

## VARIATION IN HIP AND SEPAL PARAMETERS OF INVASIVE *ROSA RUGOSA* BETWEEN SITES AND YEARS

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### Abstract

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*Rosa rugosa* is among the most invasive species in Europe, and it is considered a severe threat to the diversity and stability of coastal habitats. In Lithuania, it is a widespread invasive species occurring in coastal and inland areas. This research aimed to estimate the variation in *R. rugosa* hip and sepal parameters within and among sites from coastal and inland areas, and investigate the effects of environmental factors on the hip and sepal sizes. Field studies were performed at four coastal and three inland sites in 2008, and the studies were repeated in 2016. We collected 100 mature hips at each site and measured the hip width, hip length and sepal length. We analysed variation in hip and sepal parameters between the study years, and the effect of meteorological factors and agrochemical properties of the soil on hip and sepal sizes. This study revealed significant variation in *R. rugosa* hip width, hip length and sepal length among the studied sites. The largest hips and sepals were found in the coastal habitat at the Smeltė site, whereas the smallest hips and sepals were recorded in inland habitat at the Staviškės site, where *R. rugosa* occurred in woodland. The comparison of hip and sepal sizes at the same sites during two study years revealed irregular variation. Mean hip width and mean length of sepals in 2008 were significantly more prominent than in 2016, whereas no significant differences in hip length were found between the study years. The content of phosphorus in the soil negatively correlated, whereas the content of carbonates positively correlated with the sepal length. A strong negative relationship was found between the sunshine duration and hip length and width ratio. However, the revealed relationships of the hip and sepal parameters with the environmental factors could be a coincidence or a result of the cumulative effect of the multiple factors' interaction and should be investigated separately.

**Keywords:** coastal habitats, fruits, inland habitats, meteorological factors, reproductive traits, shrub, soil properties.

### INTRODUCTION

*Rosa rugosa* Thunb. (Rosaceae) is a rhizomatous shrub, forming dense thickets. It is recognised as an invasive alien species in several countries of Europe (WEIDEMA, 2006; GUDŽINSKAS & ŽALNERAVIČIUS, 2017; NENTWIG et al., 2018). The invasion of *R. rugosa* and its effect on native species and communities have been extensively studied in the coastal areas of Europe and North America, particularly along the coasts of the Northern Atlantic, the North Sea and the

Baltic Sea (BRUUN, 2005; ISERMANN, 2008; JØRGENSEN & KOLLMANN, 2009; HILL et al., 2010; GARBARY et al., 2013; KUNTTU & KUNTTU, 2017). A strong negative impact of *R. rugosa* has been found on the diversity of native species (ISERMANN, 2003, 2008; WEIDEMA, 2006) and the structure of coastal plant communities (BRUUN, 2005; WEIDEMA, 2006). Besides, the increasing frequency of spontaneous hybridisation of *R. rugosa* with native congeners in Europe has been noted (WEIDEMA, 2006; KELLNER et al., 2012); therefore, this process may negatively affect the genetic

stability of native *Rosa* species. Although the ecological effect of invasive *R. rugosa* is mainly negative, from the socio-economic perspective, it is frequently considered a useful plant primarily because of its ornamental and medicinal properties (HASHIDOKO, 1996; CUNJA et al., 2016; DUDRA et al., 2016; MÁRMOL et al., 2017; OLECH et al., 2017).

*Rosa rugosa* is native to the Northern Pacific region in Eastern Asia (BRUUN, 2005). In the native range, it usually grows below 100 m a. s. l. in sandy soil and mainly occupies dune, hillside, rocky shore and meadow habitats (CUIZHI & ROBERTSON, 2003; BRUUN, 2005). In Europe, this species was introduced as early as 1796 (BRUUN, 2005). Since the 19th century it has been widely cultivated in gardens, ornamental plantations, and for coastal sand stabilisation (NORDSTROM et al., 2000; BRUUN, 2005; ISERMANN, 2008).

In Lithuania, *R. rugosa* is a widely distributed alien species occurring in coastal areas of the Baltic Sea as well as in inland areas (GUDŽINSKAS, 2000; GUDŽINSKAS & ŽALNERAVIČIUS, 2017). Since the 1970s, extensive experiments on the cultivation of *R. rugosa* in seminatural ecosystems have been performed in Lithuania. It has been recommended for cultivation as an ornamental and fruit plant, for stabilisation of steep hill slopes, continental sands and coastal dunes (APALIA et al., 1978). Large scale introduction of *R. rugosa* has resulted in its wide naturalisation and further spread, particularly since the 1990s, in seminatural and natural ecosystems. Currently, it is included into the List of Invasive Species of Lithuania (GUDŽINSKAS & ŽALNERAVIČIUS, 2017).

Studying *R. rugosa* distribution and habitats invaded in Lithuania, we noted substantial variation in the size and shape of hips and sepals in coastal and inland habitats. Therefore, we had a question what factors determine the size of hips and sepals? The hip size is an essential reproductive trait, because larger hips usually contain more seeds, which play a vital role in the spread of *R. rugosa* over significant distances and invading new areas (BRUUN, 2005; KOLLMANN et al., 2009; TONG et al., 2017; ZHANG et al., 2018). Although persistent sepals do not play an essential role in reproduction, they are an integral part of the hip. The size of sepals is a functional trait because they perform photosynthesis and, at a certain level, contribute to the accumulation of organic material in the plant.

This research aimed to answer the following questions: (a) what is the variation in *R. rugosa* hip and sepal parameters at different sites?; (b) how do the analysed traits differ between years in the same population?; (c) what is the effect of the coastal and inland habitat?; (d) how do soil agrochemical characteristics and meteorological factors affect hip and sepal parameters?

## MATERIALS AND METHODS

### Study sites

Thickets of *R. rugosa*, occupying at least 100 m<sup>2</sup> in homogeneous habitat, were selected for this study. We performed a sampling of *R. rugosa* hips in two stages, in August and September of 2008 and 2016. Coastal thickets of *R. rugosa* were selected in the Curonian Spit (Neringa city), Nemirseta (Palanga city) and Smeltė (Klaipėda city). In the continental part of the country, for the study, we selected sites in Darželiai village (Varėna district), Staviškės (Vilnius city) and Pikeliai village (Raseiniai district). In total, this species was sampled at seven sites (Fig. 1, Table 1).

The habitat types of the study sites were identified and named after the EUNIS Habitat Classification (EUROPEAN ENVIRONMENTAL AGENCY, 2017). Hips of *R. rugosa* were collected from the northern fixed grey dune (B1.41), Baltic sand beach perennial community (B1.232), unmanaged xeric grassland (E1.D), unmanaged mesic grassland (E2.7) and mixed Scots pine-birch woodland (G4.4) habitats (Table 1). The coverage of *R. rugosa* shrubs at the sampling sites ranged from 30% to 70%. All sites, except for mixed Scots pine-birch woodlands, were open, well-illuminated, without or with insignificant (less than 5%) coverage of native shrubs. Coverage of the tree layer, dominated by *Pinus sylvestris* and *Betula pendula*, in the sampled mixed Scots pine-birch woodland habitat was ca. 50%.

### Sampling procedures

Individual reproductive shoots for sampling were selected with at least 1 m distance from the stand's edge and at least 2 m between sampled shoots. Two hips, the central and one lateral, were collected from the upper branch of 50 shoots. At each study site, 100 ripe hips (turned orange or red) of *R. rugosa* without evident mechanical injuries, deformations and symp-

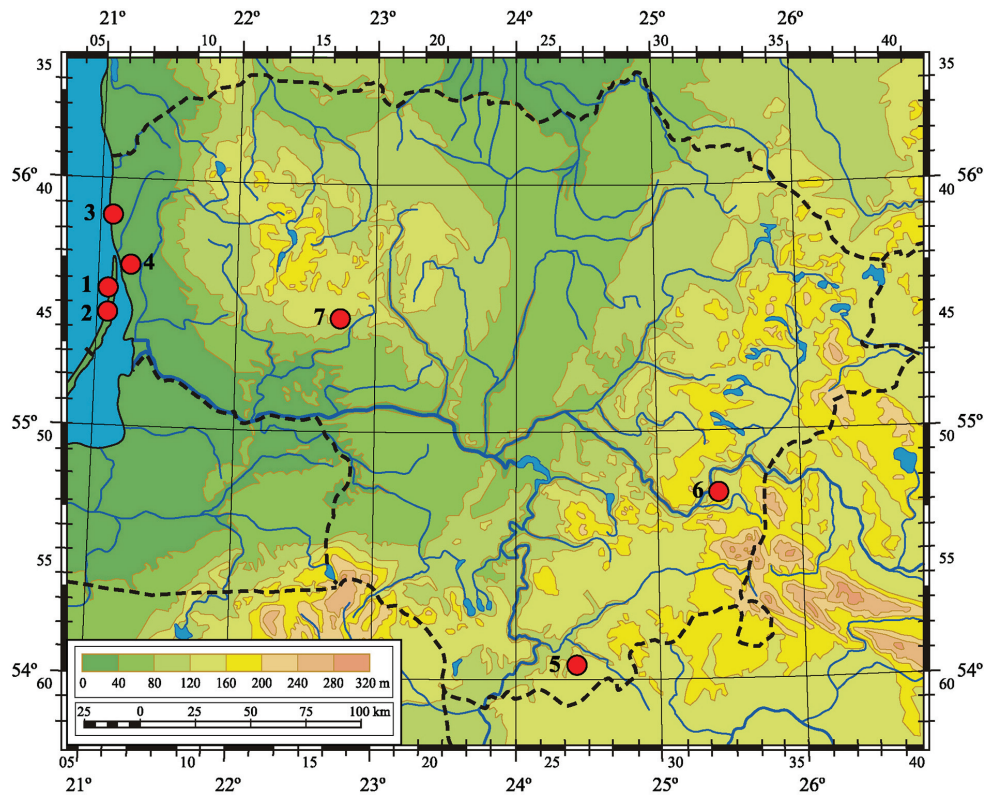


Fig. 1. Map of *Rosa rugosa* hip sampling sites in 2008 and 2016. Site numbers correspond to the numbers in Table 1

Table 1. Location of *Rosa rugosa* hip sampling sites and occupied types of habitats according to the EUNIS habitat classification

Site No.	Site name	Administrative unit	Latitude (°N)	Longitude (°E)	Elevation (m a.s.l.)	Habitat type
1	Juodkrantė	Neringa	55.950257	21.943774	6	B1.41
2	Avikalnis	Neringa	55.516227	21.116153	1	B1.41
3	Nemirseta	Palanga	55.866539	21.058786	7	B1.232
4	Smeltė	Klaipėda	55.638430	21.152712	2	B1.232
5	Darželiai	Varėna	54.012920	24.340600	116	E1.D
6	Staviškės	Vilnius	54.755192	25.336300	116	G4.4
7	Pikeliai	Raseiniai	55.463909	22.685917	144	E2.7

toms of diseases were collected. Picked up hips were placed into the labelled plastic bag and brought to the laboratory for further analysis.

The collected hips of *R. rugosa* were analysed at the laboratory the same or the following day. Hip width, length and length of the longest sepal were measured using an electronic calliper (*WZ SL 150D*) with the precision of 0.1 mm. The length of the hip was measured from the pedicel to the base of the hip neck. The width of the hip was measured approximately at its middle (Fig. 2). The ratio between the hip length and width was calculated, dividing the length by the width.

### Environmental conditions

The data on meteorological conditions of the study sites were extracted from the published Yearbooks of the Lithuanian Hydrometeorological Service (KITRIENĖ, 2009; KAZLAUSKIENĖ & KITRIENĖ, 2017). Information obtained from the closest to the study site Meteorological Station was considered. The mean temperature of January and July, the sum of precipitation of the year and duration of annual sunshine (in hours) were analysed.

Mixed soil samples of ca. 1 kg, composed of four subsamples (ca. 0.25 kg) taken across the studied stand of *R. rugosa*, were prepared for agrochemical

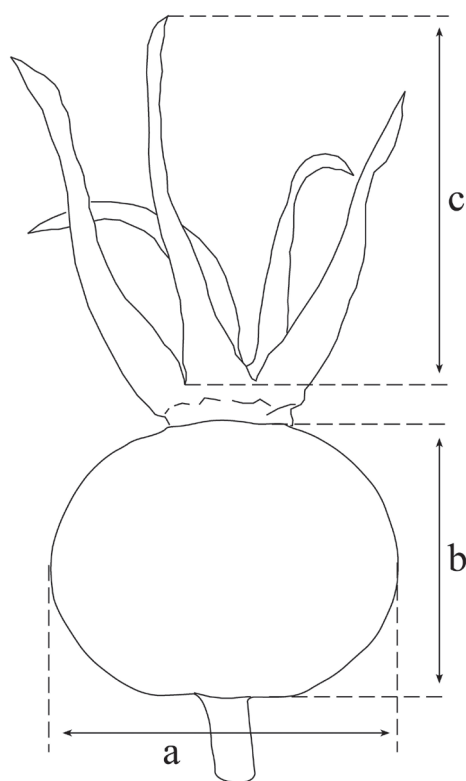


Fig. 2. Scheme of the measurement of the hip width (a), length (b) and the sepal length (c)

analyses. The soil was dug from 0–30 cm depth after removing the living plants and the layer of plant debris. Agrochemical analyses of soil samples were performed at the Laboratory of Agrochemical Analyses of the Lithuanian Research Centre for Agriculture and Forestry (Kaunas, Lithuania) according to certified procedures and protocols (VOLUNGEVIČIUS et al., 2015). The following agrochemical parameters were analysed: quantity of humus (%), pH (in water solution, mol/l, in KCl suspension), the content of phosphorus ( $P_2O_5$ ), potassium ( $K_2O$ ), total nitrogen and total carbonates ( $CaCO_3$ ) (mg/kg).

### Statistical analyses

The results of descriptive statistical analysis were reported as means and standard deviations (mean  $\pm$  SD). The normality of data distribution was evaluated using Shapiro-Wilk's test. The data on the hip morphological parameters (width and length of hips, length of sepals) were normally distributed; therefore, parametric tests were applied. One-way ANOVA tests were used to compare differences between hip

length, hip width, hip length and width ratio and the length of sepals, and  $F$  value was presented, indicating in parenthesis the number of degrees of freedom ( $df$ ) between groups and within groups. Student's  $t$ -test was applied to determine the difference between hip and sepal parameter between years two data sets. As most of the data sets on meteorological conditions and soil properties were non-normally distributed, Spearman's rank-order correlation ( $r_s$ ) was used to test for dependencies between the environmental data and means of morphological parameters; however, Pearson's linear correlation ( $r$ ) was used to test dependencies between normally distributed datasets of morphological characters. Differences and correlations were considered significant at  $p < 0.05$ . All calculations were performed using PAST 3.20 (HAMMER et al. 2001).

## RESULTS

### Hip and sepal traits

The analysis of hip measurements revealed that mean hip width at individual study sites ranged from  $16.11 \pm 2.59$  mm (Staviškės) to  $29.48 \pm 2.57$  mm (Smeltė) in 2008 and from  $15.89 \pm 2.42$  mm (Staviškės) to  $28.67 \pm 4.03$  (Smeltė) in 2016 (Table 2). The width of individual hips at the study sites ranged from 12.0 mm to 39.0 mm in 2008 and from 11.1 mm to 45.3 mm in 2016. ANOVA tests revealed significant differences between the means of hip width among study sites in 2008 ( $F(6, 693) = 303.2$ ,  $p < 0.001$ ) and 2016 ( $F(6, 693) = 213.1$ ,  $p < 0.001$ ).

The mean length of hips at the study sites ranged from  $12.37 \pm 2.05$  mm (Staviškės) to  $19.49 \pm 2.31$  mm (Pikeliai) in 2008 and from  $12.36 \pm 1.68$  (Staviškės) to  $21.33 \pm 2.97$  (Pikeliai) in 2016 (Table 2). The length of individual hips at the study sites ranged from 9.1 mm to 29.0 mm in 2008 and from 8.7 mm to 45.5 mm in 2016. ANOVA tests revealed significant differences between the means of hip length among study sites in 2008 ( $F(6, 693) = 157.9$ ,  $p < 0.001$ ) and 2016 ( $F(6, 693) = 154.8$ ,  $p < 0.001$ ).

The ratio between hip length and width, which describes a dominant form of hips, at the study sites ranged from  $0.64 \pm 0.05$  (Smeltė) to  $0.87 \pm 0.08$  (Darželiai) in 2008 and from  $0.73 \pm 0.07$  (Juodkrantė) to  $0.82 \pm 0.08$  (Darželiai) in 2016 (Table 2). The ratio of individual hip length and width ranged from



Table 2. Descriptive statistics of *Rosa rugosa* hip and sepal characters at the study sites in 2008 and 2016 (mean  $\pm$  SD)

Sites	Year of sampling	Hip width (mm)	Hip length (mm)	Hip length and width ratio	Sepal length (mm)
Juodkrantė	2008	24.21 $\pm$ 2.46	16.94 $\pm$ 1.79	0.70 $\pm$ 0.06	29.22 $\pm$ 4.95
	2016	24.75 $\pm$ 2.62	17.96 $\pm$ 1.76	0.73 $\pm$ 0.07	23.37 $\pm$ 3.55
Avikalnis	2008	25.07 $\pm$ 3.11	18.03 $\pm$ 2.44	0.72 $\pm$ 0.08	30.87 $\pm$ 5.57
	2016	23.83 $\pm$ 3.28	17.94 $\pm$ 3.50	0.75 $\pm$ 0.10	25.75 $\pm$ 5.23
Nemirseta	2008	27.07 $\pm$ 2.77	18.77 $\pm$ 1.67	0.70 $\pm$ 0.04	27.19 $\pm$ 4.41
	2016	22.22 $\pm$ 2.74	17.07 $\pm$ 1.71	0.77 $\pm$ 0.08	20.47 $\pm$ 3.70
Smeltė	2008	29.48 $\pm$ 2.57	18.83 $\pm$ 1.68	0.64 $\pm$ 0.05	35.51 $\pm$ 6.26
	2016	28.67 $\pm$ 4.03	20.82 $\pm$ 2.35	0.73 $\pm$ 0.09	29.21 $\pm$ 6.74
<b>All coastal pooled</b>	2008	<b>26.46 <math>\pm</math> 3.40</b>	<b>18.14 <math>\pm</math> 2.06</b>	<b>0.69 <math>\pm</math> 0.07</b>	<b>30.70 <math>\pm</math> 6.15</b>
	2016	<b>24.87 <math>\pm</math> 3.99</b>	<b>18.45 <math>\pm</math> 2.81</b>	<b>0.75 <math>\pm</math> 0.09</b>	<b>24.70 <math>\pm</math> 5.91</b>
Darželiai	2008	22.19 $\pm$ 2.11	19.27 $\pm$ 1.78	0.87 $\pm$ 0.08	31.20 $\pm$ 5.14
	2016	21.41 $\pm$ 2.26	17.45 $\pm$ 1.92	0.82 $\pm$ 0.08	30.27 $\pm$ 5.01
Staviškės	2008	16.11 $\pm$ 2.59	12.37 $\pm$ 2.05	0.77 $\pm$ 0.08	20.99 $\pm$ 2.96
	2016	15.89 $\pm$ 2.42	12.36 $\pm$ 1.68	0.78 $\pm$ 0.07	19.49 $\pm$ 4.22
Pikeliai	2008	28.80 $\pm$ 3.69	19.49 $\pm$ 2.31	0.68 $\pm$ 0.06	29.42 $\pm$ 4.57
	2016	28.54 $\pm$ 3.47	21.33 $\pm$ 2.97	0.75 $\pm$ 0.10	35.09 $\pm$ 5.75
<b>All inland pooled</b>	2008	<b>22.37 <math>\pm</math> 5.75</b>	<b>17.04 <math>\pm</math> 3.90</b>	<b>0.77 <math>\pm</math> 0.11</b>	<b>27.20 <math>\pm</math> 6.17</b>
	2016	<b>21.95 <math>\pm</math> 5.87</b>	<b>17.05 <math>\pm</math> 4.31</b>	<b>0.78 <math>\pm</math> 0.09</b>	<b>28.28 <math>\pm</math> 8.24</b>
<b>All sites pooled</b>	2008	<b>24.70 <math>\pm</math> 4.98</b>	<b>17.67 <math>\pm</math> 3.03</b>	<b>0.73 <math>\pm</math> 0.10</b>	<b>29.20 <math>\pm</math> 6.39</b>
	2016	<b>23.62 <math>\pm</math> 5.09</b>	<b>17.84 <math>\pm</math> 3.60</b>	<b>0.76 <math>\pm</math> 0.09</b>	<b>26.24 <math>\pm</math> 7.22</b>

0.50 to 1.11 in 2008 and from 0.40 to 1.34 in 2016. Thus, the form of hips can be defined as ranging from strongly depressed to ovoid. ANOVA tests revealed significant differences between the ratio of hip length and width among populations in 2008 ( $F(6, 693) = 130.9$ ,  $p < 0.001$ ) and 2016 ( $F(6, 693) = 13.4$ ,  $p < 0.001$ ).

The mean length of sepals at individual study sites ranged from 20.99  $\pm$  2.96 mm (Staviškės) to 35.51  $\pm$  6.26 mm (Smeltė) in 2008 and from 19.49  $\pm$  4.22 mm (Staviškės) to 35.09  $\pm$  5.75 mm (Pikeliai) in 2016 (Table 2). The length of sepals on individual hips ranged from 14.1 mm to 53.0 mm long in 2008 and from 11.5 mm to 51.0 mm in 2016. ANOVA tests revealed significant differences between the length of sepals among the study sites in 2008 ( $F(6, 693) = 81.4$ ,  $p < 0.001$ ) and in 2016 ( $F(6, 693) = 127.2$ ,  $p < 0.001$ ).

### Variation in different years

Comparing hip features and sepal length at the same sites in two study years applying Student's  $t$ -test revealed an irregular pattern of variation. Differences in the hip width were nonsignificant at four study sites in 2008 and 2016. At three study sites,

hips were significantly wider in 2008 than in 2016. The most significant differences in the hip width between years were registered in Nemirseta (Table 2, Fig. 3). The hip length was significantly different in 2008 and 2016 at all sites, except for Avikalnis and Staviškės (Fig. 3). Although the hip width in 2008 was the same or more prominent than in 2016, the hip lengths at Juodkrantė, Smeltė and Pikeliai sites were larger, whereas, at Nemirseta and Darželiai, it was smaller in 2016 than in 2008 (Table 2, Fig. 3).

The ratio of hip length and width in 2008 and 2016 was significantly different at all study sites, except Staviškės. The analysis revealed that the ratio of hip length and width was larger in 2016 than in 2008 at all coastal sites, whereas at inland sites, the ratio varied irregularly (Table 2, Fig. 3). Thus, in 2016, the hips of *R. rugosa* occurring in coastal habitats were less compressed than in 2008.

The sepals' length was also significantly different between years at all sites, except for Darželiai (Table 2, Fig. 3). The analysis revealed that sepals in 2008 were more extended than in 2016 at all sites, except for Pikeliai. It should be noted that at the Staviškės site, the length of sepals was significantly different in 2008 and 2016. In contrast, no significant differences

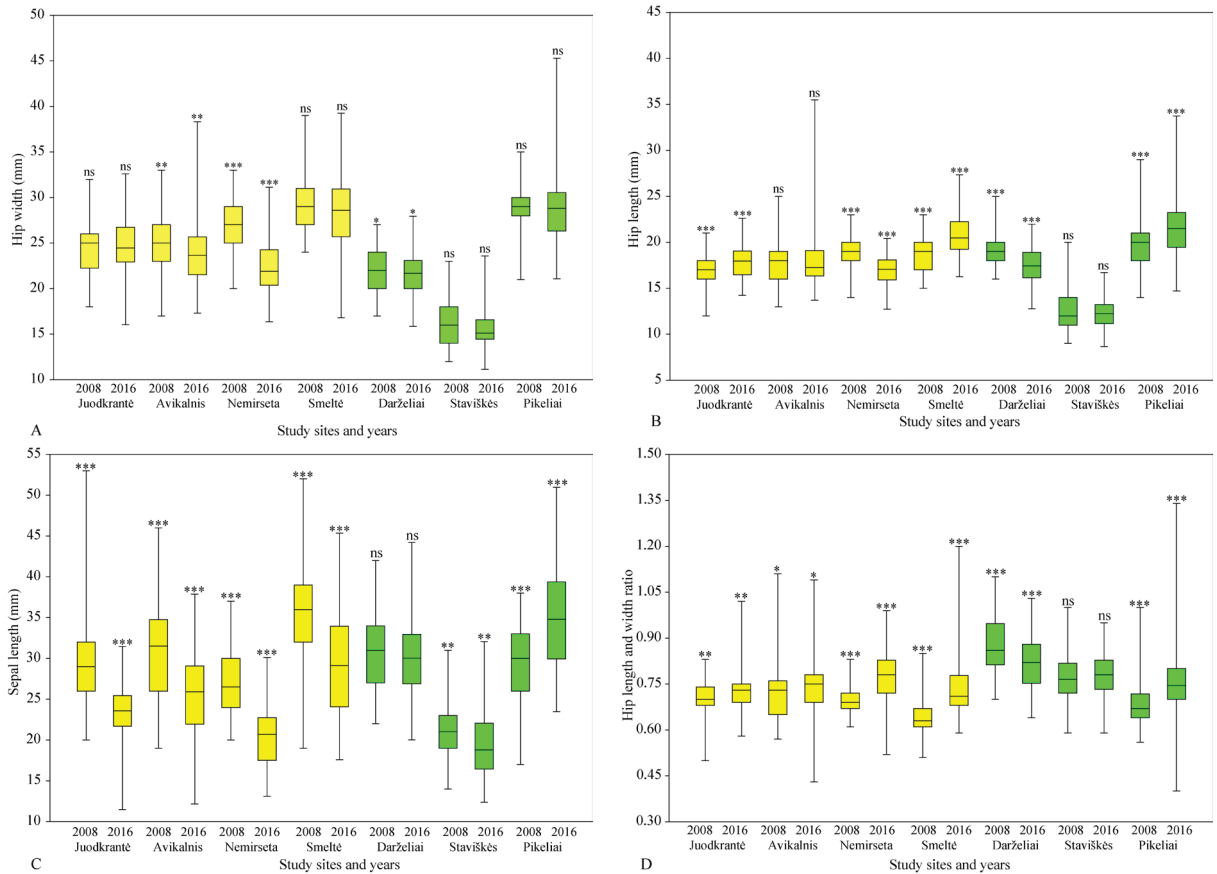


Fig. 3. Box plots with a comparison of hip length (A), hip width (B), sepal length (C) and the ratio between hip length and width (D) in *Rosa rugosa* populations in 2008 and 2016. The box represents the second and third quartiles (25–75%), horizontal line inside the box represents the median, and whiskers represent the minimum and maximum values. Yellow box plots represent coastal and green box plots represent inland habitats. Significance of differences between the study years at the same site according to Student's *t*-test results is indicated above the whiskers: \* –  $p < 0.05$ ; \*\* –  $p < 0.01$ ; \*\*\* –  $p < 0.001$ ; ns – non-significant

of all analysed hip parameters were found at this site between the study years.

Data analysis on the hip parameters and sepal length of pooled coastal, inland and all sites between the study years revealed interesting regularities. According to Student's *t*-test results, the hip width at all sites pooled was significantly larger ( $t = 4.04$ ,  $p < 0.001$ ) in 2008 than in 2016. At coastal sites, hips were also significantly wider ( $t = 6.06$ ,  $p < 0.001$ ) in 2008 than in 2016, whereas at inland sites differences were nonsignificant ( $t = 0.88$ ,  $p = 0.377$ ) between years. In contrast, hips in 2008 were shorter than in 2016 (Table 2), however, differences were nonsignificant at all sites pooled ( $t = 0.98$ ,  $p = 0.325$ ), at coastal ( $t = 1.75$ ,  $p = 0.081$ ) and inland ( $t = 0.01$ ,  $p = 0.992$ ) sites. The same trend was found analysing

the hip length and width ratio. The ratio was significantly larger in 2016 than in 2008 at all sites pooled ( $t = 7.46$ ,  $p < 0.001$ ), however, at inland sites the difference between years was nonsignificant ( $t = 1.28$ ,  $p = 0.202$ ), whereas at coastal sites the difference was significant ( $t = 10.48$ ,  $p < 0.001$ ). Thus, hips in 2016 were generally less compressed than in 2008, particularly at coastal sites. A somewhat different pattern of sepal length variation between the study years was found. Although sepals at all sites pooled were significantly longer in 2008 than in 2016 ( $t = 8.13$ ,  $p < 0.001$ ), at inland sites differences were nonsignificant ( $t = 1.82$ ,  $p = 0.069$ ) and slightly shorter in 2008 than in 2016. In contrast, at coastal sites, sepals were significantly longer ( $t = 14.07$ ,  $p < 0.001$ ) in 2008 than in 2016. Thus, differences in all analysed

parameters at inland sites between years were non-significant, whereas these parameters at coastal habitats were significantly different.

### Effect of environmental conditions

The mean annual temperature at the study sites in 2008 and 2016 varied insignificantly. At the coastal sites, it ranged from 8.7°C to 9.4°C in 2008 and from 8.2°C to 9.1°C in 2016. At the inland sites, the mean annual temperature went from 7.8°C to 8.1°C in 2008 and from 7.3°C to 7.4°C in 2016. The mean temperature of January in 2008 ranged from -1.6°C to 1.1°C, whereas in 2016, it ranged from -7.7°C to -3.9°C. The mean temperature of June in 2008 (varied from 15.1°C to 16.8°C) was lower than in 2016 (from 15.9°C to 17.4°C). The sum of annual precipitation in 2008 ranged from 688.1 mm to 886.5 mm, and it was higher than in 2016, when it ranged from 686.4 mm to 848.3 mm. The annual duration of the sunshine comprised 2060–2067 h at the coastal sites, and 1612–1770 h at the inland sites in 2008, whereas in 2016, it comprised 1911–2001 h at the coastal, and 1581–1603 h at the inland habitats. However, a few statistically significant relationships were found between the values of hip and sepal parameters and meteorological factors. A strong negative correlation was found between the annual duration of the sunshine and the hip length and width ratio ( $r_s = -0.71$ ,  $p = 0.004$ ). Significant moderate negative correlations were also found between the hip length and width ratio and the mean annual temperature ( $r_s = -0.55$ ,  $p = 0.040$ ) as well as the sum of annual precipitation ( $r_s = -0.54$ ,  $p = 0.048$ ). The hip width also negatively correlated with the mean June temperature ( $r_s = -0.53$ ,  $p = 0.049$ ).

The content of total nitrogen in the soil at *R. rugosa* sites, in general, was low and ranged from 0% to 0.48%. The content of phosphorus and potassium varied significantly between the study sites (their content ranged from 23 mg/kg to 697 mg/kg and from 14 mg/kg to 187 mg/kg, respectively). Humus content in the soil of the study sites was in general low, and only at Pikeliai sites, the soil contained a moderate amount of humus (3.66%). Soil pH in the habitats of the studied sites was close to neutral or slightly alkaline (pH 6.3–7.6). Differences between the agrochemical properties of the soil samples from the same sites in 2008 and 2016 were nonsignificant.

The analysis revealed a few significant correlations between the agrochemical properties of the soil and hip and sepal parameters. A moderate negative correlation was found between the content of phosphorus in the soil and sepal length ( $r_s = -0.58$ ,  $p = 0.029$ ), and a moderate positive correlation was found between the content of carbonates in the soil and sepal length ( $r_s = 0.67$ ,  $p = 0.009$ ).

## DISCUSSION

### Hip and sepal sizes

Quite a few studies on the variation in *R. rugosa* hip and sepal parameters have been performed in the native and invasive ranges of the species. Mature hips of *R. rugosa* are usually characterised as depressed-globose, 15–20 mm (BRUUN, 2005) or 18–20 mm (LEWIS et al., 2014) long and 20–25 mm wide (CUIZHI & ROBERTSON, 2003; BRUUN, 2005; LEWIS et al., 2014). The results of this study revealed specific differences in hip sizes, particularly at a site level. Although mean values of the hip width of the pooled sites are comparable with the hip width reported by other authors (CUIZHI & ROBERTSON, 2003; BRUUN, 2005; LEWIS et al., 2014), at two studied sites, mean width significantly exceeded the reported values (Table 2). In the populations from China, the mean hip width range from  $20.40 \pm 5.00$  mm to  $24.40 \pm 3.30$  mm (TONG et al., 2017). Thus, the mean values of the hip width at two sites (Smeltė and Pikeliai) from Lithuania exceeded the values of those from China.

Mean hip length at the sites from Lithuania (Table 2) slightly exceeded mean length values reported by other authors (CUIZHI & ROBERTSON, 2003; BRUUN, 2005; LEWIS et al., 2014). The reported hip length values from China range from  $16.90 \pm 3.00$  mm to  $20.30 \pm 3.60$  mm (TONG et al., 2017). Thus, the mean hip length in the studied populations of *R. rugosa* in China and Lithuania (Table 2) are similar.

We suppose that at least some populations of *R. rugosa* with significantly wider hips may represent descendants of purposefully selected accessions or cultivars with large hips (BUTKIENĖ, 1971; MONDER, 2012). According to BUTKIENĖ (1971), at least 50 accessions of *R. rugosa* obtained from collections, nurseries and other sources have been cultivated for experiments and used for further propagation in

Lithuania since the mid-1960s. Furthermore, studies on the genetic diversity of *R. rugosa* in the native and invasive ranges have revealed its multiple introductions from East Asia and a large genetic diversity of invasive populations (KELAGER et al., 2013) and support our presumption.

ZHANG et al. (2018) have reported that the mean hip length and width ratio in two studied native populations from China is  $0.94 \pm 0.11$  (range 0.80–1.18), whereas the mean ratio in five populations in its invasive range from Germany, Denmark and Sweden is significantly lower,  $0.72 \pm 0.09$  (range 0.59–1.02). Our results are comparable with the native and invasive populations; however, the hip length and width ratio of individual hips from Lithuania varied in a broader range (0.40–1.34). It should be noted that the hip length and width ratio in Darželiai ( $0.87 \pm 0.08$ ) was close to the value reported for two populations from China (ZHANG et al., 2018). This fact enables us to suppose that *R. rugosa* in Darželiai maybe represents wild accession of the species, which has not undergone breeding.

Quite contrasting results of *R. rugosa* hip sizes have been obtained by CUNJA et al. (2016). They have analysed 30 hips of *R. rugosa* cultivated in Volčji Potok Arboretum (Central Slovenia) and have revealed that the mean length and width of the studied hips is the same ( $15.90 \pm 0.40$  mm long and  $15.90 \pm 0.40$  mm wide), and mean length and width ratio is  $1.01 \pm 0.02$  (the results expressed as mean  $\pm$  SE). The mean length of hips from Slovenia is the same as the smallest mean length revealed in Lithuania at the site level in Staviškės. The study's authors have indicated that hips are collected from five adjacent plants (CUNJA et al., 2016); therefore, the sampled plants might represent the same clone with small, uniform, almost perfectly globose hips. Interestingly, similar results have been reported from one population in China, where the length and width of hips are nearly the same ( $20.40 \pm 0.50$  mm and  $20.20 \pm 3.60$  mm, respectively), and the ratio between the hip width and length is  $1.00 \pm 0.15$  (TONG et al., 2017). In other populations from China, studied by TONG et al. (2017), the ratio between the hip length and width ranges from  $0.70 \pm 0.20$  to  $0.81 \pm 0.17$  and is like the ratio reported from the populations in Germany, Denmark and Sweden (ZHANG et al., 2018) and similar to that revealed during this study. Therefore, it is

quite probable that the almost perfectly globose hips of *R. rugosa* is an inherited character rather than influenced by environmental conditions.

It is usually indicated that the hips of *R. rugosa* have 20–30 mm long erect sepals (CUIZHI & ROBERTSON, 2003; BRUUN, 2005; LEWIS et al., 2014). The results of our study revealed significant variation in the mean sepal length of the studied populations. Sepals were relatively short and quite uniform at some sites, whereas at other sites, they tended to be much longer, and their length was much more variable (Table 2). The values of mean sepal length at two studied sites, Smeltė and Pikeliai, were significantly more significant than the reported maximum sepal length (Table 2). During this study, we also noticed that exceptionally long sepals were characteristic of almost all hips of the same shrub, and it enabled us to suppose that this feature may be determined by the genetic properties of the individual.

### Variation in different years

Variation in hip and sepal parameters at the same sites in different years was irregular. In Nemirseta, all values of the hip and sepal parameters were significantly different between the study years. In contrast, at other sites, significant differences were found between one, two or three analysed characters (Table 2, Fig. 3). Such an intricate variation cannot be explained by agrochemical properties of the soil, because differences in all analysed soil features were nonsignificant or even the same in different years. Meteorological conditions also do not explain such variation in years, because the same characters varied irregularly even at closely located coastal sites (Juodkrantė, Avikalnis, Smeltė and Nemirseta) under almost identical meteorological conditions (Table 2, Fig. 3). Analysis of the results on variation in hip and sepal parameters between years according to the site location revealed certain regularities. We found that the mean values of the studied individual parameters at coastal and inland sites also varied irregularly between the study years (Table 2). It should be noted that differences in all studied parameters at inland sites pooled were nonsignificant between the two study years. Differences in hip length were also nonsignificant at coastal pooled sites between the study years. Such a pattern of variation suggests the effects of meteorological conditions. However, revealed re-



liable correlations did not support this presumption. The variation might be influenced by the microclimatic conditions or other local ecological factors existing at the study sites, particularly in coastal areas, and not analysed during this research (CONTI et al., 2017; OHLER et al., 2020).

Irregular hip and sepal parameter variation in years may also depend on different ageing of fertile shoots of *R. rugosa*. It is possible that the hip and sepal size changes with the increase of absolute age of a shoot (WENK & FALSTER, 2015; JOHANSSON et al., 2018); however, this phenomenon should be studied separately under experimental conditions. Hip and sepal size may also be influenced by the total hip yield on an individual shrub in a particular year.

### Effects of environmental conditions

The effect of meteorological conditions on the traits of *R. rugosa*, including the characteristics of hips, has been analysed for five sites in China (TONG et al., 2017). They have found only two reliable correlations between the hip parameters and meteorological conditions: between annual precipitation and hip width, and the length and width ratio. Surprisingly, we found a negative correlation between the sum of annual precipitation and the hip length and width ratio. This relationship contradicts the relationship revealed in China (TONG et al., 2017); however, it is hard to explain the cause of this phenomenon, and further studies based on more sampling sites are required. We also found a strong significant negative correlation between the annual duration of the sunshine and the hip length and width ratio. Moderate negative correlations between the mean annual temperature, mean June temperature and the hip length and width ratio were found. It should be noted that similar results have been obtained in China. TONG et al. (2017) have found a negative, although statistically unreliable, the correlation between mean annual temperature and hip length. We suppose that reaction of *R. rugosa* to meteorological factors may be slow and delayed for a certain period, like in some tree species (KOPROWSKI et al., 2012).

Many plant species occur in certain types of soils. The soil chemistry may strongly affect the growth of a plant, its competitiveness and expression of growth, and functional and reproductive traits (FUKAMI & NAKAJIMA, 2013; SUDING et al., 2013). Phosphorus is a

key mineral nutrient required for plant growth, fruit set and plant metabolism (HOLFORD, 1997; LAMBERS et al., 2011). However, we found a moderate negative correlation between phosphorus content in the soil and sepal length. Thus, *R. rugosa* in the soils with higher phosphorus content produce shorter sepals. A moderate positive correlation between carbonates' content in the soil and sepal length was found in this study. In our opinion, the revealed relationships of sepal parameters with the soil agrochemical properties could be a coincidence or a result of the cumulative effect of the interaction of multiple factors and should be investigated separately.

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## INVAZINIO RAUKŠLĖTALAPIO ERŠKĖČIO (*ROSA RUGOSA*) VAISIŲ IR TAURĖLAPIŲ DYDŽIO VARIACIJA TARP POPULIACIJŲ SKIRTINGAIS METAIS

Zigmantas GUDŽINSKAS, Mindaugas RASIMAVIČIUS

### Santrauka

Raukšlėtalapio erškėtis (*Rosa rugosa*, Rosaceae) Europoje yra viena labiausiai paplitusių invazinių augalų rūšių. Didžiausią pavojų ji kelia pajūrio buveinių stabilumui ir jų biologinei įvairovei. Lietuvoje *R. rugosa* yra invazinė rūšis, plačiai paplitusi pajūrio kopose ir žemyninėse pievų, smėlynų bei pamiškių buveinėse. Europoje gana plačiai tyrinėtas *R. rugosa* ekologinis poveikis, tačiau duomenų apie augalo reprodukcines savybes ir jų priklausomybę nuo aplinkos sąlygų beveik nėra. Šio tyrimo tikslas – ištirti *R. rugosa* vaisių dydžio ir taurėlapių ilgio variaciją ir šių rodiklių priklausomybę nuo aplinkos sąlygų. Tyrimų medžiaga rinkta 2008 ir 2016 metais. Ištirtos septynios *R. rugosa* populiacijos, esančios pajūrio kopų, žemyninių pievų ir miškų buveinėse. Kiekvienoje populiacijoje buvo surinkta po 100 sunokusių sveikų vaisių. Išmatuotas kiekvieno vaisiaus skersmuo, ilgis ir ilgiausio taurėlapio ilgis. Išnagrinėjus surinktus duomenis buvo nustatyti reikšmingi *R. rugosa* vaisių skersmens, ilgio ir taurėlapių ilgio skirtumai tarp taisy pačiais metais tirtų populiacijų. Nustatyta, kad tirtose populiacijose vidutinis vaisių skersmuo 2008 m. ( $24,70 \pm 4,98$  mm) buvo reikšmingai didesnis negu

2016 m. ( $23,62 \pm 5,09$  mm). Vidutinis vaisių ilgis 2008 m. ( $17,67 \pm 3,03$  mm) ir 2016 m. ( $17,84 \pm 3,60$  mm) reikšmingai nesiskyrė. Vidutinis taurėlapių ilgis tirtose populiacijose 2008 m. buvo reikšmingai didesnis ( $29,20 \pm 6,39$  mm) negu 2016 m. ( $26,24 \pm 7,22$  mm). Nustatytas stiprus neigiamas koreliacinis ryšys tarp saulės švytėjimo trukmės ir vaisiaus ilgio bei skersmens santykio ( $r_s = -0,71$ ,  $p = 0,004$ ). Vidutinio stiprumo neigiamas ir reikšmingas koreliacinis ryšys nustatytas tarp vaisiaus ilgio ir skersmens santykio bei vidutinės metinės temperatūros ( $r_s = -0,55$ ,  $p = 0,040$ ). Išnagrinėjus duomenis paaiškėjo, kad tarp fosforo kiekio dirvožemyje ir taurėlapių ilgio yra reikšmingas neigiamas vidutinio stiprumo koreliacinis ryšys ( $r_s = -0,58$ ,  $p = 0,029$ ), o tarp karbonatų kiekio dirvožemyje ir taurėlapių ilgio yra vidutinio stiprumo teigiamas koreliacinis ryšys ( $r_s = 0,67$ ,  $p = 0,009$ ). Lietuvoje pajūrio buveinėse *R. rugosa* vaisiai buvo didesni negu natūraliame areale Kinijoje. Žemyninėse buveinėse augančių *R. rugosa* vaisių dydis labai nevienodas, bet, norint tiksliau įvertinti jų variacijos priklausomybę nuo buveinių sąlygų, būtini didesnės apimties tyrimai.