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INVENTORY OF ALLERGENIC POLLEN URBAN DENDROFLORA AS A BASIS FOR DESIGNING HEALTHIER GREEN INFRASTRUCTURE

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Abstract

The paper considers the potential impact of allergenic pollen urban dendroflora on public health. The aim of the study was to make quantitative and qualitative analysis of urban park woody taxa emitting allergenic pollen in order to increase the awareness of landscape architects and medical practitioners. The case study was conducted in the second largest park in Bulgaria – Sveti Vrach, Sandanski. The town is famous as climatotherapy and spa resort of international importance. The total number of the investigated trees was 2673, and the number of shrub specimens – approximately 2640. The results from the detailed inventory of park dendroflora estimated that the total number of taxa was 199 in terms of species and the infraspecific taxa, belonging to 49 families and 109 genera. Analysis of the systematic structure of the examined specimens was performed. Geographic distribution, reproductive characteristics, foliage permanence, and allergenicity level of taxa were also analysed. Considering the allergenic potential value of tree species, 34.9 % of tree specimens had a high allergenic potential, 10.6 % of tree individuals had a very high allergenicity level, while 4.8 % – a moderate one. As a result, half of all the researched trees (50.2 %) had a moderate to very high allergic potential. The most frequent shrub species had moderate to low/very low alergenicity potential. Only 4.9 % of shrub specimens had a high to very high allergenicity level. Tree density and Diversity Index were also calculated, as factors that most affect the final allergenicity value of the park. Adopted strategies for risk mitigation has been suggested and addressed to future urban greening initiatives and landscape design for achieving biodiversity-friendly green infrastructure and sustainable urban environment.

Key words: allergenic plants, biodiversity, ecosystem services, green spaces, tree pollen, urban planning.

Introduction

The subject of health-related ecosystem services of urban green spaces is a global issue in urban planning (Roy et al. 2012, Salmond et al. 2016, Vasiljevic et al. 2018). In the last decades, a great number of studies have suggested positive effects of green spaces on the mental and physical health status of population (Pretty et al. 2005, Gidlöf-Gunnarsson and Öhrström 2007, Lee and Maheswaran 2011, Ward Thompson et al. 2012, Dzhambov and Dimitrova 2014, Grazuleviciene et al. 2014, Jonker et al. 2014, Markevych et al. 2014, Staneva et al. 2016).

Urban greenery may have a positive impact on the reduction of psychophysiological stress, associated with time spent in outdoor physical activities in a natural environment, such as urban forest, parks or other residential green spaces (Sugiyama et al. 2008, McCurdy et al. 2010, Balseviciene et al. 2014, Harting et al. 2014, Nieuwenhuijsen et al. 2014). However, the topic of green infrastructure and human health has been approached very differently by natural science and epidemiology (Kumar et al. 2019). Along with the multiple environmental, economic, social and cultural benefits that contribute to human well-being, urban trees pose some health hazards determined as 'ecosystem disservices' (Lyytimäki and Sipilä 2009, Tomalak et al. 2011, Cariñanos et al. 2017, Ćwik et al. 2018, Battisti et al. 2019). Some epidemiological studies directly link urban green spaces with allergic sensitization to pollen and asthma (D'amato et al. 2007, DellaValle et al. 2012, Scharte and Bolte 2012, Lovasi et al. 2013, Andrusaityte et al. 2016).

Allergic respiratory response to pollen in sensitized individuals, pollinosis, allergic rhinitis, hay fever, allergic rhinoconjunctivitis or asthma exacerbations, is an extremely common disease worldwide (Wuthrich et al. 1995, Strachan et al. 1997, Bousquet et al. 2001, Dales et al. 2004, Ridolo et al. 2007, Greiner et al. 2012). The prevalence of pollinosis at some European locations is presently estimated to be up to 40 % and has a remarkable clinical impact since pollination period covers about half the year (D'amato et al. 2007). There is a lack of sufficient data to build up a clear picture of prevalence of asthma and pollinosis in Bulgaria. The values obtained in Hristov (2013) study for the prevalence of asthma and allergic rhinitis (95 % CI): 14.9 % (13.5–16.2 %) and 39.3 % (37.5–41.1 %), respectively, differ significantly from those accepted for the country so far.

Tree pollen emissions can be considered main source of emission of coarse particulate matter in urban environments (Cariñanos et al. 2017). Nikolov el al. (2015) palynological survey shows that the tree pollens are a significant part (78.2–83.8 %) of total pollen grains in the air. According to Nikolov el al. (2015), tree pollen allergens play a key role in the sensitization and in the occurrence of allergic symptoms in hypersensitive individuals in Bulgaria.

In relation to higher ambient air pollutant concentrations and the interaction between pollen and air pollutants, urban citizens have shown to be more prone to pollen allergies (asthma and allergic rhinitis) than those who live in rural areas (Von Ehrenstein et al. 2000, Riedler et al. 2001, D'Amato et al. 2007).

Tree pollen grains are released higher above the ground and can be transported and deposited in large distances from its source (Skjøth et al. 2007, Galan et al. 2008). The production and dispersion of pollen depends on the plant taxon and meteorological factors, such as temperature, precipitation, humidity, wind speed and direction, as well as diurnal rhythm and thunderstorm events (Latalowa et al. 2005, Emberlin et al. 2007, Sofiev et al. 2012, Elliot et al. 2013, Ščevková et al. 2015). There is some evidence that climatic warming over the past decades resulted in earlier and lengthened pollen seasons for many tree species and earlier seasonal appearance of respiratory symptoms and their prolonged duration, respectively (Emberlin et al. 1997, Frei 1998, Emberlin et al. 2002, Fitter and Fitter 2002, Beggs 2004, Ziska et al. 2011, Vardoulakis and Heaviside 2012).

Among the main sources of allergenic pollen emissions in urban areas are species from some of the most commonly used ornamental tree genera in European cities: *Acer* L., *Cupressus* L., *Pinus* L., *Platanus* L., *Quercus* L. and *Tilia* L. (Cariñanos et al. 2017). Depending on geographical location, a wide variety of trees are common producers of pollen aeroallergens in Europe (e.g. genera of birch (*Betula*), alder (*Alnus*), hazel (*Corylus*), oak (*Quercus*), olive (*Olea*), and cypress (*Cupressus*)). The most allergenic tree pollen is produced by birch in North, Central and Eastern Europe, and by olive and cypress in the Mediterranen regions (D'amato et al. 2007).

The value of overall allergenic risk that species pose in the area they grow was epitomized in the Index of Urban Green Zone Allergenicity (IUGZA), developed by Cariñanos et al. (2019). Cariñanos et al. (2019) postulate that a forest-type landscape design, with high density of tree per 1 ha, and monospecific tree plantations, contribute to the remarkable increase in the IUGZA. High biodiversity environment is well appreciated not only in the landscape design along with the other recreational values and health and well-being benefits of urban green spaces (Fuller et al. 2007, Hoyle et al. 2017, Gao et al. 2019). Many authors suggest that contact with biodiversity-rich environments can boost immunological tolerance and reduce sensitivity to allergens (Hanski et al. 2012, Rook 2013).

Asthma and allergic rhinitis adversely alters the quality of life of suffers, their performance and productivity (Bousquet et al. 1994, Meltzer 2016). Furthermore, the costs for treating rhinitis and asthma are a considerable annual financial burden on patients and healthcare systems (Nathan 2007, Pawankar 2014).

Since the associations of urban green spaces with allergic conditions are diverse and the effect of greenery on health is complex, Andrusaityt et al. (2016) suggests that further investigation on species composition of green spaces, air quality and population groups should be conducted.

Sveti Vrach Park dendroflora was selected for object of study, as Sveti Vrach is one of the largest parks in Bulgaria. Moreover, the town of Sandanski is well-recognized natural sanatorium for the treatment of respiratory diseases, famous as climatotherapy and spa resort of international importance (Kostadinov et al. 1983). It attracts a large number of visitors annually as one of the most popular recreational areas in the region, offering a wide range of active and passive leisure activities.

The purpose of this study is to perform quantitative and qualitative analysis of urban park woody ornamentals producing allergenic pollen in order to increase the awareness of landscape architects, medical practitioners and sensitized park visitors to this health issue with large-scale socio-economic impact.

Object and Methods

Study area

The study was conducted in 2019 in the Sveti Vrach Park, Sandanski (41°34′15″ N; 23°17′00″ E; 200 m a.s.l). This centennial park is one of the largest urban parks in Bulgaria and according to its master plan covers an area of 335 dka. The first plantations from *Pinus sylvestris* and *Pinus nigra* established in 1916 (Penzov 2016) nowadays stand out in the historical core of the park, along with the centuries-old riparian *Platanus orientalis* trees. The scope of the inventory included the historical part, which is declared a monument of garden and park art, and the east, north and south extentions.

In terms of climate, Sandanski falls whithin the South Bulgarian climate province, Sandanski-Petrich climate region (Sabev and Stanev 1963). The climate is characterized by a mild winter with a positive January mean temperature – +2.5 °C, and a long and hot summer with July and August average temperature 24.6 °C. The mean annual temperature for Sandanski is 13.9 °C. Northwest and west winds prevail with an average speed of 2 m/s. The mean annual precipitation is 534 mm, most of it being concentrated in the winter months. Moisture deficit during the major part of the growing season – lasting from last decade of June to the first decade of October is common. Sandanski is the driest region in the country, with the lowest relative humidity in all of Bulgaria (53–54 % for July and August).

Urban park woody taxa composition was identified by applying the route method, inventorying the specimens along the whole alley network and in the depth of the groups and massifs. Due to the different dendrometric characteristics, species were divided by their biological type into two groups – trees and shrubs (incl. lianas and subshrubs). Their absolute and relative specimen quantities were presented, apart from those applied as hedges and groundcovers.

The names of the species and cultivated varieties are consistent with the International Plant Names Index (IPNI 2020) and the RHS Horticultural databases (RHS 2020). In addition, the reproductive traits of dioecious specimens were determined in case they were evident. The permanence of species foliage – evergreen or deciduous was considered. Floristic elements of indigenous species were established after Assyov et al. (2012).

The allergenicity rating of the surveyed woody species was determined after Ogren Plant-Allergy Scale (OPALS) (Ogren 2015) and PollenLibrary (2020). According to these scales species with a ranking of 1 on the scale are least likely to cause allergenic reactions in most people, whereas plants assigned a 10 should be regarded as highly allergenic. In general, plants that rank from 1 to 5 should be considered low-risk plants. Two allergenic ratings are used for dioecious species in which male and female reproductive attributes occur on separate individuals.

Tree density (trees per hectare) and Shannon-Wiener Diversity Index (*H*) (Shannon and Weaver 1949) were also calculated, as factors that most affect the final allergenicity value of green spaces (Cariñanos et al. 2019) by formula (1).

$$H = -\sum_{i=1}^{k} \cdot p_i \cdot \log(p_i), \qquad (1)$$

where: $p_i = \frac{n_i}{N}$, n_i is number of individuals of species *i*, *N* is the total number of samples.

Shannon-Wiener Diversity Index (*H*) accounts for both abundance and evenness of the species present. The equitability (evenness) (E_H) can be calculated by the formula (2).

$$E_H = \frac{H}{H_{\max}}, \qquad (2)$$

where $H_{max} = \log(N)$.

Equitability assumes a value between 0 and 1 with 1 being complete evenness.

The climate analysis of the site is based on the data of Hydrological and Meteorological Service of Sandanski (meteorological station 190 m a.s.l.) (BCRB 1983, CRB 1990).

Results and Discussion

Sandanski is located in Southwestern Bulgaria, in the Sandanski-Petrich valley, between the Kresna and Rupel gorges. The town is situated amphitheatrically on the farthest southwestern slopes of Pirin Mountain along the lower flow of the Sandanska Bistritsa River. Another waterbody in the Sveti Vrach Park is a pond.

Climate. The environmental variables, which most affect the floristic composition of the parks, as well as production and dispersion of pollen, are: temperature, precipitation, humidity, wind speed and direction. The southern Bulgarian geographical location and low altitude of the city of Sandanski in combination with the specific relief of the region is a prerequisite for the formation of specific favourable microclimate, influenced by the Mediterranean. The whole park territory is situated along a river, which contributes to air circulation and relative humidity levels. On the other hand, steep slopes frame the park territory in its central part. The relationship between wind direction and pollen dispersion is positive since these winds would transport pollen to the city located mainly southwardly.

The varied native flora of this climatic region is influenced by the Mediterranean (Gateva and Delkov 2001). The environmental conditions and the irrigation of Sveti Vrach park theritory allow the establishment of many exotic species. However, the warm and arid climate would result in earlier and lengthened pollen season.

Woody species composition

A detailed inventory of Sveti Vrach Park woody dendroflora was carried out in 2019. Urban park dendroflora consists of totally 174 species identified. The total number of taxa was 199 in terms of species and the infraspecific taxa, belonging to 49 families and 109 genera. Vakarelov et al. (1982) established 176 taxa in the park. The results of the two inventories cannot be compared, because the scope of our inventory includes additionally the contemporary extentions of the park theritory northwards and southwards.

The analysis of the systematic structure of Sandanski park dendroflora revealed the predominant families, genera and taxa among Gymnosperms (23.1 %) and Angiosperms (76.9 %). The Gymnosperms include 46 taxa belonging to 4 families, 16 genera, 35 species, 4 varietas and 12 cultivars, while the Angiosperms include 153 taxa belonging to 45 families, 93 genera, 139 species, 2 subspecies, 3 varieties and 20 cultivars. Amongst the Gymnosperms families, the Cupressaceae (11.6 %) is represented by 9 genera, 16 species, 2 varieties, 9 cultivars, followed by Pinaceae (10.1 %) – 5 genera, 17 species, 2 varieties, 2 cultivars, Ginkgoaceae (0.5 %) – 1 species and Taxaceae (1.0 %) – 1 species, 1 cultivar. Amongst the Angiosperms families, the Rosaceae (10.05 %) is represented by 12 genera, 19 species, 3 cultivars, followed by Oleaceae (6.5 %) – 7 genera, 13 species, Leguminosae (5.0 %) – 9 genera, 9 species, 1 cultivar, Caprifoliaceae (5.0 %) – 3 genera, 9 species, 1 variety, 1 cultivar, Sapindaceae (4.5 %) – 3 genera, 8 species, 1 cultivar, Salicaceae (4.0 %) – 2 genera, 7 species, 2 varieties, 1 cultivar, Berberidaceae (3.0 %) – 3 genera, 6 species, Hydrangeaceae (3.0 %) – 3 genera, 4 species, 3 cultivars, Malvaceae (3.0 %) – 2 genera, 4 species, 3 cultivars, Moraceae (2.5 %) – 4 genera, 4 species, 1 cultivar, Bignoniaceae (2.0 %) – 2 genera, 4 species, Apocynaceae (1.5 %) – 2 genera, 3 species, Betulaceae (1.5 %) – 3 genera, 3 species, Buxaceae (1.5 %) – 1 genera, 1 species, 2 cultivars, Cornaceae (1.5 %) – 1 genera, 3 species, 1 cultivar, Ebenaceae (1.5 %) – 1 genera, 3 species, Fagaceae (1.5 %) – 2 genera, 3 species, Lythraceae (1.5 %) – 2 genera, 2 species, 1 cultivar, Adoxaceae (1.0 %) – 1 genera, 2 species, 1 cultivar, Asparagaceae (1.0 %) – 2 genera, 2 species, Celastraceae (1.0 %) – 2 genera, 2 species, Elaeagnaceae (1.0 %) – 1 genera, 1 species, 1 cultivar, Juglandaceae (1.0 %) – 2 genera, 2 species, Lamiaceae (1.0 %) – 2 genera, 2 species, Magnoliaceae (1.0 %) – 1 genera, 2 species, Platanaceae (1.0 %) – 1 genera, 2 species. The other 19 families (Anacardiaceae, Aquifoliaceae, Araliaceae, Asclepiadaceae, Cannabaceae, Hamamelidaceae, Hypericaceae, Lauraceae, Meliaceae, Myrtaceae, Paulowniaceae, Pittosporaceae, Polygonaceae, Rutaceae, Simaroubaceae, Solanaceae, Tamaricaceae, Ulmaceae, Vitaceae) – are represented by one species each. The genera represented with the largest number of species were *Lonicera* – 7 spp.; *Acer* – 6 spp.; *Fraxinus* – 5 spp.; *Pinus* – 5 spp.

The total number of the surveyed trees was 2673, and the number of shrub specimens – approximately 2640 (Table 1). The number of shrub individuals is approximative, because some shrub species were planted in large groups or hedges which made counting difficult.

The number of angiosperm tree specimens (56.8 %) slightly exceeded Gymnosperm tree specimens (43.2 %). The biological type analysis showed that trees amount 56.9 %, while shrubs – 37.4 %, lianas – 4.0 %, subshrubs – 1.7 % of the total number of species.

In the dendrological list, 36.6 % of species belong to Bulgarian dendroflora, including the adventive species from the Mediterranean, Asia and North America, while the majority (63.4 %) were introduced or hybrids, respectively.

With reference to sexual attributes, 81.0 % of the species were hermaphrodite or monoecious (had both sexes on the same specimen), while 11.5 % were dioecious (separated sexes in different specimens). In 7.5 % of the listed species male and female reproductive organs occur dioeciously or monoeciously. Our study faced some limitations in sex determination of individuals, because some specimens were planted or grew in dense large communities or hedges, others were sheared or their crowns were inaccessible, third were not yet reproductively mature.

The foliage permanence was also considered, because it affects the pollen dispersion. Deciduous species (78.5 %) in the dendrological list dominated over the evergreen species (21.5%), while deciduous tree specimens were 56.1 % of all the examined trees.

Species allergenicity level

Considering the allergenic potential value of tree species, 34.9 % of tree specimens had a high allergenic potential, 10.6 % of tree individuals had a very high allergenicity level, while 4.8 % – a moderate one (Table 1). As a result, half (50.2 %) of all the examined trees had a moderate to very high allergic potential.

The most frequent allergenic species of Gymnosperms were members of Cupressaceae family (Table 2). The most common allergenic pollen tree species of Angiosperms were: *Platanus orientalis*, *Ulmus minor*, *Alnus glutinosa*, which are autochthonous and are part of natural riparian forest.

The indigenous dominant species *Platanus orientalis* has a notable presence in

Table 1. Species allergenicity level.

Allergenicity level	Species and infraspecific taxa	Specimens number	Specimens %
9–10 Very high	**Trees**	**282**	**10.55**
	Cryptomeria japonica (Thunb. ex L.f.) D.Don	6	0.22
	Cupressus arizonica Greene /'Pyramidalis'/	33	1.23
	Cupressus sempervirens /var. *horizontalis*, var. *pyramidalis*/	67	2.51
	Juniperus communis 'Hibernica' ♂	1	0.04
	Juniperus excelsa M.Bieb.	1	0.04
	Juniperus virginiana L.	3	0.11
	Taxus baccata L. ♂	3	0.11
	Acer negundo L. ♂	35	1.31
	Acer saccharinum L.	4	0.15
	Alnus glutinosa (L.) Gaertn.	56	2.10
	Betula pendula Roth	23	0.86
	Broussonetia papyrifera (L.) L'Hér. ex Vent. ♂	2	0.07
	Maclura pomifera (Raf.) C.K.Schneid. ♂	3	0.11
	Morus alba L.	35	1.31
	Olea europaea L.	1	0.04
	Quercus suber L.	3	0.11
	Salix alba L.	6	0.22
	Shrubs	**92**	**3.48**
	**Juniperus × pfitzeriana* (Späth) P.A.Schmidt	25	0.95
	**Juniperus sabina* 'Tamariscifolia'	32	1.21
	Laurus nobilis L. ♂	7	0.26
	Ligustrum japonicum Thunb.	10	0.38
	Ligustrum ovalifolium Hassk.	8	0.30
	Ligustrum vulgare L.	10	0.38
7–8 High	**Trees**	**933**	**34.90**
	Chamaecyparis lawsoniana (A.Murray bis) Parl.	85	3.18
	Chamaecyparis pisifera /'Ellwoodii', 'Plumosa', 'Squarrosa'/	9	0.34
	× *Cupressocyparis leylandii* 'Silver Dust'	1	0.04
	Ginkgo biloba L. ♂	2	0.07
	Platycladus orientalis (L.) Franco /'Aurea Nana'/	101	3.78
	Taxodium distichum (L.) Rich.	1	0.04
	Thuja occidentalis L. /'Smaragd', 'Columna'/	75	2.81
	Thuja plicata Donn ex D.Don	3	0.11
	Ailanthus altissima (Mill.) Swingle	40	1.50
	Celtis australis L.	52	1.95
	Fraxinus americana L.	43	1.61
	Fraxinus pennsylvanica Marshall	20	0.75
	Fraxinus excelsior L.	4	0.15
	Gymnocladus dioica (L.) K.Koch ♂	8	0.30
	Ilex aquifolium L. ♂	8	0.30
	Juglans regia L.	57	2.13
	*Liquidambar styraciflua*L.	6	0.22

Allergenicity level	Species and infraspecific taxa	Specimens	
		number	%
	Platanus orientalis L.	246	9.20
	Platanus occidentalis L.	2	0.07
	Populus alba L.	11	0.41
	Populus x canescens (Aiton) Sm.	1	0.04
	Populus nigra var. *italica* Münchh. ♂	3	0.11
	Quercus rubra L.	9	0.34
	Ulmus minor Mill.	146	5.46
	Shrubs	**37**	**1.40**
	Buxus sempervirens L. /'Suffruticosa'; 'Arborea'/	17	0.64
	Corylus avellana L.	5	0.19
	Fontanesia phillyreoides Labill.	15	0.57
	Hedera helix L.	*	*
5–6 Moderate	**Trees**	**128**	**4.79**
	Sequoiadendron giganteum (Lindl.) J.Buchholz	4	0.15
	Acer tataricum subsp. *ginnala* (Maxim.) Wesm.	3	0.11
	Acer palmatum Thunb.	1	0.04
	Acer platanoides L. /'Globosum'/	27	1.01
	Acer pseudoplatanus L.	25	0.94
	Aesculus hippocastanum L.	20	0.75
	Castanea sativa Mill.	1	0.04
	Catalpa ovata G.Don	3	0.11
	Catalpa speciosa (Warder ex Barney) Warder ex Engelm.	2	0.07
	Diospyros sp.	10	0.37
	Diospyros lotus L.	7	0.26
	Diospyros kaki L.f.	6	0.22
	Fraxinus angustifolia subsp. *oxycarpa* (Willd.) Franco & Rocha Afonso	5	0.19
	Fraxinus ornus L.	3	0.11
	Pterocarya fraxinifolia (Poir.) Spach	10	0.37
	Salix cinerea L.	1	0.04
	Shrubs	**749**	**28.35**
	**Celastrus orbiculatus* Thunb.	8	0.30
	Cornus sericea 'Flaviramea'	2	0.08
	Cotinus coggygria Scop.	1	0.04
	Elaeagnus × submacrophylla 'Limelight'	12	0.45
	Forsythia × intermedia Zabel	511	19.34
	Laburnum anagyroides Medik.	38	1.44
	**Lonicera japonica* Thunb. /'Halliana'; var. chinensis (P. Watson) Baker/	30	1.14
	Lycium barbarum L.	10	0.38
	Salix eleagnos Scop.	1	0.04
	Syringa vulgaris L.	125	4.73
	Tamarix tetrandra Pall. ex M.Bieb.	1	0.04
	Viburnum tinus L.	10	0.38

Allergenicity level	Species and infraspecific taxa	Specimens	
		number	%
	Trees	**1127**	**42.16**
	Cedrus deodara (Roxb. ex D.Don) G.Don	76	2.84
	Picea abies (L.) H.Karst.	33	1.23
	Picea omorica (Pancic) Purk.	1	0.04
	Picea orientalis (L.) Peterm.	1	0.04
	Picea pungens Engelm. /'Glauca'/	55	2.06
	Pinus halepensis Mill.	18	0.67
	Pinus nigra J.F.Arnold	366	13.69
	Pinus pinea L.	6	0.22
	Pinus strobus L.	1	0.04
	Pinus sylvestris L.	32	1.20
	Pseudotsuga menziesii /var. *Viridis* (Schwer.) Franco; var. *glauca* (Beissn.) Franco/	23	0.86
	Albizia julibrissin Durazz.	63	2.36
	Catalpa bignonioides Walter	15	0.56
	Cercis siliquastrum L.	36	1.35
	Eriobotrya japonica (Thunb.) Lindl.	3	0.11
	Gleditsia triacanthos L. /'Inermis'/	21	0.79
	Koelreuteria paniculata Laxm.	31	1.16
	Magnolia grandiflora L.	18	0.67
	Magnolia kobus DC.	12	0.45
3–4 Low	*Malus nidzwetzkyana* Dieck ex Koehne	4	0.15
	Melia azedarach L.	22	0.82
	Paulownia tomentosa Steud.	2	0.07
	Prunus dulcis (Mill.) D.A.Webb	2	0.07
	Prunus mahaleb L.	1	0.04
	Prunus serrulata 'Kanzan'	2	0.07
	Prunus cerasifera Ehrl. /'Pissardii'/	11	0.41
	Pyrus communis L.	9	0.34
	Robinia pseudoacacia L.	186	6.96
	Sorbus intermedia (Ehrh.) Pers.	3	0.11
	Styphnolobium japonicum (L.) Schott	7	0.26
	Tilia platyphyllos Scop.	25	0.94
	Tilia tomentosa Moench	25	0.94
	Tilia cordata Mill.	17	0.64
	Shrubs and subshrubs	**1599**	**60.52**
	Acca sellowiana (O.Berg) Burret	1	0.04
	Amorpha fruticosa L.	57	2.16
	Berberis julianae C.K.Schneid.	5	0.19
	Berberis thunbergii DC.	8	0.30
	Berberis vulgaris L.	28	1.06
	**Campsis radicans* (L.) Seem.	31	1.17
	Citrus trifoliata L.	1	0.04
	**Cotoneaster dammeri* C.K. Schneid.	3	0.11

Allergenicity level	Species and infraspecific taxa	Specimens	
		number	%
	**Cotoneaster horizontalis* Decne.	3	0.11
	Cornus alba L.	20	0.76
	Cornus sanguinea L.	3	0.11
	Deutzia scabra Thunb. /'Candidissima', 'Plena'/	113	4.28
	Deutzia gracilis Siebold & Zucc.	80	3.03
	Euonymus japonicus Thunb.	16	0.61
	**Fallopia aubertii* (L.Henry) Holub	3	0.11
	Hibiscus syriacus L. /'Red Heart', 'Woodbridge', 'Monstrosus'/	210	7.95
	Hydrangea arborescens 'Annabelle'	1	0.04
	**Hypericum calycinum* L.	*	*
	Lagerstroemia indica L. /'Durant Red'/	67	2.54
	Lonicera fragrantissima Lindl. & J. Paxton	35	1.32
	Lonicera maackii (Rupr.) Maxim.	1	0.04
	Lonicera nitida E.H. Wilson	*	*
	Lonicera pileata Oliv.	*	*
	Lonicera tatarica L.	3	0.11
	Nerium oleander L.	15	0.57
	Osmanthus fragrans Lour.	8	0.30
	**Parthenocissus quinquefolia* (L.) Planch.	25	0.95
	Philadelphus coronarius L.	85	3.22
	Photinia x fraseri 'Red Robin'	5	0.19
	Physocarpus opulifolius Maxim.	15	0.57
	Pittosporum tobira (Thunb.) W.T.Aiton	1	0.04
	Prunus laurocerasus L.	80	3.03
	Punica granatum L.	45	1.70
	Pyracantha coccinea M.Roem.	35	1.32
	Rosmarinus officinalis L.	6	0.23
	**Ruscus aculeatus* L.	3	0.11
	**Spiraea cantoniensis* Lour.	101	3.82
	Spiraea japonica L.f.	68	2.57
	**Spiraea x vanhouttei* (Briot) Zabel	160	6.06
	**Symphoricarpos orbiculatus* Moench	128	4.84
	**Vinca major* L.	*	*
	**Vinca minor* L.	*	*
	Vitex agnus-castus L.	1	0.04
	Weigela florida (Bunge) A. DC.	23	0.87
	**Wisteria sinensis* (Sims) Sweet	15	0.57
	Yucca gloriosa L.	86	3.26
	**Periploca graeca* L.	5	0.19
1–2 Very low	**Trees**	**203**	**7.59**
	Abies alba Mill.	21	0.79
	Abies cephalonica Loudon	2	0.07
	Abies concolor (Gordon) Lindl. ex Hildebr.	3	0.11
	Abies pinsapo Boiss.	15	0.56

Allergenicity level	Species and infraspecific taxa	Specimens	
		number	%
	Cedrus atlantica (Endl.) Manetti ex Carrière /‘Glauca’/	84	3.14
	Cedrus libani A.Rich	2	0.07
	Ginkgo biloba L. ♀	2	0.07
	Taxus baccata ‘Fastigiata’ ♀	5	0.19
	Acer negundo L. ♀	16	0.60
	Broussonetia papyrifera (L.) L’Hér. ex Vent. ♀	1	0.04
	Ficus carica L.	26	0.97
	Ilex aquifolium L. ♀	4	0.15
	Cydonia oblonga Mill.	1	0.04
	Maclura pomifera (Raf.) C.K.Schneid. ♀	3	0.11
	Morus alba ‘Pendula’ ♀	1	0.04
	Salix babylonica L./var. *pekinensis* ‘Tortuosa’/ ♀	17	0.64
	Shrubs	**165**	**6.25**
	Chaenomeles × superba (Frahm) Rehder	10	0.38
	Mahonia aquifolium (Pursh) Nutt.	145	5.49
	Mahonia japonica (Thunb.) DC.	2	0.08
	Nandina domestica Thunb.	5	0.19
	Viburnum opulus ‘Roseum’	3	0.11
	Total trees	**2673**	**100**
	Total shrubs	**2642**	**100**

Note: ♂ – males, ♀ – females, * – groundcover, liana, hedges.

Table 2. Characteristics of the most-frequent allergenic tree and shrub species in Park Sveti Vratch.

Species	Origin	Foliage permanence		Sexual/ reproductive characteristics		Allergenicity level
		Ever green	Deciduous	Monoecious or hermaphrodite	Dioecious	
Trees						
Platanus orientalis	Med		✓	✓		High
Ulmus minor	Eur-Med		✓	✓		High
Chamaecyparis lawsoniana	West. N-Am	✓		✓		High
Thuja occidentalis	N-Am	✓		✓		High
Cupressus sempervirens	E-Med-Anat-OT	✓		✓		Very high
Juglans regia	Eur-As/Paleo		✓	✓		High
Alnus glutinosa	Med-CAs		✓	✓		Very high
Celtis australis	Med		✓	✓		High
Acer negundo	Adv (N-Am)		✓		✓	♂ Very high ♀ Very low
Fraxinus americana	Adv (N-Am)		✓	✓	✓	♂ High ♀ Very low

Species	Origin	Foliage permanence		Sexual/ reproductive characteristics		Allergenicity level
		Ever green	Deciduous	Monoecious or hermaphrodite	Dioecious	
Ailanthus altissima	Adv (N-Ch)		✓	✓	✓	♂ High ♀ Very low
Cupressus arizonica	N-Am	✓		✓		Very high
Shrubs						
Forsythia × intermedia	Hybr		✓	✓		Moderate
Syringa vulgaris	Carp-Bal		✓	✓		Moderate

Note: the abbreviations for ‘Origin’ are in accordance with Conspectus of the Bulgarian vascular flora: Distribution maps and floristic elements (Assyov et al. 2012).

the park landscape, with its centennial specimens, reaching more than 2.5 m DHB and huge crown volumes. Many authors (Varela et al. 1997, Alcázar et al. 2004, Gioulekas et al. 2004, Biçakçi and Tosunoğlu 2019, Cariñanos et al. 2020) suggest that *Platanus* genus is one of the main causative agents of tree pollen allergy in the Mediterranean area because of its abundant presence in urban green infrastructure.

Alnus glutinosa, *Betula pendula* and *Juglans regia* are highly allergenic species. *Alnus glutinosa* and *Juglans regia* were growing along the river banks, where the air circulation is good and probably pollen can be dispersed by air currents.

Another species with high degree of allergenicity is *Olea europaea* (Gioulekas et al. 2004), which was presented by a single specimens in the park theritory, but is quite common as an orchard tree in the private gardens in Sandanski. Its frequent use should be reconsidered**.**

Fraxinus is another Oleaceae genus emitting highly allergenic pollen (Guerra et al. 1995). The reproductive attributes of ash trees show a continuum from pure male to pure female trees with a variety of intermediate hermaphrodite stages that can vary between years (FRAXIGEN 2005). Moreover, the cross-reactivity that can be established between Oleaceae species (e.g. Fraxinus spp., *Forsythia* spp., *Ligustrum spp., Syringa* spp. etc.) due to the presence of shared allergens must be taken into consideredation (Pajarón et al. 1997, Rodríguez et al. 2001). The large scale use of non-native species from genus *Fraxinus* (63 specimens) in comparison to the use of native ones (12 specimens) is not appropriate. Moreover, the native species *Fraxinus angustifolia* subsp. *oxycarpa* and *Fraxinus ornus* have lower degree of allergenicity and higher ornamental qualities.

Cypress trees are also prominent ornamentals in the park Sveti Vratch scenery. However, they have very high value of allergenic potential (Gioulekas et al. 2004, Charpin et al. 2013, Biçakçi and Tosunoğlu 2019). Additionally, another Cupressaceae taxa – *Cryptomeria japonica* (Japanese cedars), is one of the most severe allergenic tree species (Okuda 2003, Yamada et al. 2014). Cross-reactivity among some Cupressaceae species from genera *Juniperus, Thuja, Cupressus* and *Chamaecyparis* has been suggested (Schwietz et al. 2000).

Acer negundo, *Ailanthus altissima* and *Robinia pseudoacacia* generate pollen sensitization (Ballero et al. 2003, Compés et al. 2006, Ribeiro et al. 2009). Disurbingly, these species are wide spread and are included in the list of invasive alien species in Bulgaria and EU (Petrova et al. 2012). Ailanthus could be monoecious, andromonoecious, hermaphrodite or dioecious tree (Kowarik and Säumel 2007, Holec et al. 2014).

Male individuals from Moraceae family (e.g. *Maclura* spp., *Broussonetia* spp., *Morus* spp.) dispersing their allergenic pollen can cause severe respiratory symptoms (Navarro et al. 1997, Qazi et al. 2019).

The most frequent shrub species had moderate to low/very low alergenicity potential (tables 1 and 2). Only 4.9 % of shrub specimens had a high to very high allergenicity level. It is not recommendable to establish hedges or large plantations of allergenic shrubs, even sheared, as they are a rich local source of pollen emitted at human height (Alcázar et al. 1999).

Urban green zone allergenicity

The value of overall allergenic risk that species pose in the area they grow Urban Green Zone Allergenicity (IUGZA) (Cariñanos et al. (2019) considers a variety of plant characteristics and factors to evaluate the allergenic potential of urban green spaces. The lack of phoenological and aerobiological monitoring records and clinical statistics on patient sensitization in this region so far prevent estimation of IUGZA for Park Sveti Vrach and assessment of the real threat of allergenic pollen taxa to park visitors.

The density of existing trees, species richness and the Shannon Index are the characteristics and factors that most affect the final allergenicity value (Cariñanos et al. 2019). Results from the inventory of arboreal ornamentals in Sveti Vrach Park show a very good value of species richness – 199 taxa. Taking into account the abundance of species, Shannon's Index = 4.17 indicate a great diversity due to the high number of taxa and the evenness of park woody ornamentals – 0.79. A very low average density of 79.8 trees/ha was established.

Therefore, the recommendations given by Cariñanos and Casares-Porcel (2011) for designing and maintenance of green spaces with low allergy impact should be followed in Sveti Vrach Park management. They include: increased urban biodiversity, controlled introduction of exotic species, invasive species management, botanical sexism avoidance, avoidance of formation of large focal pollen sources and screens, selection of low pollen producing species, adoption of appropriate management and maintenance strategies, involvement of experts and consultants at the planning process, establishment of local by-laws guidelines for low allergy impact design of urban green spaces. Additionally, McInnes et al. (2017) suggest developing detailed maps at national level of allergenic pollen producing taxa in order to improve understanding of relationships between allergenic pollen exposure and human health outcomes.

Conclusions

Sveti Vrach Park in Sandanski is a real 'dendrological hotspot' in a town – natural sanatorium – for the treatment of respiratory diseases, climatotherapy and spa resort of international importance. Considering the allergenic potential value of species, which could represent a risk to the citizens and visitors, almost half of the trees and 4.9 % of shrub specimens had high or very high allergenic potential. The highly allergenic members of Cupressaceae, Betulaceae, Moraceae, Oleaceae and Salicaceae families should be avoided in the design of new green areas and revitalization of existing ones in the urban park territory, unless female specimens, female cultivars or species with lower degree of allergenicity are selected. *Acer negundo, Ailanthus altissima* and *Robinia pseudoacacia*, as an invasive species should be controlled and even removed and destroyed in some of the park sectors.

Phoenological and aerobiological monitoring records of allergenic pollen producing plants and clinical statistics on patient sensitization in Sandanski region should be done by specialists in order to identify the taxa that triggers pollenosis or asthma on a local level and to assess the real threat of allergenic pollen taxa to park visitors.

The research on allergenic woody plant taxa in Sveti Vrach Park provides useful risk assessment information to medical practitioners and local authorities responsible for city landscaping. Urban green infrastructure planning and managment should consider the allergenicity criterion. Interdisciplinary expertise in these processes is crutial for establishment of sustainable low allergy-risk green spaces.

Despite the fact that alergennic pollen can be transported in long distances by the wind, steps can be taken to minimize the pollen load and potential hazard in surrounding urban area. Providing public information on that subject could also help affected citizens with pollenosis and pollen-related asthma to take self-imposed preventative measures.

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