analysis was performed with the level of significance of $P \leq 0.05$. Statistical analysis was performed using STATISTICA 8 software package (StatSoft, Inc.). Multivariate canonical discriminant analysis (CDA) of the most important ecological and biological characteristics (9 variables) was performed using STATISTICA 8 software package (StatSoft, Inc.) with the site as a grouping variable. Squared Mahalanobis distance was used to determine differences between the localities. CDA derives a linear combination of the variables that has the highest possible multiple correlation with the groups *(19)*. This technique was used to find linear combination of quantitative variables that provide maximal separations between the locations. Multivariate statistics and F approximation based on Rao's approximation to the distribution of the likelihood ratio was used to test the independence of location means *(20)*.

RESEARCH RESULTS

Table 1 shows the results of descriptive statistics for the measured dendrometric parameters of the Wild Service Tree.

TABLE 1

Characteristics of Wild Service Trees (*Sorbus torminalis* (L.) Crantz) from three sites in the Republic of Croatia.

Locality	DBH (cm)	Trunk height (m)	Tree height (m)	Crown height (m)
Medvednica	23.2±8.0 a	6.1±2.8 a	13.0±3.4 a	6.9±2.5 a
Psunj	24.7±17.1 a	6.2±4.0 a	14.2±7.7 a	8.0±4.4 a
Južni Dilj	10.8±8.8 b	2.4±1.2 b	8.1±5.5 a	5.7±4.8 a
F test	3.85	4.50	2.83	0.84
P value	0.04	0.02	0.08	0.44

Note: values with the same letter within the same column are not statistically significant according to LSD test at $P \leq 0.05$

The results of the LSD test revealed significant differences in altitudes of the researched sites ($P \leq 0.0001$). The average seed yield at all three sites was good and there were few variations and no significant difference. The results of dendrometric measurements showed no statistically relevant differences between the sites with regard to tree ($F=2.83$,; $P=0.08$) and crown heights ($F= 0.84$, $P=0.44$) whereas there were statistically significant differences in DBH ($F=3.85$, $P=0.04$) and trunk heights ($F=4.50$, $P=0.02$). The trees on Psunj had the largest average DBH of 24,7 cm, followed by the trees on Medvednica with DBH of 23,2 cm and on Južni Dilj with 10,8 cm. The trunks of the Wild Service Trees from Medvednica and Psunj measured almost the same average height (6,1 m and 6,2 m) while the trunk height of trees on Južni Dilj was to 2,4 m only.

Table 2 presents the results of the descriptive statistics for certain morphological and biological characteristics of Wild Service Tree fruits and seed. The average weight of the Wild Service Tree fruits from the trees on Medvednica was 1.40 g, 1.26 g on Psunj and 1.13 g on Južni Dilj. There were significant differences in average weight of the Wild Service Tree fruit with regard to the researched sites ($F=3.73$, $P=0.04$). The average fruit weight for Južni Dilj was statistically smaller than the fruit weights measured at the other two sites. The average number of fruits per kilo for Medvednica was 714 pieces, for Psunj 794 pieces and for Južni Dilj 885 pieces.

The results of descriptive morphometric analysis revealed that the fruits collected on Medvednica had the largest average length (15.85 mm) followed by the fruit length on Psunj (14.12 mm) while the shortest fruit lengths were measured on Južni Dilj (13.82 mm). A significant difference in fruit lengths of the Wild Service Tree was obtained with respect to the researched sites ($F=11.53$, $P=0.001$). The average fruit length on Medvednica was significantly longer than on the other two researched sites.

TABLE 2

Characteristics of fruits and seed of the Wild Service Tree (*Sorbus torminalis* (L.) Crantz) from three sites in the Republic of Croatia.

Locality	Fruit weight (g)	Fruit lengh (mm)	Fruit width (mm)	Fruit length/ Fruit width	Absolute seed weight (g)	Number of sound seeds in fruit (pcs)	Seed germination at the end of stratification (%)
Medvednica	1.40±0.20 a	15.85±1.34 a	12.10±0.68 a	1.31±0.12 a	27.93±5.64 a	1.60±0.55 a	16.10±12.22 b
Psunj	1.26±0.32 a	14.12±1.68 b	11.77±0.85 a	1.20±0.13 b	29.25±5.10 a	1.21±0.73 a	44.60±21.21 a
Južni Dilj	1.13±0.26 b	13.82±1.16 b	11.83±1.18 a	1.18±0.11 b	26.33±7.03 a	1.49±0.60 a	38.60±17.42 a
F test	3.73	11.53	0.28	8.29	1.40	1.85	7.42
P value	0.04	0.001	0.75	0.002	0.27	0.18	0.004

Note: values with the same letter within the same column are not statistically significant according to LSD test at $P \leq 0.05$

There were no significant differences in the morphological characteristic of fruit width between the three researched sites.

The trees from Medvednica had the largest fruit length/fruit width index (1.31), followed by Psunj (1.20) and Južni Dilj (1.18). The index helps us notice that the fruits from Medvednica were more oblong-shaped compared to the other two sites. The fruit length/fruit width index showed a significant difference between the sites ($F=8.29$, $P=0.002$). The fruit length/fruit width index for the Medvednica site was significantly higher than on the other two sites.

The absolute seed weight of the Wild Service Tree from Medvednica was 27.93 g, from Psunj 29.25 g and from Južni Dilj 26.33 g. There were no significant differences in absolute seed weight among the researched sites ($F=1.40$, $P=0.27$).

TABLE 3

Correlation values for altitudes, morphological and biological characteristics of trees, fruits and seed of the Wild Service Tree (*Sorbus torminalis* (L.) Crantz) from three sites in the Republic of Croatia.

Variable	Altitude (a.m.s.l.)	Trunk diameter (cm)	Trunk height (m)	Tree height (m)	Crown height (m)	Number of fruits in kg (pcs)	Fruit weight (g)	Absolute seed weight (g)	Number of sound seed in fruit (pcs)	Seed germination at the end of stratification (%)	Fruit length (mm)
Altitude (a.m.s.l.)	1										
DBH (cm)		1									
Trunk height (m)		0.68	1								
Tree height (m)		0.89	0.76	1							
Crown height (m)		0.72		0.82	1						
Number of fruits in kg (pcs)						1					
Fruit weight (g)						–0.96	1				
Absolute seed weight (g)						–0.48	0.42	1			
Number of sound seed in fruit (pcs)						–0.65	0.55		1		
Seed germination at the end of stratif. (%)	–0.57							0.50		1	
Fruit length (mm)	0.67					–0.75	0.82		0.48		1
Fruit width (mm)						–0.80	0.77	0.43	0.46		0.42
Fruit length/Fruit width	0.71									–0.55	0.77

Note: The table shows only the significant correlations with $P \leq 0.05$

There were 1,60 pieces of filled (sound) seeds per one Wild Service Tree fruit from Medvednica, 1.21 pieces from Psunj and 1.49 pieces from Južni Dilj, but there was no significant difference between the sites (F=1.85, P=0.18).

At the end of the 105-daystratification period the average percentage of seed germination for the trees from Medvednica was 16.10%, for Psunj 44.60% and for Južni Dilj 38.60%. The results of the ANOVA revealed a significant difference in this biological characteristic with respect to the researched sites (F=7.42, P=0.004). The average seed germination percentage for Medvednica was significantly higher than on the other two researched sites. Table 3 shows the correlation values with regard to the altitude and individual morphological and biological characteristics of Wild Service Tree fruits and seed.

We established a statistically significant positive correlation between altitude and fruit length (r=0.67), as well as between altitude and fruit shape index (r=0.71). There was a positive correlation between fruit weight and absolute seed weight (r=0.42), i.e. between fruit weight and the number of filled (sound) seeds in a fruit (r=0.55). The absolute seed weight and seed germination at the end of the stratification were also closely correlated (r=0.50). There were no significant correlations between tree and fruit characteristics, but positive correlation existed among all tree characteristics except trunk and crown height.

The multivariate analysis clearly explained that the main differences in *Sorbus torminalis* (L.) Crantz from Medvednica are caused by changed climatic conditions due to the higher altitude of this site.

The Squared Mahalanobis distance was significantly different for Medvednica as well as for Južni Dilj and Psunj (Table 4).

TABLE 4

Squared Mahalanobis distance between the three sites.

Locality	Medvednica	Psunj	Južni Dilj
Medvednica	0.00		
Psunj	198.01***	0.00	
Južni Dilj	164.98****	6.28 n.s.	0.00

Canonical function 1 (Can1) accounted for 98% of total variance and was highly correlated (i.e. had correlation coefficient higher than 0.3) to altitude, and the remaining 2% of total variance was explained by canonical function 2 (Can2) which was highly correlated to DBH, tree height, crown height, weight of a thousand seeds and seed germination at the end of stratification (Table 5).

All correlations with the canonical structure were negative, and tree characteristics had higher correlation coefficients than seed characteristics.

The graphical representation of the canonical scores (Figure 1) showed that Medvednica is separated from Južni Dilj and Psunj by Can1, while Can2 failed to separate any of the studied locations.

DISCUSSION AND CONCLUSION

On Medvednica the Wild Service Tree grows at the highest average altitude in the Republic of Croatia (499 m). An average difference in the altitude distribution of the Wild Service Tree between the sites on Medvednica and Psunj is 272 m and between Medvednica and Južni Dilj 227 m. The smallest difference was measured between the sites on Psunj and Južni Dilj (46 m).

TABLE 5

Results of canonical discriminant analysis (CDA) classifying altitude, trees, morphological and biological characteristics of fruits and seed of the Wild Service Tree (*Sorbus torminalis* (L.) Crantz) from three sites in the Republic of Croatia.

Variable	Factor Structure Matrix Correlations Variables – Canonical Roots (Pooled--within-group correlations)		Raw Coefficients for Canonical Variables		Standardized Coefficients for Canonical Variables	
	Can 1	Can 2	Can 1	Can 2	Can 1	Can 2
Altitude (a.m.s.l.)	–0.47	0.27	–0.04	0.01	–1.73	0.26
DBH (cm)	–0.04	–0.61	0.05	–0.03	0.56	–0.30
Tree height (m)	–0.02	–0.57	–0.32	–0.31	–1.60	–1.56
Crown height (m)	0.01	–0.31	–0.02	0.38	–0.09	1.41
Number of fruits in kg (pcs)	0.06	0.10	0.00	0.00	1.16	0.59
Weight of one thousand seeds (g)	0.01	–0.35	–0.06	–0.08	–0.38	–0.52
Number of sound seeds in fruit (pcs)	–0.04	0.19	0.29	0.83	0.16	0.47
Seed germination at the end of stratif. (%)	0.13	–0.33	0.08	0.00	1.37	0.04
Fruit length/Fruit width	–0.12	0.09	3.66	–3.27	0.40	–0.35
Constant	8.02	2.19				
Eigenvalue	47.58	0.83				
Cumulative Proportion	0.98	1.00				

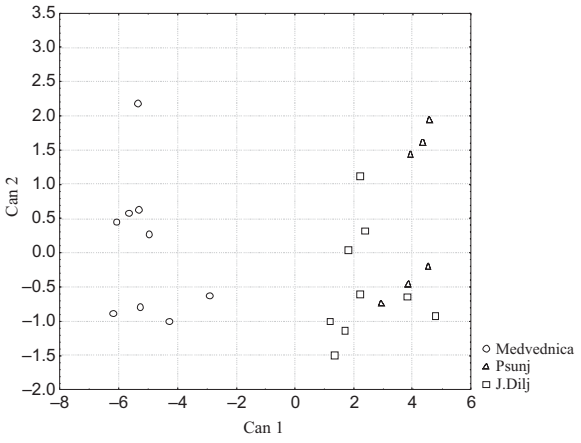

Figure 1. *The plot showing the first two canonical discriminant variables on altitudes, trees and morphological-biological characteristics of fruits and seed of the Wild Service Tree (*Sorbus torminalis *(L.) Crantz) from three sites in the Republic of Croatia.*

According to Matić and Vukelić *(7),* the Wild Service Tree occurs in continental Croatia more abundantly on hilly terrain (altitudes of 150 to 400 m) and on deep humous soils in the community with the Sessile Oak and the Hornbeam (*Epimedio-Carpinetum*/Ht. 1938/Borh. 1963). According to Đuričić *(21),* such communities found on Kalnik contain as many as 50 Wild Service Trees. Although much more rarely, the Wild Service Tree occurs on dry terrains of Slavonia in the community with the Pedunculate oak and Hornbeam (*Carpino betuli – Quercetum roboris* / Anić 1959 / Rauš 1969).

In the northern parts of its distribution range the Wild Service Tree grows on warmer positions in the lowland vegetation belt, in central Europe it occurs in the mountainous or lower mountainous belt (800–1000 m). In Greece it can be found on altitudes of up to 1000 m, in Italy up to 1100 m, on Sicily up to 1250 m, in Lebanon up to 1400 m and in the mountains of Caucus up to 1500 m. In Asia Minor (Turkey) the Wild Service Tree reaches its maximum with respect to the vertical distribution and stretches all the way up to 2200 m *(5)*.

In Romania the Wild Service Tree grows in the mountainous vegetation belt at the altitudes of 100 to 400 m *(22)*. According to K. Espahbodi *et al. (23),* the Wild Service Tree in the northern areas of Iran has the best growth and habitates at the altitudes ranging between 1500 and 1800 m on northern and north-western positions and deep soils. On these sites Wild Service Trees can reach the heights of over 32 meters and have diameters of up to 100 cm.

According to Zare *et al. (24)* the Wild Servce Tree grows on steep slopes of the western and south-western mountain ranges of Iran, on poor and usually skeletal soils in the community with oak and beech.

During research on ecological requirements and distribution of the Wild Service Tree in the Slovak Republic, data was collected from 34 localities. Most of the localities (23%) were situated at the altitudes ranging between 251 and 300 m, while 20% were at the altitude between 351 and 400 m. The least frequent were the altitudes between 401 and 450 m (15%), as well as those between 301 and 350 m. Three localities (9% for all the three) were situated at the altitudes between 451 and 500 m and between 551 and 600 m. One locality (3%) was at the altitude between 501 and 550 m and one between 701 and 750 m. More than 90% of the analyzed localities were situated at the altitude of 500 m *(25)*. In Slovakia the Wild Service Tree occurs mainly in southern regions. It grows at lower altitudes of up to 650 m while on the localities Stolické Hills near Ratkovské Bystré it reaches the altitude of 800 m *(26)*.

According to N. Barengo *et al. (27)* the Wild Service Tree bears fruit every two years or three times in four years and fruit bearing are those trees whose crowns have enough light. An estimate of the fructification for four species from the genus *Sorbus* L. from different localities in the Republic of Croatia in the period between 2003 and 2005 revealed that the mentioned species do not yield abundantly every year. A decline in yield in the period between 2003 and 2005 was evident for all the four species and on most localities. It is believed that an extremely good yield in dry 2003 physiologically exhausted the trees and led to a decline in the yield in the following two years. In 2003 the Wild Service Tree had a full and in 2004 and 2005 poor yield. Based on their ability to fructify the mentioned species exhibit the properties of post-pioneer rather than of pioneer tree species *(28)*.

In the extremely dry 2003, when this research was carried out, Wild Service Trees had a good yield on all three localities with very few variations.

According to K.K. Rasmussen *(9)* the Wild Service Tree in Denmark flowers from the end of May to the beginning of June with small variations between populations, depending microclimate, while fruits mature in October. In the northern parts of its distribution area, fruits ripen about a month later compared to the center of the distribution range *(8)* while fruits on shaded trees never fully ripen even during warm and sunny years (observations, *9*).

In Croatia the best time for collecting Wild Service Tree fruits is in the second half of September as, compared to Denmark, they ripen somewhat earlier.

In our research the average number of fruits per kilo ranged from 714 pieces on Medvednica to 885 pieces on Južni Dilj. According to Herman *(4)* the number of fruits per kilo is much larger than this and ranges from 2,600 to 2,950 pieces.

The largest average fruit weight of 1.40 g was weighed for the trees from Medvednica. The average fruit weight from Psunj was by 0.14 and from Južni Dilj by as much as 0.27 g lower than that from Medvednica. These significant differences in fruit weights and trunk diameter can lead to the conclusion that Wild Service Trees with larger diameters give bigger fruits. Fruit weight is influenced by length (R=0.82) rather than by width of the fruit (R=0.77).

K. Espahbodi *(23),* who conducted research in Iran, obtained the average fruit weight (4.000 pieces) of 1.24 g (range from 0.89 to 1.71) which coincides with the data we obtained on Psunj. The same author did not obtain statistically significant correlation between fruit weight, i.e. DBH of the Wild Service Tree and seed germination. The fruit weight was in a negative correlation to DBH (R=–0.350, p=0.027).

According to Espahbodi *et al. (23),* the average length of Wild Service Tree fruits on the territory of Iran was 15.32 mm (range from 12.75 to 18.64 mm). L. Bednorz measured an average length of Wild Service Tree fruits in Poland of 13.92 mm (range from 8.20 to 19.60 mm). The same author states that fruits usually have bigger length than width and gives an average fruit shape index of 1.20 (range from 0.87 to 1.68) which fully matches our trees from Psunj. With regard to the shape, most fruits in the Republic of Poland were widely ovoid (±57%) or globose (±41%) while only a small percentage was partially ovoid, elliptical or widely ovoid. In our research the largest average length of 15.85 mm and the shape index of 1.31 were obtained for the fruits from Medvednica at the average altitude of 499 m, followed by the average fruit length of 14.12 mm and shape index of 1.20 for Psunj, while the trees on Južni Dilj had the shortest fruits of 13.82 mm and the index of 1.18. We obtained a positive and strong correlation between fruit length and altitude (R=0.67), i.e. fruit shape index and altitude (R=0.71), which means that in Croatia the higher the altitude, the longer the fruits. In general the fruit length (FL) represents the basis for determining fruit shape (R=0.77). L. Bednorz (10) gives a table and a description of the fruit shape index of the Wild Service Tree which ranges from <1.5 to >2.5. According to the same author the morphological properties which describe the size and the shape are more variable for the seed than for fruits of the Wild Service Tree. The dimensions of fruits and seed are positively and significantly correlated and the largest correlation (R=0.72) was demonstrated between fruit length and seed length *(10)*. For McAllster *(12)* fruit dimensions are an important property for the genus *Sorbus* L. and fruit length is less variable than fruit width which varies depending on the availability of water and the number of viable seeds. There are many studies which deny this assumption. The same author points out that, in the case of the Wild Service Tree, fruit width is less variable compared to the length despite great variability in seed numbers per fruit. The dimensions of the Wild Service Tree fruits measured on three sites in Croatia match those from other countries where similar research was conducted.

Espahbodi *et al. (23)* measured an average fruit width of 11.01 mm (range from 9.46 to 12.62 mm). L. Bednorz reports an average fruit width of 11.66 mm (range from 8.20 to 15.50 mm). In our research the largest fruit width of 12.10 mm was measured on the fruits from Medvednica, while those from Psunj (11.77 mm) and Južni Dilj (11.83 mm) had almost the same width and no significant difference was recorded for this property. When determining fruit shape, width seems to be a less important property than length.

In Poland the researchers proved very little dependence between the geographic distribution of the Wild Service Tree and ten researched morphological properties of fruits and seed. Neither did they prove a statistically relevant difference between each property and the latitude and longitude *(10)*. Certain morphological properties of fruits (shape, color, number and dimensions of lenticel) and seed (shape) play an important role in differentiating between the species from the genus *Sorbus* L. *(3, 12)*. The research carried out in the Republic of Poland showed that the Wild Service Tree, unlike other five indigenous species from the genus *Sorbus* L., is the most variable species. The properties of fruits and seed do not seem to have a major role in the research of geographical variability of the Wild Service Tree in Poland *(10)*.

According to Frehner and Fürst *(29)* seed participates in the fruit mass with only 2%. The same authors also reported that 1 kilo of fruits gives between 650 and 850 seeds while there are between 65,000 and 85,000 seeds in a kilo. For Beti Piotto and Anna Di Noi *(30)* an average number of Wild Service Tree seeds in a kilo ranges from 28,000 to 56,000 (40,000 to 50,000) and the average seed germination is 70–80%.

K. Espahodi *et al. (23)* who conducted a research in Iran, did not obtain any statistically relevant correlations between seed dimensions, i.e. weight and germination percentage. The research carried out by Baskin and Naskin *(31)* and Navaro and Guitian *(32)* shows a positive impact of seed dimensions on germination. Gamieley *et al. (33)* recommend collecting larger seeds for obtaining higher germination percentages. However, this does not hold true for species from the genus *Sobus* L..

Our research did not demontrated statistically significant differences in absolute seed weight with respect to the sites. Certain values of absolute seed weight for statistically and significantly different trees with respect to DBH (age) indicate that diameter, i.e. the age of a Wild Service Tree has no impact on dimensions, i.e. absolute seed weight. However, there is a positive correlation between fruit weight and absolute seed weight (R=0.42).

Gynoecium in *Sorbus torminalis* (L.) Crantz consistently showed two carpels and formed two loculi with two ovules per each locule. Therefore, four seeds per fruit was the maximum possible number. For most authors the number of seeds per fruit ranges between 2 and 4. The research on 13 populations of the Wild Service Tree (520 fruits) led to the discovery of several fruits with 5–6 seeds. This implies three developed gynoeciums, which was unknown before *(10)*. In our study an average number of filled (sound) seeds per one fruit ranged from 1.21 on Psunj to 1.60 on Medvednica. According to L. Bednorz *(10)* the number of seeds in one fruit ranges from 0 to 6 (most often 2). Among all researched quantity properties of fruits and seeds, the author obtained the largest degree of variability for the number of seeds per fruit (CV=59.68). Out of the 13 researched Wild Service Tree populations in Poland, fruits with no seeds were discovered in five populations (especially Brekinia) *(10)*.

Most populations had an average of two seeds per fruit, but there were also populations with more than 6 seeds per fruit. The number of seeds was in a positive and significant correlation with fruit dimensions and seed length and in a negative correlation with seed width and diameter. Our research also revealed a positive correlation between the number of seeds in a fruit and fruit length (R=0.48), i.e. width (R=0.46). The study in Poland demonstrated that three morphological properties (number of lenticels on fruit, number of seeds per fruit and seed length) are the main factors contributing to the differences between populations of the Wild Service Tree *(10)*. According to the research that K. Espahbody *et al.* conducted in Iran *(23)* an average number of filled (sound) seeds per fruit was 1.91 pieces (range from 0.72 to 2.97). The authors recorded a positive correlation between the number of filled (sound) seeds per fruit and the total number of seeds per fruit (R=+0.587, p=0.001). An average number of seeds in Wild Service Tree fruits in Iran was by 0.48 pieces larger compared to all the three sites in Croatia. In K. K. Rasmussen's research *(9)* an average number of seeds in a fruit was 2.00. According to the author the number of seeds in Wild Service Tree fruits is significantly larger (F=14.3, P=0.0002) for populations in central parts of its distribution area (2.2±0.07) compared to those on northern boundaries (1.9±0.07). No significantly relevant differences were obtained for fruit dimensions or dry matter in pulp with regard to the central parts or borders of its distribution area, although Wild Service Tree fruits seem to be a bit heavier on the limits of its distribution area. When compared to fruits from the edges of the range, those from the central parts showed a significantly bigger success in propagation when expressed in dry matter of the seed (F=31.1, P<0.0001). A strong correlation between seed properties and latitude *(34, 35)* was confirmed by many other studies. A larger weight of fruits and pulp on the borders of the distribution area can be attributed to the fact that in the north most fruits never fully ripen which is why in autumn they contain more starch and moisture. It can be said that flowering starts much later near the edges of the range, more fruits are rejected *(36),* ripening takes place later *(37),* fruits are smaller, contain fewer seeds per fruit *(36, 38)* and fruit bearing is less frequent *(39)*. In their study K. K. Rasmussen *et. al.* claim that populations on the borders of the distribution area have a less successful propagation, which could affect the spreading and the range of the species. According to L. Bednorz *(10)* the number and dimensions of fruits and seeds are important biological properties which, among other things, influence the ability for generative propagation of the Wild Service Tree.

The two mentioned studies on the northern and southern limits of the species' range resulted in identical data on the numbers of seeds per fruit (1.90, 1.91), while the number of seeds for populations in the centre was by 0.30 pieces larger. Based on the data from our study, an average number of filled (sound) seeds per Wild Service Tree fruit in Croatia is by as many as 0.47 pieces lower compared to populations on borders of the distribution area. The low number of seeds per fruit can be explained by small density of Wild Service Trees in the studied populations and by small isolated populations with low gene flow between the neighboring populations as well as by the decrease in gene numbers. Due to inadequate silvicultural practices Wild Service Trees often grow in stressful ecological conditions, which can result in reduced fertilization. A positive and quite strong correlation between the number of filled (sound) seeds and seed weight (R=0.55) was obtained, which means larger fruits should be collected as they give many more filled seeds.

Nikolaeva *(40)* studied the capability of seeds from the genus *Sorbus* trees to germinate at low temperatures and in moist conditions (stratification). M. Winkler *(41)* points out that the seeds of the Service Tree and the Wild Service Tree germinate in darkness during artificial stratification. In order to break the double dormancy of Wild Service Tree seeds from Croatia, only 105 days of stratification turned out to be sufficient, which is 15 days shorter than suggested by the ISTA Rules *(18)*. After stratification at 3 °C, the seed from all three sites was ready for spring sowing in the nursery. In our case at the end of the stratification the seed from Psunj achieved the best germination percentages (44.60%), followed by Južni Dilj (38.60%) and Medvednica (16.10%). The above presented facts lead to the conclusion that the higher the altitude, the higher the level of seed dormancy and consequently longer stratification is needed. We demonstrated a positive and quite strong correlation between seed germination at the end of stratification and absolute seed weight (R=0.50) indicating that larger seeds are less dormant and require a shorter period of stratification.

Barclay and Crawford *(42)* also studied the impact of altitude of the seed origin on the duration of cold stratification for the Mountain Ash Tree. The authors concluded that Mountain Ash seeds from lower altitudes required longer periods of cold stratification, which is a complete contrast to our conclusions about the Wild Service Tree. This is an interesting fact which needs to be further studied on more species from the genus *Sorbus* L. and on more sites at different altitudes. According to Devillez *(43)* the temperature of 2 °C was sufficient for breaking the double dormancy of Mountain Ash (*Sorbus aucuparia* L.) seed and the germination which started after 50 days of cold stratification and lasted between 50 and 190 days. It is the evidence of seed variability with respect to requirements for cold stratification, i.e. of variability in degrees of dormancy within one seed lot. In a paper Barclay and Crawford *(42)* stated that Mountain Ash seeds began to germinate after 126 days of stratification (with germination below 10%) only for the three lots from lower altitudes (8, 102 and 402 m).

The research on the influence of tree age on seed germination of the Wild Service Tree in Iran revealed significant differences (p<0.05) between age (DBH) and germination percentage. The best seed germination percentage in both years when the research was conducted was obtained for the middle-aged trees of 25–35 cm di-

ameter. The dependence between the DBH class and the seed physiology from the genus *Sorbus* L. was also confirmed. The seed collected from middle-aged trees (DBH 25–35 cm) is believed to require shorter time for breaking dormancy, i.e. it is less dormant. Knowing this physiological property, seed germination can be increased and larger (more vital) seedlings can be obtained *(23)*.

Therefore, the observed differences between the three studied sites might be attributed to changed climatic and soil conditions.

Multivariate analysis further confirmed a high influence of ecological conditions on *Sorbus torminalis* (L.) Crantz. Medvednica was clearly separated from the other two locations by Can 1, which occupied 98% of the total variability and was highly correlated only with altitude. This site had the highest altitude (Table 1). The tree and fruit characteristics occupied a negligible portion of the total variability (only 2%) and were represented by Can 2 which failed to separate any of the studied sites (Figure 1).

The populations in less favorable locations (such as Medvednica in our study) are endangered due to lower sexual propagation potential. Therefore, special attention must be paid to proper forest management in such locations in order to preserve this important tree in terms of both abundance and genetic diversity.

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