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Article

Selection of Garden Roses to Improve the Ecosystem Services They Provide

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Abstract: With pronounced morphological and phenological diversity, garden roses have always been part of urban plantings. The significance of roses in ornamental and utilitarian (edible) horticulture can significantly be amended with novel ecosystem services, by shifting their breeding targets towards more than aesthetic and nutritional value. Thus the aim of this paper was to investigate the possibilities of newly bred (within the past decade) garden roses from the 'Mella' series as a possible ornamental, disease tolerant and bee attracting cultivars to be recommended in urban ecosystems, adding values to their current ecosystem services. Research goals were to determine the morphological characteristics; honey and wild bees' abundance and its correlation with rose morphological and floral characteristics; disease resistance/tolerance to main rose fungal diseases; and suitability of 'Mella' roses in urban greenery providing multiple ecosystem services. Plant material included seven garden rose cultivars from the 'Mella' series. Analyses included complete morphological—qualitative and quantitative characterization of plant and flower traits, fragrance panel scoring and volatile components analyses, counts of honey bees visiting flowers and counts of different wild bee species as potential pollinators. Based on the obtained results significant variability in vegetative and generative plant characteristics was noted in investigated 'Mella' roses. With their 'naturalistic' overall appearance, comparable with wild roses, 'Mella' cultivars differed in plant height and habitus, number and type of flowers, leaf coloration and glossiness, but 'Barbie Mella' and 'Ruby Mella' positioned as the most decorative ones. 'Barbie Mella' was highly scored for overall fragrance, with the most divergent panel records for fragrance components and mixed volatile compounds, characterized by the balanced ratio (almost 1:1:1) between aromatic alcohol + terpenoids, straight-chain alkanes and long-chain alkanes. In relation to the honey bee's attraction, a combination of plant height, fragrance, flower type (single, simple), flower diameter and accessibility seems to be crucial, rather than any characteristic solely. As an outstanding bee-attractor 'Barbie Mella' should be promoted as an ornamental disease-tolerant rose cultivar. Due to their aesthetic values, disease tolerance and bees visitations, 'Mella' roses 'Barbie', 'Ruby', 'Ducat' and 'Exotic' should be planted as a part of urban semi-natural gardens/landscapes, concomitantly contributing to the multiple ecosystem services—provisioning, regulating, cultural and supporting. Until their worldwide availability, other 'Mella'-like wild and cultivated roses should be investigated and promoted likewise.

Keywords: disease resistance; ecosystem services; pollinators' attraction; rose breeding; sustainability; urban ecosystems

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1. Introduction

The significance of roses in ornamental and edible gardening—with one word as 'ornafruits' [1] is indisputable. Their shrubs are an effective element of horizontal and vertical landscaping, while petals and fruits are a source of vitamins, minerals and other biochemically active compounds [2–4]. Rose flowers are a source of tannins [5], antiseptic, contains gallic acid, galusic tannin, glycoside quercetin [6], essential oils [7–9], wax and minerals. The petals, especially from red and pink varieties, have found application in making tea, rose juice, jelly and the sweet known as ratluk [10]. The genus Rosa's natural distribution is exclusively in the northern hemisphere, and contains more than 400 species [11]. Roses originated from Central Asia, where even half of all wild rose species are found today [12]. Thanks to their extreme adaptability to variable environmental factors, roses have spread from the center of origin and crossed continents, combining all their best features and qualities into new varieties, so that today we have over 30,000 varieties of different appearance, color, smell, habit, with or without the presence of thorns and different use value [13]. The goals of breeders of garden roses have changed throughout history. In the past, greatest attention has been paid to the aesthetic values of flowers, such as color [10], fragrance, and re-blooming [14,15], resistance to low temperatures [16], dwarf growth [17] and others. Today, with the development of environmental awareness, the market demands healthy plants requiring as little use of pesticides as possible. This is one of the reasons why today in rose breeding most attention is paid to disease resistance, resistance to low and high temperatures, or extreme habitat conditions [18,19]. Disease tolerance/resistance emerges as an important plant characteristic due to multiple requests and constrains in urban environment [20], especially when creating resilient environment as a part of sustainable green cities. Breeding garden roses is a process that never ends and breeding goals nowadays are shifting from merely aesthetic towards more environmentally and wildlife friendly, providing urban ecosystem services and aligning with Sustainable Development Goals—SDG [21].

City green infrastructure improves the quality of life by providing a range of ecosystem services [22]. Green spaces are important components of every city, expanding the ecological diversity, representing structural and functional elements that make cities and urban areas more suitable for housing [23], reducing the extreme microclimatic conditions, urban heat island effect, as well as air pollution. According to Millennium Ecosystem Assessment [24] these functions are divided into four types of ecosystem services—provisioning, regulating, cultural and supporting, while some of them applicable on urban greenery were evaluated by Pušić et al. [25] (Figure 1).

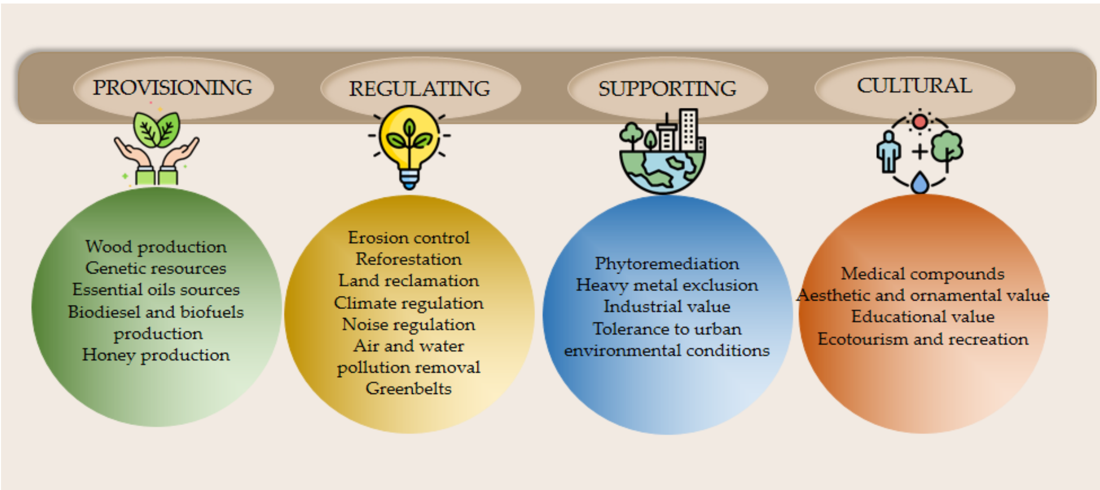

Figure 1. Most frequent ecosystem services of ornamental urban greenery, according to Pušić et al. [25]. Reprinted by permission from Springer Nature Customer Service Centre GmbH: Springer Nature, Environmental Science and Pollution Research, Assessment and potential of ecosystem services of ornamental dendroflora in public green areas, Pušić et al. [COPYRIGHT License Number 5394750869158] (2022).

Besides highly appreciated aesthetic value, associated with urban greenery, it contributes to biodiversity of both flora and fauna. Pollinator attraction and habitat creation is one of the very important ecosystem services that plant species can provide. Roses, as part of urban ecosystems, are known for their positive effect on the city's physical, biological, and socioeconomic aspects, through improving air quality, helping to regulate climate, altering aesthetic surroundings, increasing enjoyment of everyday life, and improving health [26]. However, plant compositions, including roses in urban gardens can be important habitats for pollinator communities within cities [27,28]. Among them, the bees are flying insects from the *Hymenoptera* that are close relatives of wasps and ants. They are known for their role in pollination. There are over 16,000 known bee species in seven recognized families, while members of six families (*Andrenidae*, *Apidae*, *Colletidae*, *Halictidae*, *Megachilidae*, *Melittidae*) can be found in the surrounding area [29,30]. According to literature data and novel research, 706 bee species have been recorded from Serbia. Nevertheless, the number of bee species is expected to be even higher [31]. A significant number of studies indicate a high diversity of bee species in cities, thus, appropriate management of vegetation in cities will be required so that urban areas can become hot spots for certain groups of bees [32,33]. The long evolutionary path and co-evolution between flowering plants and bees as their pollinators has led to an unbreakable morphological connection and consequently direct dependence between individual groups of bees and certain plant taxa [34]. Modern horticulture, with a clear tendency to breed new, attractive flowers, has led to the emergence of a large number of double flowers varieties with drastically different morphology compared to wild varieties with simple flowers, interfering with the pollination or significantly decreasing it. This practice can lead to a significant decline in the number and pollinators' diversity [35], thus restoration of balance between desirable traits for humans and pollinators should be of the utmost importance.

Accordingly, the aim of this paper was to investigate the possibilities and purpose of newly bred garden roses from the 'Mella' series as ornamentals with multiple ecosystem services. To investigate possible added values, goals were to determine the: (i) morphological characteristics of 'Mella' roses; (ii) fragrance components and human perception; (iii) honey bee abundance and its correlation with rose morphological and/or fragrance characteristics; (iv) disease resistance/tolerance of 'Mella' roses to main rose fungal diseases and (v) suitability of 'Mella' roses as urban elements providing multiple ecosystem services in addition to their ornamental value.

2. Materials and Methods

2.1. Plant Material and Growth Conditions

Plant material included seven garden rose cultivars from the 'Mella' series, bred by a private breeding company 'Pheno Geno Roses'—'Barbie Mella', 'Ruby Mella', 'Ducat Mella', 'Amulet Mella', 'Crystal Mella', 'Mellite Mella' and 'Exotic Mella', currently marketed mainly in Serbia, Netherlands, Poland, France, Italy, Hungary, Germany and UK. These cultivars were named by the Latin word for honey, thus registered as Mella, due to initial field observations that pollinators prefer these selections over others in the collection, during their trial testing.

Garden roses used in the experiment were three-years-old and grew in the open field conditions, at the 'Pheno Geno Roses' private company, in Temerin, Northern Serbia (45°24′19″ N 19°53′13″ E/45.105166° N 19.886833° E). This rose nursery is situated 20 km from Novi Sad, second largest city in Serbia. The area is characterized as a typical continental climate with extremely warm summers and cold winters. The experimental field (30 m long × 20 m wide, containing rows belonging to the 'Mella' collection and one neighboring row of 'Carmine Vase' cultivar from another collection of roses characterized by double flowers) was established in the fall of 2015, by in situ bud grafting. The number of grafted plants was 150 per cultivar, but resulted in 140 plants of 'Barbie Mella', 137 plants of 'Ruby Mella', 127 plants of 'Ducat Mella', 130 plants of 'Amulet Mella', 110 plants of 'Crystal Mella',115 plants of 'Mellite Mella' and 115 plants of 'Exotic Mella', positioned in separate rows. The distance between plants was 10 cm, while the row distance amounted one meter.

2.2. Qualitative and Quantitative Plant and Flower Characteristics

Morphological—qualitative and quantitative characterization following the UPOV protocol [36] for roses (*Rosa* L.) was performed during the full blossom, when the intensive spring vegetative growth was fully achieved. Qualitative analyses were performed in the late spring—early summer of 2018 (except for the hips that formed later) on ten plants per cultivar by two independent researchers to reduce the subjectivity.

Qualitative vegetative traits included:

Growth type—GT: 1—miniature, 2—dwarf, 3—bed, 4—shrub, 5—climber and 6—ground cover.

Growth habit—GH: 1—upright, 3—semi-upright, 5—intermediate, 7—moderately spreading and 9—strongly spreading.

Intensity of green color (upper side)—IGC: 3—light, 5—medium and 7—dark.

Leaf anthocyanin coloration—LAC: 1—absent and 9—present.

Glossiness of upper side—GUS: 1—absent or very weak, 3—weak, 5—medium, 7—strong and 9—very strong.

In addition to plant traits, qualitative generative (flower) traits included:

Flowering laterals—FL: 1—absent and 9—present.

Type—TP: 1—single, 2—semi-double and 3—double.

Color group—CG: 1—white or near white, 2—white blend, 3—green, 4—yellow, 5—yellow blend, 6—orange, 7—orange blend, 8—pink, 9—pink blend, 10—red, 11—red blend, 12—purple red, 13—purple, 14—violet blend, 15—brown blend and 16—multi colored. These scores were further detailed with color tones (weak, medium or strong).

Color of center (only varieties with flower type double)—CC: 1—green, 2—yellow, 3—orange, 4—pink, 5—red and 6—purple

Shape—SH: 1—round, 2—irregularly rounded and 3—star-shaped.

Profile of upper part—PUP: 1—flat, 2—flattened convex and 3—convex.

Profile of lower part—PLP: 1—concave, 2—flat, 3—flattened convex and 4—convex.

Fragrance (observed by smelling)—FG: 1—absent or weak, 2—medium weak, 3—medium, 4—medium strong and 5—strong.

Main color on the outer side (only if clearly different from inner side)—MCOS: RHS Color Chart.

Time of first flowering—TFF: expressed as a day when first flowers were open.

Hips shape in longitudinal section—HSLS: 1—funnel-shaped, 2—pitcher-shaped and 3—pear-shaped.

Color (at mature stage)—CMS: 1—yellow, 2—orange, 3—red, 4—brown and 5—black.

Quantitative—metrical characterization was performed for plant height, leaf length and width (all in cm), as well as following generative traits: Number of flowering shoot (Only varieties with no flowering laterals)—NFS; Number of flowering laterals—NFL; Number of flowers per lateral (Only varieties with flowering laterals)—NF/L; Number of petals—NOP; Diameter—DM (cm); Petals Length—PL (cm); Petals Width—PW (cm); Hip length—HL and Hip width—HW (both in cm).

Quantitative analyses were also performed in the late spring—early summer of 2018 on three plants per cultivar as well as three stems per each plant. On each stem five leaves and five flowers were considered for subsequent morphological analyses. Three plants per cultivar were considered as appropriate for quantitative analyses due to the clonal propagation with buds originating from a single mother plant.

2.3. Disease Tolerance or Resistance

Disease resistance/tolerance was monitored in 3 consecutive years for main rose disease causing agents: powdery mildew caused by *Sphaerotheca pannosa* var. *rosae*, syn. *Podosphaera pannosa*; downy mildew caused by *Peronospora sparsa*; black spot caused by *Diplocarpon rosae*; leaf spot caused by *Pseudomonas syringe* and rust caused by *Phragmidium* sp. Disease resistance/tolerance was monitored by two researchers (to exclude the subjectivity) in three periods each year: Mid-June, Mid-July and Mid-September. Different time points were chosen to cover the most prevalent diseases, their development and progress as well as to concomitantly monitor the genotypes' responses. Disease observations were not assessed on individual plants, but as an average assessment of all 110–120 plants per given cultivar in the experimental field.

Overall scores on the 1–5 were given based on the complete results, while individual scores for the symptoms were labeled as 0—for the absence of symptoms and 1—for their appearance.

In addition to the leaf infection area the whole plant reaction to the pathogen was taken into consideration. The detailed 5-point scoring system for each class was as the following:

1—Infected leaf area amounts 75–100%. There are no or almost no leaves on the whole plant. The rare leaves have completely become brown.

2—Infected leaf area is 50–75%. The lower part of the plant is completely without leaves while on the upper part leaves that have started to get brown can be found.

3—Infected leaf area amounts 25–50%. Leaves are present on the whole plant, while leaves close to the soil started to get brown.

4—Infected leaf area amounts 5–25%. Leaves on the whole plant are still green or started to get pale-green color.

5—Infected leaf area amounts 1–5%. There are no infections or very sporadic on certain leaves. The leaves on the whole plant are green and the overall plant impression is healthy.

2.4. Fragrance Analysis and Volatile Compounds Investigation

In addition to the overall fragrance evaluation as a qualitative trait, 10 panel specialists were gathered to perform the scoring of the specific fragrance components—top notes (citrus, aromatic), heart notes (floral, green, fruity, spicy) and base notes (woody, earthy/balsamic). Fragrance scoring was performed on fully open flowers on intact rose bushes in the morning including five different 'Mella' cultivars—'Barbie', 'Ruby', 'Ducat', ' Amulet' and 'Exotic', whilst 'Carmine Vase' from another rose collection and different flower morphology, was used as a control cultivar. Every cultivar was smelled 3 times corresponding to three random flowers per plant (in one-hour intervals) on 5 replicate plants per cultivar, for each top, heart and base note by 10 people, of different gender, seniority, specialties and interests in roses, reducing the subjective scoring. The same 5 replicate plants per cultivar were chosen for smelling, but the flowers on these bushes were randomly elected by each of the 10 panelists. Values obtained from 5 plants for each cultivar, by all 10 panelists were subsequently averaged in order to simplify the presentation of the results. Besides human perception and scoring of floral scent as a possible cultural ecosystem service, more detailed headspace volatiles extraction and GC-MS analysis was commercially purchased from Brightlabs laboratory (Venlo, The Netherlands). Again, five rose cultivars ('Barbie', 'Ruby', 'Ducat', 'Amulet' and 'Exotic') were investigated within the 'Mella' collection, with 'Carmine Vase' as a control cultivar. The extraction method included flower grinding in liquid nitrogen (10 flowers from each of the 5 replicate plants per cultivar), with the addition of hexane containing 2-nonadecanone and vortex for 4 h at 2000 rpm. Samples were amended with anhydrous sodium sulfate and vortex for another 20 min. Clear supernatant was then transferred to vials, after being centrifuged for 15 min. Headspace method included drawing air from flowers through 0.7 × 3 cm Porapak Q 80/100 poly-di-vinyl-benzene filter for 24 h. Volatiles were eluted using hexane. After adding ethyl myristate, samples were evaporated to 0.5 mL of hexane phase.

Further analysis was done using GC-MS G34455B from Agilent. Agilent gas chromatograph was equipped with fused silica capillary HP-5MS column (30 m × 0.25 mm; film thickness 0.25 m) and coupled with mass spectrometer.

2.5. Honey Bee Abundance and Pollinators' Diversity

In order to uniform the samples, a block of 120 plants per cultivar was considered as an experimental tier. Thus, five divergent 'Mella' varieties (in terms of the plant height, flower number, color, flower simplicity and fragrance, represented in the uniformed number of plants—120)—'Barbie', 'Ruby', 'Ducat', ' Amulet' and 'Exotic' Mella were chosen for the subsequent analysis of honey bee abundance and pollinators diversity (number of different bee species visiting flowers). Analyses were performed in the same nursery and the year as all other investigations, during the full bloom. New cultivar—'Carmine Vase' from another rose collection was introduced in this part of the research, as a cultivar with opposed characteristics, due to double flower type and absence of fragrance.

During the research in this group of insects, two methods were used: sampling of adult individuals with entomological nets along the transect (for wild bee species) and visual recording of the number of species that can be determined in the field. Linear transects of 30 m length which followed individual rose cultivars (120 plants per tier) were formed. Sampling along the transect was performed once a day, each day (six days corresponding to six replicates) for each rose cultivar, from 10th to 15th June, for 15 min, by slowly moving through the transect, covering all 120 plants in the experimental tier per cultivar. All bee specimens were sampled with entomological nets except the honey bee (*Apis mellifera*), which was identified in the field. Daily sampling was performed in the period from 8 to 15 h under fine weather conditions (sunny, low wind speed, temperature higher than 15 °C). Collected bees specimens were later identified to the level of genus in the laboratory. Identification key for European bee genera was used [37].

2.6. Data Analysis

The obtained quantitative data were statistically processed by analysis of variance, using STATISTICA 14 software (Tibco, Palo Alto, CA 94304, USA). The significance of differences between mean values was determined using Tukey's Honest Significant Difference test with the confidence level of $p \leq 0.05$.

3. Results

3.1. Qualitative and Quantitative Plant Characteristics

Growth type (shrub) was uniform in all investigated cultivars, whilst the growth habit varied from semi-upright in 'Barbie', 'Rubie' and 'Ducat' Mella, through intermediate in 'Amulet' and 'Exotic' Mella to moderately spreading in 'Crystal' and 'Mellite' Mella rose cultivars (Table 1). Leaf anthocyanin coloration was present in all cultivars, but intensity of green color on the upper side differed in 'Rubie' and 'Mellite Mella' (designated as medium) from other cultivars (designated as dark). Glossiness of the upper leaf side was the most variable vegetative qualitative trait, taking state from absent or very weak in 'Rubie Mella', weak in 'Exotic' and 'Mellite', medium in 'Barbie' 'Ducat' and 'Amulet' to strong in 'Crystal Mella' rose.

Table 1. Qualitative and quantitative vegetative characteristics of the investigated 'Mella' rose collection.

Cultivar/Trait	'Barbie Mella'	'Ruby Mella'	'Ducat Mella'	'Amulet Mella'	'Crystal Mella'	'Mellite Mella'	'Exotic Mella'
Plant							
GT	shrub	shrub	shrub	shrub	shrub	shrub	shrub
GH	semi upright	semi upright	semi upright	inter-mediate	moderately spreading	moderately spreading	inter-mediate
Height (cm)	80.0 ± 12 ^{ab*}	42.6 ± 8.0 ^{c}	69.0 ± 11.5 ^{b}	42.0 ± 6.0 ^{c}	70.0 ± 7.0 ^{b}	95.0 ± 9.0 ^{a}	85.0 ± 7.0 ^{ab}
Leaf							
IGC	dark	medium	dark	dark	dark	medium	dark
LAC	present	present	present	present	present	present	present
GUS	medium	absent or very weak	medium	medium	strong	weak	weak
Length (cm)	4.4 ± 1.3 ^{a}	2.4 ± 0.3 ^{c}	2.5 ± 0.3 ^{bc}	3.4 ± 0.6 ^{abc}	3.7 ± 0.3 ^{abc}	4.1 ± 0.4 ^{ab}	4.7 ± 0.4 ^{a}
Width (cm)	2.8 ± 0.7 ^{ab}	1.4 ± 0.2 ^{d}	1.6 ± 0.2 ^{cd}	2.2 ± 0.3 ^{bcd}	2.8 ± 0.3 ^{ab}	2.4 ± 0.4 ^{abc}	3.3 ± 0.3 ^{a}

GT—Growth type; Growth habit (excluding climbers)—GH; Intensity of green color (upper side)—IGC; Leaf anthocyanin coloration—LAC; Glossiness of upper side—GUS. * Mean values designated with the same letter were not significantly different according to Tukey's Honest Significant Difference test ($p \leq 0.05$).

Quantitative vegetative trait—plant height varied significantly according to Tukey's Honest Significant Difference test. Minimal plant height was achieved in 'Amulet' and 'Ruby' rose (42.0 ± 6.0 and 42.6 ± 8.0 cm), whilst maximal average value was recorded for 'Mellite Mella' rose cultivar (95.0 ± 9.0 cm). Differences in leaf quantitative traits—length and width were also statistically significant, according to the same test (Table 1).

3.2. Qualitative and Quantitative Flower Characteristics

Regarding the flowering shoot qualitative characteristics, flowering laterals were present in all investigated cultivars except in 'Crystal Mella' rose (Table 2). Time of the first flowering was dated from June 1st in 'Ruby Mella' to June 6th in 'Amulet Mella' and 'Exotic Mella', while on June 3rd other 4 cultivars started blooming. As to the flower type, it ranged from single in majority of investigated cultivars, over semi-double in 'Mellite Mella' and 'Exotic Mella' to double in 'Crystal Mella'. In relation to the double flower type, only 'Crystal Mella' had white color of flower center. Each of the investigated cultivars belonged to different color group, from white in 'Crystal Mella' (code NN155C) to dark red in 'Amulet Mella' (code N045A) as shown in Table 2. Flower shape was rounded in four investigated cultivars and irregularly rounded in three. Profile of the upper part showed no variation, since it was described as flat in all cultivars, whilst the profile of the lower part varied from flat in four cultivars, over flattened convex in 'Barbie Mella' and 'Exotic Mella' to concave in 'Mellite Mella'. Outer side's clearly different petals' color occurred only in 'Exotic Mella' and was characterized as light yellow (code 012D).

All investigated 'Mella' cultivars were characterized by pitcher-shaped hips, whilst their color varied from yellow-orange in 'Exotic Mella' to orange-red 'Ducat Mella' and red in 'Amulet Mella', with other four cultivars belonging to orange group of hips' color.

Table 2. Qualitative generative characteristics of the investigated 'Mella' rose collection.

Cultivar/Trait	'Barbie Mella'	'Ruby Mella'	'Ducat Mella'	'Amulet Mella'	'Crystal Mella'	'Mellite Mella'	'Exotic Mella'
Flowering shoot							
FL *	present	present	present	present	absent	present	present
Flower							
TP	single	single	single	single	double	semi-double	semi-double
CG	medium purple red	medium purple red	medium yellow	dark red	white	yellow orange/pink	pink red
CC	/	/	/	/	white	/	/
SH	rounded	irregularly rounded	irregularly rounded	rounded	rounded	rounded	irregularly rounded
PUP	flat	flat	flat	flat	flat	flat	flat
PLP	flattened convex	flat	flat	flat	flat	concave	flattened convex
FG	4	1	1	1	1	1	3
Petals							
MCOS	/	/	/	/	/	/	012D
TFF	June 3rd	June 1st	June 3rd	June 6th	June 3rd	June 3rd	June 6th
Hips							
HSLS	pitcher-shaped	pitcher-shaped	pitcher-shaped	pitcher-shaped	pitcher-shaped	pitcher-shaped	pitcher-shaped
CMS	orange	orange	orange-red	red	orange	orange	yellow-orange

* Flowering laterals—FL; type—TP; Color group—CG; Color of center (only varieties with flower type double)—CC; Shape—SH; Profile of upper part—PUP; Profile of lower part—PLP; Fragrance—FG on the 1–5 scale; Main color on the outer side (only if clearly different from inner side)—MCOS; Time of first flowering—TFF; Hips shape in longitudinal section—HSLS; Color (at mature stage)—CMS.

Fragrance as an important factor in the human perception and pollinators' attraction was described with overall score, ranging from 0 (absent or weak) in 'Crystal Mella' to 4 in 'Barbie Mella' (Table 2), and subsequently scored by the panel according to the presence of different fragrance components (Table 3). In addition to being highly scored for overall fragrance, 7 times panelists recorded medium fragrance (belonging to lemon, mint, flowery, peach and vanilla smell) in 'Barbie Mella'. On the contrary, only one record for sweet/honey smell in 'Ruby Mella' and one record for flowery smell in 'Exotic Mella' was noted. 'Ducat Mella', 'Amulet Mella' and control 'Carmine Vase' were all characterized by absent or weak fragrance (with 30 out of 30 records), belonging to various notes (Table 3).

Table 3. Human perception of floral scent in the investigated 'Mella' rose collection.

Fragrance panel			'Barbie Mella'			'Ruby Mella'			'Ducat Mella'			'Amulet Mella'			'Exotic Mella'			'Carmine Vase'		
			A/W	*M*	*S*	*A/W*	*M*	*S*	*A/W*	*M*	*S*	*A/W*	*M*	*S*	*A/W*	*M*	*S*	*A/W*	*M*	*S*
Top Notes	Citrus	orange	1 *			3														
		lemon	1	3		2						3			8			7		
		apple	6			6			5			3			4			6		
	Aromatic	mint		1					1			1								
		anise																		
		eucalyptus																		
Heart Notes	Floral	flowery	3	1		5			6			4			6	1		8		
		rose-like	1						3			4			4			4		

		jasmine							1	
	Green	forest	1				2	1	2	
		herbaceous	1		2			2		2
		grass			2		5	4	1	1
	Fruity	fruity	3				1	2	1	
		sweet, honey	2		5	1	3			
		peach		1						
	Spicy	spicy								
		peppery	1				1		1	1
		cinnamon								
Base Notes	Woody, earthy	moss	1		1		1	4		1
		woody	1		2		1		1	
		coniferous			1			1		
	Balsamic	balsamic								
		musky					1			
		vanilla	1	1				1		

*—Number of panelists that scored the fragrance presence; A/W—absent or weak; M—medium; S—strong fragrance.

Quantitative flower trait—number of flowering shoots was recorded only in 'Crystal Mella' (with 10 ± 2.0 shoots), the only cultivar with no flowering laterals. On the opposite, numbers of laterals took average values from 1.4 ± 0.1 in 'Exotic Mella' to 6.4 ± 1.7 in 'Ruby Mella', whilst number of flowers per those laterals varied from maximum 10.8 ± 0.2 in 'Mellite Mella' down to 4.8 ± 1.5 and 4.8 ± 1.3 in 'Ducat' and 'Amulet Mella', respectively (Table 4).

Table 4. Quantitative generative characteristics of the investigated 'Mella' rose collection.

Cultivar/ Trait	'Barbie Mella'	'Ruby Mella'	'Ducat Mella'	'Amulet Mella'	'Crystal Mella'	'Mellite Mella'	'Exotic Mella'
Flowering shoot							
NFS	/	/	/	/	10 ± 2.0	/	/
NFL	3.4 ± 1.1 ^{bc*}	6.4 ± 1.7 ^{a}	4.0 ± 0.0 ^{b}	2.6 ± 0.6 ^{bc}	/	2.4 ± 0.2 ^{bc}	1.4 ± 0.1 ^{c}
NF/L	8.6 ± 3.2 ^{a}	9 ± 4.5 ^{a}	4.8 ± 1.5 ^{a}	4.8 ± 1.3 ^{a}	/	10.8 ± 0.2 ^{a}	9.4 ± 0.4 ^{a}
Flower							
NOP	5.8 ± 0.8 ^{c}	6.6 ± 1.1 ^{c}	6.2 ± 1.1 ^{c}	6 ± 1.0 ^{c}	20 ± 1.0 ^{a}	13 ± 2.0 ^{b}	15.2 ± 3.0 ^{b}
DM	6.0 ± 1.3 ^{ab}	4.1 ± 0.4 ^{c}	4.8 ± 0.5 ^{bc}	4.6 ± 0.2 ^{bc}	6.6 ± 0.6 ^{a}	5.9 ± 0.5 ^{ab}	6.8 ± 0.7 ^{a}
Petals							
PL	2.8 ± 0.1 $^{a–d}$	2.4 ± 0.2 ^{cd}	2.7 ± 0.3 ^{bcd}	2.3 ± 0.4 ^{d}	3.3 ± 0.2 ^{a}	3 ± 0.2 ^{abc}	3.2 ± 0.4 ^{ab}
PW	2.7 ± 0.2 ^{b}	1.9 ± 0.1 ^{c}	2.1 ± 0.1 ^{c}	2.1 ± 0.3 ^{c}	3.0 ± 0.3 ^{ab}	3.4 ± 0.4 ^{a}	3.4 ± 0.3 ^{a}
Hips							
HL	1.3 ± 0.3 ^{ab}	1.3 ± 0.1 ^{ab}	1.6 ± 0.3 ^{ab}	1.1 ± 0.1 ^{b}	1.4 ± 0.4 ^{ab}	1.2 ± 0.2 ^{ab}	1.8 ± 0.2 ^{a}
HW	1.3 ± 0.3 ^{a}	1.2 ± 0.2 ^{a}	1.5 ± 0.1 ^{a}	1.0 ± 0.1 ^{a}	1.3 ± 0.3 ^{a}	1.2 ± 0.2 ^{a}	1.5 ± 0.2 ^{a}

Number of flowering shoot (Only varieties with no flowering laterals)—NFS; Number of flowering laterals—NFL; Number of flowers per lateral (Only varieties with flowering laterals)—NF/L; Number of petals—NOP; Flower diameter—DM; Petals length—PL; Petals width—PW; Hip length—HL; Hip width—HW.* Mean values designated with the same letter were not significantly different according to Tukey's Honest Significant Difference test ($p \le 0.05$).

Number of petals was the highest in the double flowers of 'Crystal Mella' (20 ± 1.0), over semi-double flowers of 'Mellite Mella' (13 ± 2.0) and 'Exotic Mella' (15.2 ± 3.0) down to 5.8 ± 0.8–6.6 ± 1.1 in other four cultivars. Consequently, semi-double and double flowers achieved the highest flower diameters (5.9 ± 0.5–6.8 ± 0.7 cm), with one exception—high value of 6 ± 1.3 cm in single flowers of 'Barbie Mella'. Petal length and width showed lesser variation, ranging from 2.4 ± 0.2 and 1.9 ± 0.1 cm in 'Ruby Mella' to 3.2 ± 0.4 and 3.4 ± 0.3 cm in 'Exotic Mella', respectively. Hip length and width varied from 1.1 ± 0.1 and 1.0 ± 0.1 cm in 'Amulet Mella' to 1.8 ± 0.2 and 1.5 ± 0.2 cm again in 'Exotic Mella', respectively.

3.3. Disease Resistance Observations

In order to meet Sustainable Development Goals (SDG), and promote sustainable gardening and pollinator diversity, investigated roses were evaluated in terms of their resistance/tolerance to main rose disease causing agents. Overall score on the 1–5 scale differed among investigated cultivars, with four cultivars labeled as medium tolerant (score 3) and three separated as tolerant (score 4), due to absence of downy mildew and rust symptoms, as well as absence (in 'Crystal Mella'), self-cleaning (in 'Barbie Mella') or rare appearance (in 'Mellite Mella') of leaf spot symptoms (Table 5). In 'Barbie Mella', 'Ruby Mella' and 'Ducat Mella' powdery mildew symptoms were not detected, while in other 4 cultivars these symptoms rarely appeared. Black spot symptoms were determined in all investigated cultivars, causing overall scores less than maximal 5 on the 1–5 scale.

Table 5. Disease tolerance of the investigated 'Mella' rose collection in three-year period.

Cultivar/Trait	**'Barbie Mella'**	**'Ruby Mella'**	**'Ducat Mella'**	**'Amulet Mella'**	**'Crystal Mella'**	**'Mellite Mella'**	**'Exotic Mella'**
Overall score 1/5	4 *	3	3	3	4	4	3
PM 0/1	0	0	0	1	1	1	1
DM 0/1	0	0	0	0	0	0	0
BS 0/1	1	1	1	1	1	1	1
LS 0/1	1	1	1	1	0	1	1
Rust 0/1	0	0	0	0	0	0	0
Remarks disease tolerance	LS occasionally appears and self-cleaning	LS rarely appears	LS rarely appears	PM and LS rarely appear	absence of LS symptoms PM rarely appear	PM and LS rarely appear (marks ranged from 1–5)	PM rarely appears, LS occasionally

PM—powdery mildew caused by *Sphaerotheca pannosa* var. *rosae*, syn. *Podosphaera pannosa*; DM—downy mildew caused by *Peronospora sparsa*; BS—black spot caused by *Diplocarpon rosae*; LS—leaf spot caused by *Pseudomonas syringe*; Rust—caused by *Phragmidium* sp. *—Overall scores on the 1–5 scale based on the complete results.

3.4. Volatile Compounds Investigation

Investigated 'Mella' roses were characterized by different volatile compounds belonging to aromatic alcohol, terpenoids and alkanes. 'Barbie' and 'Ducat' Mella roses were characterized by presence of aromatic phenylethyl alcohol, with 31.6 and 34.9%, respectively (relative percentage of the total peak area). Terpenoid citronellol was detected only in 'Ducat Mella', while geraniol and nerol were found in 4 cultivars (Table 6). Alkanes 9-nonadecene and nonadecane were present in small percentages (0.34–2.44%) in two and three cultivars, respectively. Nonadecane reached 6.02% only in 'Exotic Mella' cultivar. Higher percentages and presence in all cultivars was associated with heneicosane, hexacosane, octacosane, tetratetracontane and hentriacontane, except for heneicosane in 'Ruby Mella' (0%) and 'Ducat Mella' (0.43%). Relative percentages of straight-chain alkane heneicosane ranged from mentioned 0% in 'Ruby Mella' to 9.03% in

'Exotic Mella', while straight-chain alkane-hexacosane content ranged from 3.66 in 'Carmine Vase' to 9.52 in 'Barbie Mella'. Third straight-chain alkane—octacosane was detected in higher percentages, taking values from 10.7% in 'Ruby Mella' to 35.2% in 'Ducat Mella'. Long-chain alkanes tetratetracontane and hentriacontane were least present in 'Ducat Mella' (with 9.22 and 1.28%, respectively), while in 'Ruby Mella' their content was the highest—57.5 and 16.3 %, respectively. With the exception in 'Ducat Mella' (where octacosane dominated), tetratetracontane was the most represented alkane in the investigated rose cultivars (Table 6).

Table 6. Volatile compounds determined in investigated 'Mella' roses.

	Phenylethyl Alcohol	Citronellol	Geraniol and Nerol	Heptadecane	9-Nonadecene	Nonadecane	Heneicosane	Hexacosane	Octacosane	Tetratetracontane	Hentriacontane
'Barbie Mella'	31.6 *	0.00	5.18	0.00	0.34	1.68	6.88	9.52	14.3	25.3	2.89
'Ruby Mella'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.38	10.7	57.5	16.3
'Ducat Mella'	34.9	0.79	1.15	0.00	0.00	0.00	0.43	6.74	35.2	9.22	1.28
'Amulet Mella'	0.00	0.00	8.83	0.00	0.00	0.00	1.19	7.18	26.7	42.6	4.92
'Exotic Mella'	0.00	0.00	5.27	0.00	2.44	6.02	9.03	6.65	16.8	22.1	3.60
'Carmine Vase'	0.00	0.00	0.00	0.00	0.00	0.96	5.01	3.66	21.7	35.5	10.4

*—Values are represented with relative percentage of the total peak area.

3.5. Honey Bee's Abundance

Bees' visitations on the flowers belonging to 'Barbie Mella' ranged from 300 to 500, causing the highest variation, while those visitations ranged from 15 to 35 in the 'Amulet Mella', resulting in the lowest variation (Figure 2.). Correspondingly, the highest average number (390 ± 80 bees) was recorded on the 'Barbie Mella' cultivar, while the lowest number counted (25 ± 8 bees) was associated with 'Amulet Mella' rose. Cultivar 'Carmine Vase' did not attract bees at all (Figure 2). 'Ruby', 'Ducat' and 'Exotic' Mella cultivars were visited by 138 ± 34, 68 ± 54 and 56 ± 28 honey bees, respectively. Regarding the absolute maximal and minimal honey bee visitations per day, 500 and 15 honey bees were counted on the 'Barbie Mella' and 'Amulet Mella' cultivars (respectively), on the day #1 (10 June).

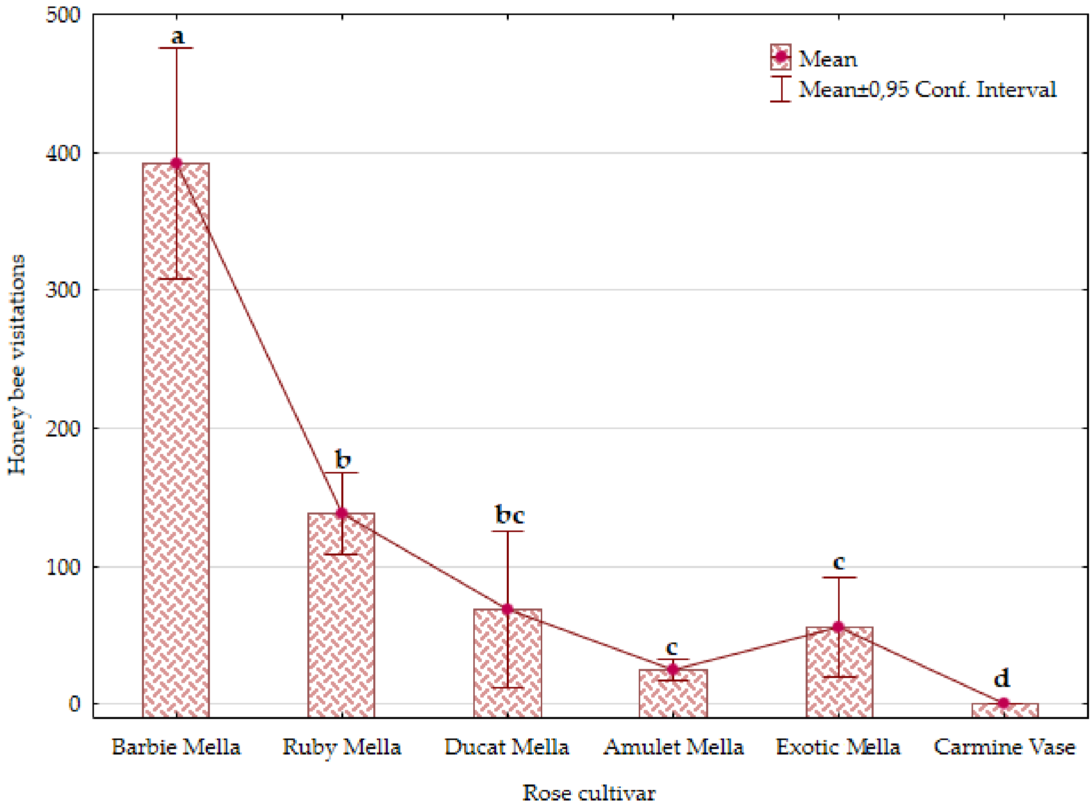

Figure 2. Honey bees abundance (expressed in the average daily number of counted bees) in different 'Mella' rose cultivars. Mean values designated with the same letter were not significantly different according to Tukey's Honest Significant Difference test ($p \leq 0.05$).

The two extremes—'Barbie Mella' and 'Carmine Vase' are presented in Figure 3a and 3b, respectively. As it can be seen in the figures, 'Barbie Mella' is characterized by simple, wild-type flowers with displayed pistil and stamens, while 'Carmine Vase' has double, enclosed flowers.

(**a**) (**b**)

Figure 3. Flower morphology of 'Barbie Mella' (**a**) and 'Carmine Vase' (**b**) roses.

Besides counts of honey bees visiting flowers, wild bees were also recorded in the same observing period. Only 11 specimens belonging to *Halictus* sp. and *Lasioglossum* sp. were detected, preferring 'Ducat Mella' with 2 female bees from *Halictus* sp. and 2 female bees from *Lasioglossum* sp. (Table 7).

Table 7. Wild bees recorded foraging on the 'Mella' cultivars.

Rose cultivar	Family	Species	Gender	Number of specimens	Legator
'Barbie Mella'	Halictidae	*Halictus* sp.	female	1	Aleksandar Đukić
'Barbie Mella'	Halictidae	*Lasioglossum* sp.	female	1	Aleksandar Đukić
'Ducat Mella'	Halictidae	*Halictus* sp.	female	2	Aleksandar Đukić
'Ducat Mella'	Halictidae	*Lasioglossum* sp.	female	2	Aleksandar Đukić
'Ruby Mella'	Halictidae	*Lasioglossum* sp.	female	1	Aleksandar Đukić
'Amulet Mella'	Halictidae	*Lasioglossum sp.*	female	1	Aleksandar Đukić
'Exotic Mella'	Halictidae	*Halictus* sp.	female	2	Aleksandar Đukić
'Exotic Mella'	Halictidae	*Lasioglossum* sp.	female	1	Aleksandar Đukić

4. Discussion

4.1. Ornamental Value of Investigated 'Mella' Roses

Green areas can significantly improve the quality of life in urban areas and play a major role in stabilizing and preserving urban ecosystems. Urban plantings may be less significant than natural greenery of the same size [38] however, these plantings may contain numerous species [39] in relatively small areas. Therefore, the diversity of species in cities can often be higher than in the natural environment. The biggest obstacle to functional biodiversity in urban plantings is that design intentions are usually focused on decorative purposes and on the visual experience, rather than the real, functional values of the plant communities being combined. Designed urban landscape contains built elements (irrigation, substrate, paving, urban furniture, fountains, etc.), and only in second place comes plant material selected because of its specific characteristics (colors, textures and sizes), maintenance requirements and ecosystem services [40]. Urban sprawl pressure leads to green areas decrease, implying the need for application of ornamental plant material that combines multiple desirable traits, from both perspectives—humanity and nature. Some wild (*Rosa canina* L., *Rosa rugosa* Thunb.ex Murray) and garden roses very similar to 'Mella' collection are 'naturalistic' in their overall appearance, incomparable with roses for cut flowers that are characterized by large double flowers and waxy petals. However, a group of professional breeders from Netherlands 'Roses4Gardens' [41] defines exactly *R. rugosa* varieties as ideal for planting in public green spaces, as healthy, hardy plants that tolerate drought, road salt and wind (even ocean breezes). In addition, they flower for several months, increase biodiversity and are easy to maintain.

According to Ferrante et al. [42] multiple components (all studied in our investigation) are responsible for ornamental value of roses—habitus, number and type of flowers, leaf characteristics, number of petals and their arrangement in simple, semi-double and double flowers, shape and size of petals, buds and flowers as well as shape, size and colors of hips. In that sense, all investigated 'Mella' roses are unique and ornamental, although it isn't their major function. Their shrubs take forms from semi-upright to moderately spreading, leaves have anthocyanin coloration and weak to strong glossiness, flowers are white to purple and single to semi-double, and finally their hips are yellow-orange to red. However, 'Barbie Mella' with semi-upright shrub, 80 cm in height and 30 purple red flowers can be emphasized as the most decorative in the collection, followed by the 'Rubi Mella' also with purple flowers, but with a significantly higher number of flowers-60 (observed through number of flowering laterals and flowers per laterals). Lower number was counted for 'Crystal', 'Amulet' and 'Exotic Mella' (10–15 flowers), while 'Ducat' and 'Mellite' were characterized by 20 and 27 flowers per plant (respectively).

4.2. Disease Tolerance of the Investigated Roses from the 'Mella' Series

Aiming to promote natural landscapes and sustainability, garden roses applied in the urban environment should poses at least the tolerance if not the resistance to main fungal diseases. Selection of resistant genotypes to abiotic stresses and parasitic diseases is a priority at the global level, as it can drastically reduce the use of pesticides on green areas and in production conditions, concomitantly improving environmental protection and human health. The two most economically significant diseases of roses are black spot (*Diplocarpon rosae* Wolf.) and powdery mildew (*Podosphaera pannosa* var. *Rosae*), which cause significant damage in the open field, but also in the controlled greenhouse environment [43,44]. Both disease agents cause symptoms on the leaf reducing photosynthetic activity, which results in direct and indirect consequences and the end result is the reduced decorativeness, yield and content of bioactive substances. In the current research powdery mildew symptoms were not detected in 'Barbie Mella', 'Ruby Mella' and 'Ducat Mella', while in other 4 cultivars these symptoms rarely appeared. However, black spot symptoms were determined in all investigated cultivars, causing overall scores in the whole sample less than maximal 5 on the 1–5 scale (occurring from 1—very often and severe to 5—never). Disease control imposes up to twenty sprays with chemicals per growing season which is not acceptable by European customers, now demanding less pesticide application to the plants and has begun testing for chemical residues on leaves to monitor growers to compliance with this request. Therefore, the application of agrochemicals in EU-countries has been curbed and occasionally even forbidden; implying that breeding for disease resistance in rose varieties is more than urgent. Furthermore, pesticides application is unacceptable in urban cores [45], due to housing proximity, implying that 'Mella' roses can successfully 'reply' to those strict requirements.

4.3. Flower Properties Important for Pollinators' Attraction

Recent studies accelerated the citizens' awareness towards the significance of wild life in urban cores. Thus, breeders, horticulturalists and landscape designers should set the breeding and designing goals together, striving to improve multiple ecosystem services at once. Although for different reasons, fragrance is an important property for both humans and pollinators. Interestingly, panel fragrance scoring that determined weak sweet/honey notes in 'Barbie', 'Ruby' and 'Ducat' cultivars (in exact order of bees' visitations) is in alignment with observations of Proctor et al. [46] that flowers specially adapted to bees have a sweet or honey like scent. Nectar plays the crucial role in attracting bees, thus 'Barbie Mella' with the highest value for the fragrance (score 4) and the most divergent volatile components was the most visited 'Mella' rose. Investigating the flowers with removed pollen and/or nectar, Li et al. [47] found that flowers without nectar attracted fewer bumble bee pollinators, while pollen removal did not cause the bumble bee's absence. Instead, compared with control flowers, the flowers that contained only nectar in mentioned study attracted more bumble bee pollinators in *Impatiens oxyanthera* flowers. However, due to results in our study, it seems that in roses, a combination of vegetative and generative characteristics plays crucial role in the pollinators' attraction. With more than 350 daily average number of honey bees in the investigated period, semi-upright growth and height around 80 cm, single—simple flower type, as well as higher value for the fragrance, seem to be the most accessible, desirable and attracting to pollinators. In the most recent study, Erickson et al. [35] exactly concluded the same—multiple floral traits (visual, chemical and nutritional) contributing to the whole flower display are responsible for pollinators' attraction. According to this study total pollinator abundance depended on corolla depth, color (especially purple like in 'Barbie Mella' and 'Ruby Mella'), nectar and flower display area, while plant-height-caused attraction was species-specific, with *A. mellifera* preferring taller garden flowering plants.

Regarding chemical traits, volatile compounds found in pertinent study on 'Mella' roses revealed differences among cultivars and possible assumption why 'Barbie Mella' was multiple times more visited cultivar than others. Besides possessing 9 out of 11 investigated components, this cultivar had the most balanced ratio (almost 1:1:1) between aromatic alcohol + terpenoids, straight-chain alkanes and long-chain alkanes (36.8, 32.7 and 28.1 relative percentages, respectively). In all other cultivars those ratios differed more than 20%. Cultivated, fragrant and essential oil-bearing Damask rose (*Rosa damascena*) contains more than 300 volatile constituents, predominantly terpenes (citronellol, geraniol and nerol) and long-chain hydrocarbons [48], as determined for the 'Mella' roses. Furthermore, similarly to our results, volatile compounds in wild rose—*R. canina* genotypes are a mixture of terpenoids, hydrocarbons and alkanes, with up to 39 % of phenylethyl alcohol as the only benzoid found in this species [49]. This compound proved to be the most responsible for pollinators' attraction in kiwi flowers, since among 18 compounds investigated, phenylethanol gave the largest antennal responses across all samples [50]. Since this compound was also very highly represented in the 'Ducat Mella' cultivar, which did not attract as many bees as 'Barbie' it can once again be assumed that the combination, rather than one trait is responsible for number of bees visiting flowers.

As to the flower type, Strzałkowska-Abramek [51] showed that the double flowers of *Prunus serrulata* 'Kanzan' offered only scarce amounts of nectar and pollen, compared to semi-double flowers of *P. serrulata* 'Amanogawa', with the recommendation that in pollinator-friendly arrangements in urban areas, these cultivars should not be considered for planting. Investigating nectar production and pollinators' attraction to *Tropaeolum majus*, *Consolida* sp., *Antirrhinum majus*, *Viola* × *wittrockiana*, *Tagetes patula* and *Alcea rosea*, with natural or modified types of flowers, Comba et al. [52] have shown that the augmentation of petals, might reduce floral rewards or their accessibility. Similarly, Corbet et al. [53] found that exotic or double flowers were far less exploited by insect visitors. Regarding roses, Zuraw et al. [54] stated that cultivated roses are not important as a source of food for insects due to numerous flower petals. On the contrary, already mentioned wild species—*R. rugosa* (with the same flower type as 'Mellas') had the greatest apicultural value due to pollen production, long flowering period and greatest flower diameter. While the majority of roses from the 'Mella' collection had a simple flower corolla, with one row of petals and available pollen/nectar, cultivar 'Exotic Mella' had semi-double flower type and 'Carmine Vase' had double flower with a significantly larger number of petals' rows. 'Exotic Mella' although with a larger number of petals in its flower corolla, attracted a significant number of honey bees, over 50. However, the obvious difference in the availability of pollen has led to a clear difference in honey bee abundance compared to the more wild-type variety—'Barbie Mella'. Interestingly, although very low (11 specimens), the number of recorded wild bee species was not significantly different in semi-double flower type 'Exotic Mella' compared with other 'Mella' cultivars. Larger sample and longer sampling period are necessary to further investigate the honey bee and wild bees' dynamic. In 'Carmine Vase' characterized by double flowers, no bee species were recorded during the studied period. A large number of petals' rows completely surrounded and enclosed the region of the ovary and pistil, thus preventing pollen accessibility.

4.4. Possible Ecosystem Services Provided by the 'Mella' Roses in the Urban Environment

Urban ecosystems are dynamic and hybrid systems consisting of natural and human-made elements whose interactions are affected not only by the natural environment but also cultural, political, economic and social factors. Growing interests towards urban gardening and urban food production [20], require presence of appropriate pollinators on the one side, concomitantly increasing urban pollinators' forage resources on the other. However, understanding the impacts that impair pollinators' behavior and pollination is especially relevant in urban environments where pollinators can enhance food security [55]. Being highly mobile and behavioral, pollinators directly impact provisioning ecosystem service [56]. Furthermore, fruits produced upon the successful pollination can contribute not only to urban food production, but as the autumn food for birds since all 'Mella' cultivars produce attractive fleshy hips, expanding the ecosystem services list.

Pollinator-attracting semi-natural urban landscapes, naturalistic planting design in urban open space as well as urban gardens with edible ornamental species, are a growing trend. However, despite many ecosystem services, urban gardening carries important challenges. The first is very limited space and the second challenge is the occurrence and spread of diseases and pests in the growing urban green, semi-natural environment and gardens. Since chemical treatment is not acceptable for both pollinators and residents, garden roses, as possible hot-spots for pollinators' attraction in urban landscapes need to be tolerant or resistant to main pathogens, contributing to several ecosystem services. To tackle the challenges of the 21st century, urban ecosystems as intertwined and multi-layered systems should not be vulnerable but able to cope with climate change and provide sustainable development. According to Hicks et al. [57] pollinator's abundance and diversity could be increased by changes in urban land use that increase floral resource availability, such as semi-natural landscapes do.

With their aesthetic values, pronounced disease tolerance, pollinators' attraction and rustic appearance investigated 'Mella' roses ('Barbie', 'Ruby', 'Ducat' and 'Exotic') completely correspond to the semi-natural gardens/landscapes, and their ecologically-based garden design and management, implementation rules, management and maintenance skills and social components, contributing to the overall ecosystem services (Figure 4). Pronounced, but not exclusive, according to Millennium Ecosystem Assessment [24], 'Mella' roses ecosystem services include provisioning (honey production, food for bees, birds and butterflies, genetic material for future crosses and rose improvement), regulating (air purification, pollinators' habitat and disease control), cultural (spiritual or inspirational service as well as aesthetic value) and supporting (tolerance to diseases, nutrient cycling and soil enrichment). As an indirect ecosystem service, upon the pollination urban food production might benefit trough increased yields of vegetables and fruits.

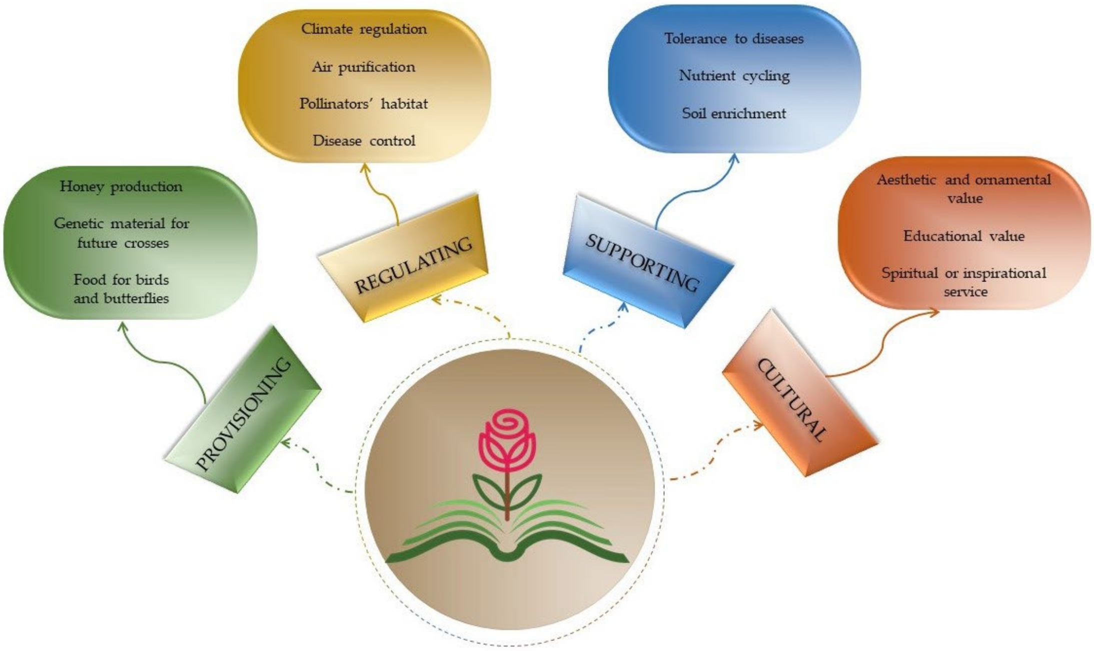

Figure 4. Ecosystem services provided by investigated 'Mella' cultivars.

5. Conclusions

Significant variability in vegetative and generative plant characteristics, contributing to their overall significant decorativeness was noted in investigated 'Mella' roses. With their 'naturalistic' overall appearance, comparable with wild roses, 'Mella' cultivars differed in plant height and habitus, number and type of flowers, leaf coloration and glossiness, but 'Barbie Mella' and 'Ruby Mella' positioned as the most decorative ones. 'Barbie Mella' was highly scored for overall fragrance, with the most divergent records for fragrance components (belonging to lemon, mint, flowery, peach and vanilla smell) noted by human panelists. Volatile compounds investigation further revealed that this cultivar was characterized by 9 out of 11 investigated volatile components, and the most balanced ratio (almost 1:1:1) between aromatic alcohol + terpenoids, straight-chain alkanes and long-chain alkanes. Since mentioned cultivar was the far most visited by the bees, it can be concluded that the combination of plant height, fragrance, volatile compounds, flower type (single, simple), flower diameter and accessibility seems to be crucial in bees' attraction, rather than any characteristic solely. As an outstanding bee-attractor 'Barbie Mella' should be promoted as ornamental disease-tolerant rose cultivar that can provide not only aesthetic value but significant pollinator-friendly habitat. In the following period, it is necessary to perform further studies regarding bees belonging to other genera, in order to define the diversity of bees that visit garden roses. Already based on the preliminary results, we can conclude that the varieties from the 'Mella' collection attract a significant number of pollinators and as such are imperative in modern horticulture in urban cores. Further research is necessary to investigate 'Mella' roses' as potential food resources for birds and/or butterflies.

Due to their combined aesthetic values, disease tolerance and bees presence, 'Mella' roses 'Barbie', 'Ruby', 'Ducat' and 'Exotic' should be planted as a part of urban semi-natural gardens/landscapes, possibly contributing to the overall ecosystem services (provisioning-honey production, food for bees, birds and butterflies, genetic material for future crosses and rose improvement; regulating-air purification, pollinators' habitat and disease control; cultural-spiritual or inspirational service as well as aesthetic value; supporting-tolerance to diseases, nutrient cycling and soil enrichment). Until their world-wide availability, other 'Mella'-like wild and cultivated roses should be investigated and promoted likewise.

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