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MORPHOLOGY AND VOLATILE COMPOUNDS INVESTIGATION IN 'FRAGRANT FRAYLA' COLLECTION OF GARDEN ROSES

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SUMMARY

The aim of this study was to investigate the morphological traits and fragrance-related volatile compounds in three garden rose cultivars from the 'Fragrant Frayla' collection: 'Draga Frayla', 'Jelena Frayla', and 'Lenka Frayla', bred by the private breeding company Pheno Geno Roses. The roses were cultivated under open-field conditions in Temerin, Serbia, without irrigation and chemical treatments. Vegetative and generative properties were assessed in June and September 2023, while headspace volatile extraction and gas chromatography–mass spectrometry (GC-MS) were employed to identify scent-related volatiles. All three cultivars exhibited high ornamental value, with shrub heights ranging from 47 to 67 cm, semi-upright to upright growth habits, double flowers with diameters from 6.6 to 8.2 cm, and petal counts from 35.8 to 83.8. Upon sensory evaluations, 'Draga Frayla', 'Jelena Frayla', and 'Lenka Frayla' were characterized by moderately strong, strong and moderate fragrances, respectively. Volatile analysis detected the presence of phenylethyl alcohol (up to 57.31% in 'Draga Frayla'), terpenoids (a total of 28.2% for citronellol, geraniol, and nerol, found exclusively in 'Jelena Frayla'), and hydrocarbons. Hydrocarbons containing fewer than 30 C-atoms were predominantly found in 'Draga Frayla' (accounting for approximately 25% of the total peak area), while those with more than 30 C-atoms were present at less than 20% in the strongly scented roses. The highest number of volatiles was detected in 'Jelena Frayla', the rose cultivar identified as the most fragrant. The results revealed a correlation between strong fragrance intensity and elevated levels of phenylethyl alcohol and alcoholic monoterpenes, whereas a diverse array of hydrocarbons, rather than their concentration, appeared to enhance scent emission.

Key words:
fragrance, GC-MS analysis, landscaping, Rosa × hybrida, selection, volatiles

Abbreviations:
GC-MS - gas chromatography–mass spectrometry

INTRODUCTION

The rose (*Rosa* spp.) represents one of the most valuable horticultural plants, domesticated since ancient time for its fragrance and medicinal properties. Today, roses are widely appreciated for their high ornamental value as landscaping plants and cut flowers, as a raw material in the production of cosmetics, pharmaceuticals and therapeutic products, as well as a source of functional food (Kalisz et al., 2023; Narandžić et al., 2023; Kunc et al., 2024). The wide spectrum of rose cultivars has resulted from a long hybridization process, which included a dozen wild rose species, as well as roses domesticated in Europe, the Middle East, and those originating from China (Baudino et al., 2019). Despite the complex hybridization, there are currently over 30,000 new rose varieties, featuring a diverse array of appearances, colors, fragrances, and flower shapes, as well as differing chemical compositions.

Significant variation in nearly all morphological traits observed in roses offers numerous possibilities for selecting varieties with commercially important properties, including ever-blooming, tolerance to biotic and abiotic stressors, abundant flowering, thornlessness, desirable colors, and other features (Singh et al., 2020). Screening valuable morphological properties is essential for determining accessions present in natural habitats that can be utilized in future rose breeding programs. The development of cultivars combining desirable characteristics, such as improved adaptability to unfavorable climate factors, tolerance to different soils, resistance to pests and diseases, and preferred ornamental features, has facilitated the increased production of low-maintenance roses (Zlesak et al., 2017).

The fragrance of roses originates from numerous compounds, with some species and varieties containing hundreds of distinct molecules. Scents from European and Chinese ancestors are combined in modern rose fragrances through breeding, creating unique scents that often cannot be found in nature (Baudino et al., 2019; Shi & Zhang, 2022). Regardless of many efforts to achieve desirable fragrances in commercially distributed roses, breeders often fail to deliver scented cultivars intended for use in landscaping or as cut flowers. The fragrance of roses is a key factor in attracting pollinators and repelling pests (Božanić Tanjga et al., 2022). Captured and preserved in various rose products (essential oils, rose water, candles, perfumes, tea, etc.), rose fragrance offers numerous health benefits for humans. It provides sensory pleasure, which can influence memory and emotional state, helping to reduce stress and boost the immune system (Harman, 2006). Due to their rich chemical composition, roses possess strong therapeutic properties, enabling the use of essential oils and extracts as respiratory antiseptics, decongestants, anti-inflammatories, expectorants, mucolytics, and antioxidants (Mileva et al., 2021). The role of roses in aromatherapy has long been recognized, contributing to the creation of therapeutic green spaces such as aromatic botanical gardens, night gardens, and sensory gardens for the visually impaired (Yang et al., 2020). Therefore, it is of utmost importance to identify and understand the role and formation of volatiles present in rose cultivars (Shalit et al., 2004). Different scent-related volatile compounds and their combinations are deemed responsible for various fragrances found in roses, such as fruity, floral, sweet, rose-like, fresh, or spicy (Oyama-Okubo & Mikanagi, 2024).

Nowadays, garden roses are primarily used in landscaping and for decoration, although researchers have recently begun to focus on other ecosystem benefits roses provide (Božanić Tanjga et al., 2022). As one of the most common components in landscape design, roses are widely used in both vertical and horizontal greening, indoors and outdoors. This study aimed to evaluate three garden rose cultivars from the 'Fragrant Frayla' collection with regard to both ornamental and fragrance value. In addition to identifying the most valuable morphological properties of interest for landscaping, the study sought to further elucidate the connection between specific volatile compounds and the perceived scent of the investigated cultivars.

MATERIAL AND METHODS

The investigated plant material included three cultivars from the 'Fragrant Frayla' garden rose collection (*Rosa* × *hybrida* L.): 'Draga Frayla', 'Jelena Frayla', and 'Lenka Frayla', bred by the private breeding company Pheno Geno Roses. The plants were cultivated in an open experimental field in Temerin, Northern Serbia (45°24′19″ N 19°53′13″ E), an area characterized by a continental climate. Established in autumn 2020 through on-site bud grafting onto *Rosa laxa* Retz., the trial involved plants spaced 10 cm apart within rows and 1 m apart between rows. No irrigation or chemical treatments were applied.

The morphological characterization encompassed the assessment of both qualitative and quantitative vegetative and generative traits. The evaluation was performed in accordance with the UPOV protocol for roses (*Rosa* L.) (UPOV, 2010). It was conducted in June 2023, following the completion of intensive vegetative growth and during the full flowering stage, with the exception of hip assessments, which were performed after fruit maturation in September of the same year. The characterization was carried out on ten plants per cultivar for both descriptive and metric traits. For each cultivar, three selected plants were evaluated, with three young shoots and three stems assessed per plant. Additionally, three leaves and three flowers were analyzed and measured from each stem. Ten hips from each of the three plants per cultivar were also evaluated. To minimize subjectivity, the analysis was conducted by three independent researchers.

In addition to the scent evaluation by human perception, the assessment of volatile compounds content was performed, as described by Božanić Tanjga et al. (2022). For the purpose of this investigation, two rose cultivars from the 'Pixie' collection, 'Blush Pixie' and 'Crimson Pixie', characterized by absent or weak scent (Narandžić et al., 2024), were included as controls. Headspace volatile extraction and gas chromatography–mass spectrometry (GC-MS) analysis were carried out by Brightlabs, located in Venlo, the Netherlands. The extraction process involved grinding 10 flowers from each of five replicate plants per cultivar in liquid nitrogen, followed by adding hexane with 2-nonadecanone and vortexing for 4 hours at 2000 rpm. After mixing with anhydrous sodium sulfate and vortexing for 20 minutes, the supernatant was centrifuged for 15 minutes and transferred to vials. For headspace analysis, air

was drawn through a Porapak Q filter for 24 hours, and volatiles were eluted with hexane. Ethyl myristate was added, and the samples were evaporated to 0.5 mL of hexane. The analysis was performed on an Agilent GC-MS system with an HP-5MS capillary column, coupled to a mass spectrometer. The relative content of each detected compound was calculated from the obtained chromatograms and presented as a percentage of the total peak area.
The statistical analyses were performed using Statistica 14 (Tibco, Palo Alto, CA, USA). A one-way analysis of variance (ANOVA) was conducted, followed by Tukey's Honest Significant Difference post hoc test ($p \leq 0.05$).

RESULTS AND DISCUSSION

Morphological characterization of rose cultivars from the 'Fragrant Frayla' collection
All three investigated rose cultivars were characterized as shrubs, with an upright growth habit in 'Draga Frayla' and a semi-upright habit in the remaining two cultivars (Tab. 1). 'Jelena Frayla' and 'Lenka Frayla' reached heights of more than 60 cm, while 'Draga Frayla' had a significantly lower average height of 47 cm. Anthocyanin coloration was confirmed in the young shoots of all the cultivars, with strong intensity in 'Draga Frayla' and 'Jelena Frayla'. The number of prickles varied from moderate in 'Draga Frayla' and 'Lenka Frayla' to a high number observed in 'Jelena Frayla'. Leaf dimensions varied from 4.1 to 5.8 cm in length, and from 2.9 to 3.8 cm in width, with the largest leaves found in 'Draga Frayla'. Only the leaves of 'Lenka Frayla' lacked anthocyanin coloration, whereas the glossiest leaves were found in 'Draga Frayla'.

Table 1. Vegetative characteristics of the investigated 'Fragrant Frayla' rose cultivars

Cultivar	**'Draga Frayla'**	**'Jelena Frayla'**	**'Lenka Frayla'**
	Plant		
Growth type *	shrub	shrub	shrub
Growth habit	upright	semi-upright	semi-upright
Height (cm)	47 ± 3 b **	66 ± 4 a	67 ± 5 a
	Young shoot		
Anthocyanin coloration	present	present	present
Intensity of anthocyanin coloration	strong	strong	very weak
	Stem		
Number of prickles	medium	many	medium
Predominant color	reddish	reddish	reddish
	Leaf		
Length (cm)	5.8 ± 0.2 a	5.3 ± 0.3 a	4.1 ± 0.1 b
Width (cm)	3.8 ± 0.1 a	3.4 ± 0.2 a	2.9 ± 0.2 b
Intensity of green color	dark	dark	dark
Anthocyanin coloration	present	present	absent
Glossiness of upper side	strong	absent or very weak	absent or very weak

Legend:
* Assessment of qualitative features was conducted in accordance with the UPOV protocol for the genus *Rosa* L. (UPOV, 2010).
** Mean values marked with different letters within a row are statistically different according to Tukey's Honest Significant Difference test ($p \leq 0.05$). The mean values are followed by ± standard deviation values.

The full flowering period was comparable across all the cultivars studied, extending from the early June to mid-September. Flowering laterals were not identified in either of the investigated cultivars, while the number of flowering shoots ranged from an average of 6.2 in 'Lenka Frayla' to 7 in 'Draga Frayla' (Tab. 2). Flower buds were characterized by medium or broad ovate shape. Flowers of all three rose cultivars belonged to type double, with colors varying from white to red (Fig. 1). An irregularly rounded flower shape was observed in 'Jelena Frayla', while the other two cultivars were characterized by rounded flowers. The flower diameter ranged from an average of 6.6 cm in 'Jelena Frayla' to 8.2 cm in 'Draga Frayla'. The smallest number of petals was found in 'Draga Frayla' (35.8), while flowers of 'Jelena Frayla' contained more than 80 petals on average. The strongest fragrance, as assessed by sensory analysis, was recorded in 'Jelena Frayla' rose, while 'Lenka Frayla' exhibited the weakest scent among the three cultivars. The petal length was similar across all the cultivars (3.5 cm on average), while the petal width reached 4.1 cm in 'Lenka Frayla'. Hips' shape and dimensions varied among the cultivars, with consistent orange color in all the investigated roses.

Table 2. Generative traits determined in three cultivars from the 'Fragrant Frayla' rose collection

Cultivar	**'Draga Frayla'**	**'Jelena Frayla'**	**'Lenka Frayla'**
Flowering shoot			
Flowering laterals *	absent	absent	absent
Number of flowering shoot	7 ± 1 a **	6.8 ± 0.8 a	6.2 ± 0.6 a
Flower bud			
Shape in longitudinal section	broad ovate	medium ovate	medium ovate
Flower			
Type	double	double	double
Color group	N045A	024C	155A
Color of center	reddish	orange	white
Shape	rounded	irregularly rounded	rounded
Upper part profile	flattened convex	flat	flattened convex
Lower part profile	flattened convex	concave	flat
Diameter (cm)	8.2 ± 0.4 a	6.6 ± 0.4 b	8 ± 0.5 a
Number of petals	35.8 ± 5 b	83.8 ± 7.2 a	50 ± 6.3 b
Density of petals	medium	medium	loose
Fragrance	medium strong	strong	medium
Petal			
Length (cm)	3.6 ± 0.1 a	3.4 ± 0.1 a	3.6 ± 0.2 a
Width (cm)	3.8 ± 0.1 a	2.9 ± 0.2 b	4.1 ± 0.1 a
Hip			
Shape in longitudinal section	pitcher-shaped	pear-shaped	funnel/pitcher-shaped
Color	orange	orange	orange
Length (cm)	1.4 ± 0.2 a	1.4 ± 0.1 a	1.7 ± 0.1 a
Width (cm)	1.7 ± 0.1 a	1.3 ± 0.2 a	1.5 ± 0.2 a

Legend:
* Assessment of qualitative features was conducted in accordance with the UPOV protocol for the genus *Rosa* L. (UPOV, 2010).
** Mean values marked with different letters within a row are statistically different according to Tukey's Honest Significant Difference test ($p \leq 0.05$). The mean values are followed by ± standard deviation values.

a b c

Figure 1. Flower morphology of the cultivars considered from the 'Fragrant Frayla' rose collection: a - 'Draga Frayla'; b - 'Jelena Frayla'; and c- 'Lenka Frayla'

Numerous rose species and varieties have been studied for their morphological traits, revealing a wide array of characteristics suited to diverse applications. For landscaping purposes, roses are required to meet several key criteria, including appropriate size and growth habit, visual appeal and fragrance, as well as resistance to biotic and abiotic stresses. In a study examining public preferences for roses in various urban settings, Wang et al. (2017) identified color as the most valued attribute, followed by flower abundance and fragrance. In like fashion, a survey conducted by Waliczek et al. (2018) on the perspectives of rose producers and consumers emphasized the demand for disease-resistant cultivars with everblooming, fragrant, and abundant red flowers, with an ideal plant height ranging from the waist to shoulder level. Zlesak et al. (2017), in their evaluation of 20 landscape roses across three locations, documented plant heights varying from approximately 28.7 to 190 cm. Ardasheva et al. (2023) recommended roses for landscaping purposes with heights ranging from 30 to 200 cm, including climbing varieties with shoots reaching lengths of up to 200 cm, encompassing a range of growth habits from climbing to large shrub forms. Božanić Tanjga et al. (2022) characterized highly ornamental garden roses in the 'Mella' collection by plant heights of 42 to 95 cm, while the 'Reka' and 'Pixie' collections, known for their miniature growth and climate resilience, featured heights from 20 to 68 cm (Narandžić et al., 2024). Depending on the landscape context and environmental conditions, all three investigated cultivars from the 'Fragrant Frayla' collection may display representative growth and form characteristics, with shrub heights reaching up to 67 cm in 'Lenka Frayla'. Since an abundance of prickles is an undesirable trait in roses due to the risk of injury in public green spaces and during cultivation and harvesting (Wang et al., 2017; Singh et al., 2020), the reduced prickle density observed in 'Draga Frayla' and 'Lenka Frayla' is advantageous, particularly in settings sensitive to child safety (Narandžić et al., 2023). The observed leaf dimensions in these cultivars align with previous reports for roses (Khaleghi & Khadivi, 2020; Božanić Tanjga et al., 2022). Andriivna & Vasyliovych (2021) underscored the contribution of leaf characteristics to the overall plant aesthetics, noting green saturation and leaf gloss as parameters as valuable as leaf size. The observed dark green color of leaves in all three investigated cultivars could enhance the expressiveness of the plants when combined with bright flower colors, especially in 'Draga Frayla', which is characterized by strong leaf glossiness - a valuable asset in plant resistance to drought and fungal diseases. The flower size, petal number, and petal dimensions in these cultivars correspond with data from previous studies. Yudanova et al. (2024) reported flower diameters in two garden rose groups ranging from 6.80 to 10.24 cm, with petal counts up to 42.15. Singh et al. (2020), investigating 59 accessions from six wild *Rosa* L. species, recorded flower diameters from 3.4 to 6.3 cm, petal lengths from 1.6 to 2.9 cm, and petal widths from 1.3 to 2.8 cm. Garden roses evaluated by Narandžić et al. (2024) showed flower diameters from 2.5 to 6.5 cm and petal counts from 22.2 to 66.4, while Božanić Tanjga et al. (2022) found average flower diameters of 4.1 to 6.8 cm, with petals up to 3.3 cm in length and 3.4 cm in width. Despite similar flower shapes across the cultivars, which were identified as the same type (double), observed differences in other generative traits may inform further selection and breeding efforts.

Analysis of scent-related volatile compounds in rose petal extracts

Notable differences in the content of volatile compounds were observed among the investigated 'Fragrant Frayla' cultivars (Tab. 3). The highest concentration of phenylethyl alcohol (expressed as a relative percentage of the total peak area) was found in 'Draga Frayla', reaching 57.31%. The cultivar 'Jelena Frayla' followed with 37.91% of this aromatic alcohol, whereas the third cultivar in the collection showed a significantly lower proportion, comparable to that in the control cultivar, 'Blush Pixie'. Terpenoids were exclusively detected in the 'Jelena Frayla' cultivar, with citronellol reaching 8.73% and a combined geraniol and nerol content of 19.47%. The alkane heptadecane was absent across all the investigated cultivars from both the 'Fragrant Frayla' and 'Pixie' collections. The alkene 9-nonadecene was not found in 'Lenka Frayla' but was present at low levels (1.04–3.62%) in the other cultivars. Nonadecane appeared only in 'Draga Frayla', in a very small proportion (0.90%). Heneicosane and hexacosane were detected in almost all the cultivars at low levels (below 7%), except for 'Lenka Frayla', where heneicosane was undetected. The highest relative percentages of heneicosane and hexacosane were observed in 'Draga Frayla' (6.07%) and 'Jelena Frayla' (2.88%), respectively. Octacosane was minimally present in 'Jelena Frayla' (4.72%) but appeared at 31.07% in the control cultivar, 'Crimson Pixie'. Alkanes with over 30 carbon atoms, such as tetratetracontane and hentriacontane, were significantly more abundant in 'Lenka Frayla', with proportions of 44% and 14.47%, respectively, compared to the other two cultivars in the same collection. High levels of these compounds were also observed in both control cultivars from the 'Pixie' rose collection.

Table 3. Volatile compounds identified in the investigated 'Fragrant Frayla' roses and two control cultivars from the 'Pixie' rose collection

Cultivar	Phenylethyl alcohol	Citronellol	Geraniol and Nerol	Heptadecane	9-Nonadecene	Nonadecane	Heneicosane	Hexacosane	Octacosane	Tetratetracontane	Hentriacontane
'Draga Frayla'	57.31[*]	0.00	0.00	0.00	3.62	0.90	6.07	2.08	12.17	15.75	1.36
'Jelena Frayla'	37.91	8.73	19.47	0.00	1.04	0.00	3.08	2.88	4.72	7.91	1.14
'Lenka Frayla'	20.84	0.00	0.00	0.00	0.00	0.00	0.00	2.45	11.07	44.00	14.47
'Blush Pixie'	18.74	0.00	0.00	0.00	2.90	0.00	1.96	1.06	7.09	54.49	10.64
'Crimson Pixie'	0.00	0.00	0.00	0.00	1.17	0.00	3.03	2.54	31.07	38.88	7.25

Legend: [*] Values are expressed as relative percentages of the total peak area. The detected compounds and their quantitative contents account for 99.26%, 86.88%, 92.83%, 96.88%, and 83.93% of the total content of the extracts, respectively (corresponding to their order of appearance in the 'Cultivar' column).

Out of the 11 investigated components, the extract from 'Jelena Frayla' petals contained 9 compounds, with only heptadecane and nonadecane absent. The extract from 'Draga Frayla' rose exhibited one fewer compound, while the extracts from 'Lenka Frayla' contained only 5 compounds. The ratio of different groups of volatile compounds found in the petals of the investigated roses is illustrated in Figure 2. The highest shares of aromatic alcohol and terpenoids were associated with the cultivars 'Jelena Frayla' and 'Draga Frayla', accounting for 66.11 and 57.31% of the total peak area, respectively. In contrast, 'Lenka Frayla' and 'Blush Pixie' possessed approximately 20% of these components, whereas the second control, 'Crimson Pixie', completely lacked aromatic alcohol and terpenoids. Hydrocarbons containing fewer than 30 C-atoms (including heptadecane, 9-nonadecene, nonadecane, heneicosane, hexacosane, and octacosane) were predominantly found in 'Draga Frayla' (approximately 25%). The other two 'Fragrant Frayla' cultivars exhibited a similar content of these components to that of 'Blush Pixie'. Compared to 'Crimson Pixie', which had a value of around 38%, all the cultivars demonstrated a lower content of volatile compounds belonging to this group. The long-chain alkanes with more than 30 C-atoms, namely tetratetracontane and hentriacontane, accounted for approximately 50-60% of the total peak area in 'Lenka Frayla' and both 'Pixie' cultivars, whereas their content in the more fragrant roses was below 10-20%.

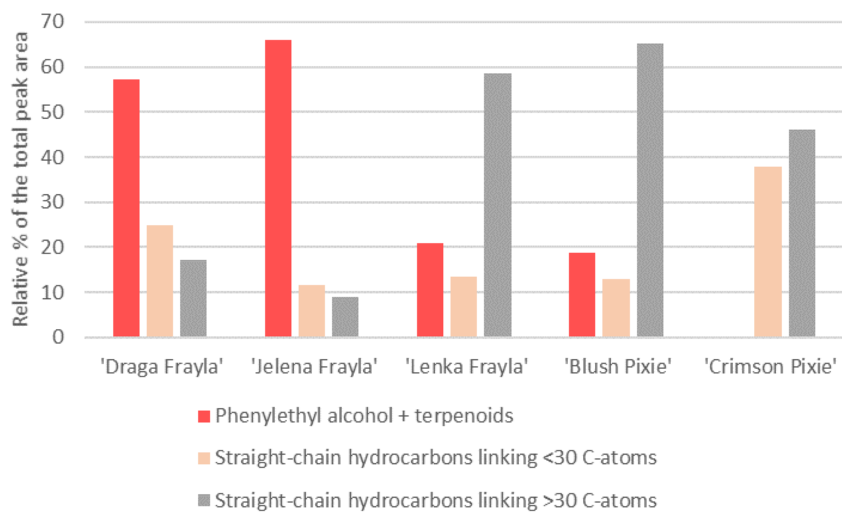

Figure 2. Relative proportions of three groups of volatile compounds in the petal extracts of investigated rose cultivars

The fragrance of roses is determined by the mixture of qualitatively different volatile compounds present in the flowers in varying amounts (Shalit et al., 2004). Among the 11 rose cultivars studied by Shalit et al. (2004), the most fragrant cultivar was characterized by a high content of aromatic alcohol (approximately 60%) and terpenoids, while the moderately and less fragrant cultivars contained no alcoholic monoterpenes and exhibited low percentages of alcohols (geraniol was observed only in the moderately fragrant cultivar 'Bernstein-Rose'). These findings align with our results, which show higher quantities of phenylethyl alcohol in 'Draga Frayla' and 'Jelena Frayla', characterized by moderately strong and strong fragrance, respectively (according to the sensory analysis performed). Among all the investigated and control cultivars, only 'Jelena Frayla' contained citronellol, geraniol and nerol in its chemical profile, indicating the influence of alcoholic monoterpenes on the stronger scent emission of its flowers. The groups of compounds detected in our study were also identified in other rose species and varieties, albeit in different ratios. Jiao et al. (2022) identified 74 volatiles in *Rosa willmottiae* flowers, belonging to different groups: alcohols, aldehydes, ketones, esters, ethers, phenols, terpenes, aliphatic hydrocarbons, aromatic hydrocarbons, and furans, with 2-phenyl ethanol present in the highest amount (20.49%). In an investigation of volatile compounds in the petals and pollen of 21 garden roses, Caser & Scariot (2022) detected 19 individual compounds, among which 2-phenylethanol, methyl eugenol, and hexanal were present in a high number of varieties. Yang et al. (2020) identified 62 volatiles emmited from *Rosa rugosa* flowers, where phenylethyl alcohol, citronellol, methylene chloride, hexane, and acetone predominated. Dobreva et al. (2021) confirmed the correlation of 2-phenethyl alcohol with the specific scent of roses, recording its content from 9% in *Rosa centifolia* to 59.6% in *Rosa damascena* extracts. The same authors observed notable amounts of monoterpene alcohols geraniol, nerol and citronellol, reaching 14.4 % and 6.1% in *Rosa alba* for geraniol and nerol, respectively, and 5.3% in *R. damascena* for citronellol. Feng et al. (2022) assessed volatile compounds in 55 scented varieties of *R.* × *hybrida*, and found that terpenes were the most abundant, followed by phenylethyl alcohol, citronellol, nerol, geraniol, and α-farnesene. The main fragrance-related constituents in Latvian *R. rugosa* hybrids were phenylethyl alcohol, citronellol, and nerol (with values reaching 79.9 %, 57%, and 39%, respectively) (Sparinska & Rostoks, 2015), while *β*-citronellol, nerol, phenylethyl alcohol, geraniol, heptadecane, nonadecane, methyl eugenol, eugenol, and geranyl acetate were identified as the most prevalent components of *R. damascena* essential oil (Kunc et al., 2024). The presence of hydrocarbons in the rose extracts, i.e. the third group of compounds identified in the 'Fragrant Frayla' and 'Pixie' roses, varied significantly, related to both the rose cultivar and the number of C-atoms in their structure. On balance, hydrocarbons were present in higher percentages in the chemical profiles of less fragrant cultivars. This pattern is evident in the total percentages calculated per cultivar. The most fragrant cultivar, 'Jelena Frayla', contained 20.76% of hydrocarbons in the total content of its extract, whereas the moderately strong scented 'Draga Frayla' featured a value of 41.95%. 'Lenka Frayla', characterized as the least fragrant cultivar among the investigated roses, exhibited 71.99% of hydrocarbons, similar to the contents found in the two 'Pixie' cultivars (78.33 – 83.93%). Jariani et al. (2024) detected different number of volatiles in *Rosa canina* with white and dark pink petals, accounting for 32 and 15 compounds, respectively. The identified compounds included aliphatic hydrocarbons, aldehydes/ketones, alcohols, and esters, with the highest proportion of the first group (above 75%) and pentacosane as the most abundant hydrocarbon in the sample obtained from white petals (22.34%). The same authors assumed a correlation between the essential oil stability and quality with the presence of long-chain hydrocarbons (such as tetratetracontane and hentriacontane) due to their lower volatility and higher viscosity compared to hydrocarbons with a lower number of C-atoms (such as heptadecane and nonadecane) (Egloff et al., 1940). According to Dobreva et al. (2021), aliphatic hydrocarbons represent valuable components of the chemical profiles of rose extracts, which despite being odorless, play role of fragrance fixators. The authors determined the total percentages of hydrocarbons ranging from 12.8% in *R. damascena* to 41.7% in *R. centrifolia*, with the highest amounts of nonadecane and nonadecene, heneicosane, tricosane, pentacosane, and heptadecane in the investigated roses. The percentages of hydrocarbons identified in the highly scented 'Jelena Frayla' and 'Draga Frayla' were also similar to the values determined by Kunc et al. (2024), ranging from 15% in *Rosa pendulina* to 36% in *Rosa spinosissima*. Regardless of the recognized patterns in chemical composition and the ratios between different groups of compounds associated with intense fragrance, the amount of fragrance released and perceived by humans or pollinators depends on many factors, including rose species, specific component combinations, and genetic triggers for fragrance release (Karami & Jandoust, 2016; Božanić Tanjga et al., 2022), warranting further exploration.

CONCLUSION

With increasing interest in their nutritional value, health-promoting benefits, and potential for integration into green infrastructure, various rose species are being continuously evaluated to gain insight into the morphological traits and chemical profiles that enhance the utility value of these genotypes. In this study, three garden roses from the 'Fragrant Frayla' collection were assessed for morphological vegetative and generative traits, as well as for the chemical profile of fragrance-related volatiles in petal extracts. The morphological characterization indicated a high ornamental value of the investigated roses, characterized as shrubs with heights ranging from 47 to 67 cm, and an expressive combination of reddish stems, dark green leaves, and double – red, orange or white – flowers up to 8.2 cm in diameter, depending on the cultivar. A sensory panel identified 'Jelena Frayla' as having the strongest fragrance, followed by a moderately strong scent in 'Draga Frayla' and the weakest fragrance in 'Lenka Frayla'. The analysis of volatile compounds responsible for the fragrance of rose flowers revealed the presence of phenylethyl alcohol, terpenoids, and hydrocarbons. 'Jelena Frayla' extracts contained the highest number of detected components (9 out of 11). The highest aromatic alcohol content was associated with the most fragrant roses, reaching up to 57.31% in 'Draga Frayla', while terpenoids were only detected in 'Jelena Frayla' (a total of 28.2% for the three identified compounds). The amounts of individual hydrocarbons varied across the cultivars without a clear pattern. Hydrocarbons containing fewer than 30 C-atoms were predominantly present in 'Draga Frayla' (approximately 25% of the total peak area), whereas long-chain alkanes containing more than 30 C-atoms accounted for over 50% of the total peak area in 'Lenka Frayla' and control samples, and less than 20% in strongly scented roses. The results obtained indicated a correlation between strong fragrance in roses and elevated levels of phenylethyl alcohol and alcoholic monoterpenes, while diverse hydrocarbon presence, rather than high quantity, may be associated with enhanced scent emission.

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