



# Assessing allergenicity of urban parks: a case study from Aydin, Turkey

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Received: 3 January 2022 / Accepted: 20 April 2022 / Published online: 11 May 2022  
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**Abstract** Allergenic pollens produced by some tree species in urban parks, a part of the urban flora, cause pollinosis, allergic rhinitis, allergic rhinoconjunctivitis, and asthma. The allergenic pollen levels of four urban parks in Aydin (Turkey) were determined using the Index of Urban Green Zones Allergenicity ( $I_{UGZA}$ ). The potential allergenicity value (PAV) of each species and the crown volume of each individual belonging to the species were used in the index calculation. According to their PAV values, tree species were classified as nil (0), low (1–6), moderate (8–12), high (16–24), and very high (27–36) allergenicity. The Shannon Diversity Index (SHDI) was used to calculate the parks' biodiversity levels. Canonical correspondence analysis, one of the ordination methods, was used to identify the species distribution among the four parks and reveal the relationship between the SHDI, number of species, tree density, and  $I_{UGZA}$ . The ratio of allergenic tree species in the four parks examined varied between 97.90

and 100%. The PAV of 9 tree species, including the genus *Cupressus* in the Cupressaceae family, was determined as very high, while the PAV of 20 tree species, including the genus *Prunus*, was revealed to be low. While the park with the lowest  $I_{UGZA}$  value (0.17) was Aytepe Recreation Area, the park with the highest  $I_{UGZA}$  value (0.52) was Pinarbasi Recreation Area. The lowest Shannon Diversity Index (SHDI) value (0.70) was detected in Aytepe Recreation Area, whereas the highest value (2.90) was determined in Nevzat Bicer Park. There was no correlation between the  $I_{UGZA}$  value and species count, tree density, and SHDI variables. Ismet Sezgin Park and Pinarbasi Recreation Area pose a risk to human health at any time of the year. The results, which focused on allergenic flora, should be used to design new parks and revitalize existing ones.

**Keywords** Allergenic potential · Index of allergenicity · Pollen allergy · Urban ecosystem · Urban green zones

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s10453-022-09745-8>.

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## 1 Introduction

Today, particulate air pollution (pollens, smoke, molds, sand, etc.) is a major public health concern because it causes various respiratory diseases (Davies-Barrett et al., 2020). Allergies and diseases caused by pollen grains are among the main public health problems nowadays (Cariñanos et al., 2019;

D'Amato & Spieksma, 1991). Pollen emissions affect human health and cause allergic reactions in 30–40% of the world's population (Bousquet et al., 2008; Pawankar, 2014; Pawankar et al., 2011). A recent study shows that pollinosis affects 2–10% of US residents and the incidence of pollinosis in Europe has increased from 1% at the beginning of the twentieth century to 20% at the end of the same century (Dai & Lu, 2000).

Owing to the allergens they carry, pollens are among the major factors that increase respiratory diseases and allergies in susceptible individuals (Bicakci & Tosunoğlu, 2019; Jianan et al., 2007). Pollen grains of anemophilous plants can cause respiratory diseases such as hay fever, allergic rhinitis, conjunctivitis, chronic bronchitis, and even asthma in susceptible individuals (Asam et al., 2015; Bicakci & Tosunoğlu, 2019; Kasprzyk et al., 2019). Allergenic rhinitis affects 40% of the European population (D'Amato et al., 2007), adversely impacting sleep quality and work and school performance (Hoyte & Nelson, 2018). Moreover, some analyses of the economic burden of allergic rhinitis have revealed a cost of US\$2–5 billion per year, considering the direct costs alone (Reed et al., 2004; Weiss & Sullivan, 2001).

Recent data show that people living in urban areas are 20% more likely to be affected by airborne pollen allergies than those living in rural areas (Bosch-Cano et al., 2011; Mrđan et al., 2017; Timm et al., 2015). The reason for this is the interaction of pollens with other air pollutants, such as CO<sub>2</sub> in urban areas (Cariñanos et al., 2002, 2007; Wyler et al., 2000; Ziska & Caulfield, 2000). The incidence of pollen-related hay fever has recently increased in urban areas (Cariñanos & Casares-Porcel, 2011).

Urban green spaces have been identified as the main source of plant species and pollen allergen emissions (Cariñanos et al., 2016a, 2017) despite their numerous benefits, such as improving physical and mental health and well-being by increasing physical activity, reducing psychophysiological stress, strengthening social contacts, reducing noise, heat, and air pollution levels (Lee & Maheswaran, 2011; Müller-Riemenschneider et al., 2013; Pereira et al., 2012, 2013). Therefore, urban green spaces have been shown among the factors triggering allergic symptoms in urban residents (D'Amato, 2002; Jianan et al., 2007). Allergenic pollen emission during the flowering period of plant species in urban green spaces and

the reactions caused by it are among the main Urban Ecosystem Disservices (UEDS) creating economic, social, environmental, and health costs on the welfare of citizens (Cariñanos & Casares-Porcel, 2011; von Dohren & Haase, 2015). Parks, which are the leading urban green spaces with the densest and most diverse plants, can make up the most important elements of UEDS due to the possibility of producing large amounts of pollens (von Dohren & Haase, 2015).

A study carried out in the USA listed pollen trees triggering asthma in urban parks in Philadelphia (Keddem et al., 2015). A study conducted in Sabadell, Spain, found no correlation between green spaces in residential areas and asthma. However, the same study showed that a closer location to parks was associated with an increased prevalence of asthma (Dadvand et al., 2014). Although research has been conducted on allergenic plant species in urban areas in Europe, no comprehensive study has been performed on this subject in Turkey. Although Turkish researchers have conducted many studies on pollen allergy in the last ten years (Bicakci et al., 2002, 2003; İnceoğlu et al., 1994; Pehlivan, 1995; Pinar et al., 1999), these studies are atmospheric pollen studies. The analysis of the pollen spectrum in urban environments has revealed that tree pollens in green spaces play an essential role in sensitizing the local population (D'Amato et al., 2007; Dales et al., 2008; Haberle et al., 2014; Liu et al., 2010; Lovasi et al., 2013; Seitz & Escobedo, 2012; White & Bernstein, 2003). Within this scope, this study aims to determine the species composition of the trees in four urban parks in Aydin (Turkey), determine the potential allergenicity value (PAV), and reveal the parks' allergenic risk levels. The study also aims to fill the existing knowledge gaps and develop guidelines on the planning and design of hypoallergenic parks.

## 2 Material and methods

### 2.1 Study area

Four parks in the city of Aydin make up the study area. İsmet Sezgin and Nevzat Bicer Park are neighborhood parks, while Aytepe and Pinarbasi are recreational areas. Pinarbasi Recreation Area (3.22 ha) has the largest area, while İsmet Sezgin Park has the smallest area (0.80 ha). These four parks were chosen

as the study area because the public often visits them, different activities are allowed, and they have a different status (Table 1; Fig. 1). Aydin is located in the Aegean region, Western Anatolia (37.838016 N latitude and 27.845627 E longitude). Its altitude is 59 m above sea level, and its population in 2020 was 292,716 (TUIK, 2021). It has a surface area of 610.62 km<sup>2</sup>. According to the 1941–2020 data, the long-term average annual total rainfall is 667.4 mm and the long-term annual average temperature is 17.7 °C. The average temperatures for January and July are 8.1 and 28.2 °C, respectively (MGM, 2021). The Mediterranean climate prevails in the city, which is located in the Mediterranean phytogeographic region of Turkey. Aydin has a rich diversity of plants in wild and cultivated forms. At higher altitudes, *Pinus nigra* Arnold subsp. *pallasiana* (Lamb.) Holmboe, *Pinus brutia* Ten., *Castanea sativa* Mill., *Juniperus oxycedrus* L. subsp. *oxycedrus*, *Quercus pubescens* Willd., *Q. infectoria* G. Olivier, *Q. cerris* L., *Q. ilex* L. dominate the area. However, at lower altitudes, *Ceratonia siliqua* L., *Laurus nobilis* L., *Fraxinus ornus* L., *Olea europaea* L., *Pistacia lentiscus* L., *P. terebinthus* L., *Arbutus andrachne* L., *A. unedo* L., and *Cercis siliquastrum* L. taxa cover broad areas (Durmuşkahya, 2006; Mataracı, 2004; Taylor, 1984).

## 2.2 Inventory of trees

An inventory of trees includes taxonomic identification at the species level (cultivar or variety if possible), reproductive characteristics, pollination characteristics, the status of being native/exotic and invasive/noninvasive. The parks were visited, and the

data on the number of trees and taxonomic characteristics in each park were recorded in a field registration form. The published sources (Akkemik, 2018; Mamikoğlu, 2010; Mamikoğlu, 2021) were used to identify tree taxa in the parks. Invasive tree species were identified with the help of the relevant sources (Arslan et al., 2015; Uludag et al., 2020). The status of allergenicity was confirmed by data from the allergen information platform (Allergome, 2021). Allergenic trees were identified by considering the “Türkiye’nin Alerjen Polen Saçan Bitkileri [Allergenic Pollen Scattering Plants of Turkey]” (Aytuğ et al., 1995) and the “Türkiye’nin Alerjen Polenleri Atlası [Allergenic Pollen Atlas of Turkey]” (Pehlivan, 1995).

## 2.3 Estimating the allergenicity index

Cariñanos et al. (2014) proposed an allergenicity index to manage the design of urban green spaces. This index is calculated for a certain area and shows the relationship between a product of different values and the analyzed surface. The product includes a measure of crown volume to predict the number of trees, allergenic potential (5 categories), pollination type (4 categories), and the length of the main pollen season period (3 categories). The index was called the Index of Urban Green Zones Allergenicity ( $I_{UGZA}$ ).  $I_{UGZA}$  is used to calculate the allergenic potential of urban green spaces. The index, expressed as a ratio, allows comparing an urban green space with a hypothetical area with similar characteristics and maximum allergenicity. The index considers various adjusted plant characteristics. The allergenicity index

**Table 1** Characteristics of the studied parks in Aydin

| Parks                     | Type of parks (Anonymous, 2021b) | Area (ha) | Activities                                                             | Location                          |
|---------------------------|----------------------------------|-----------|------------------------------------------------------------------------|-----------------------------------|
| Aytepe Recreation area    | Urban                            | 1.58      | Walking, jogging, running, outdoor gyms, picnic, cafeteria, playground | 37° 50' 49.46" N–27° 50' 17.09" E |
| İsmet Sezgin Park         | Neighborhood                     | 0.80      | Outdoor gyms, cafeteria, playground                                    | 37° 51' 9.09" N–27° 50' 4.46" E   |
| Nevzat Bicer Park         | Neighborhood                     | 1.47      | Outdoor gyms, cafeteria, playground                                    | 37° 51' 16.95" N–27° 50' 42.12" E |
| Pınarbasi Recreation Area | Urban                            | 3.22      | Walking, jogging, running, outdoor gyms, picnic, cafeteria, playground | 37° 51' 11.05" N–27° 51' 3.95" E  |

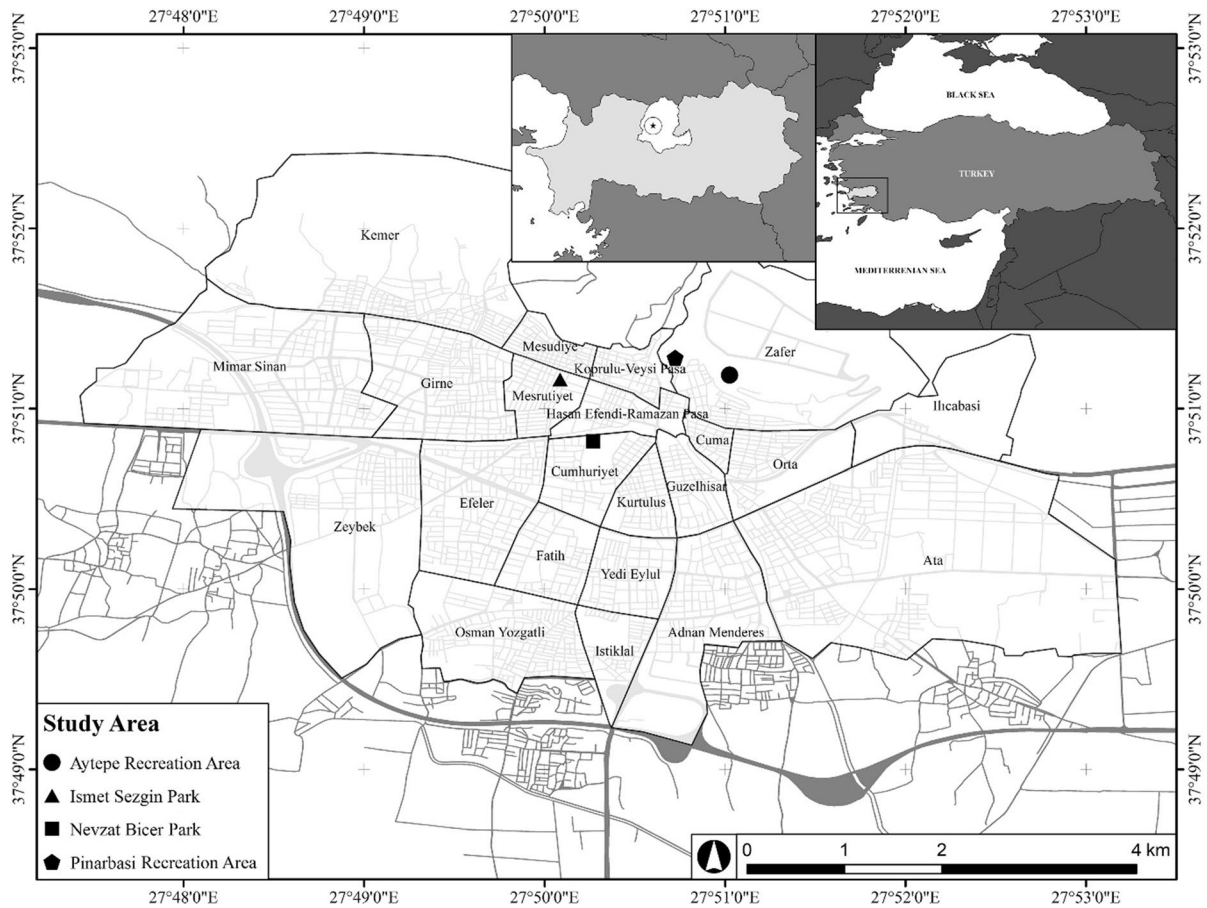


**Fig. 1** Study area (the data and map layers for the neighborhood were obtained from the appropriate source (Anonymous, 2021a). The map was created using the WGS84/UTM Zone 35 N coordinate system.)

is an excellent tool for assessing the allergenicity of urban parks (Kasprzyk et al., 2019).

The potential allergenicity of urban parks in Aydin was calculated using  $I_{UGZA}$ , developed by Cariñanos et al. (2014, 2016a, 2016b). To calculate  $I_{UGZA}$ , the potential allergenicity value (PAV) of each species associated with some biological and phenological parameters was calculated in relation to the intrinsic allergenicity of a species. Each parameter with a meaning in the PAV is assigned a numerical value between 0 and 3 according to its contribution to the intrinsic allergenicity of the species. As a reference, maximum values are assigned to species taken as a reference for pollination type (3), length of the flowering period (3), and allergenic potential (4). The highest PAV is 36 since all pollen types considered as the main local allergens can be assigned an allergenic

potential value of 4 (Cariñanos et al., 2014, 2016a, 2016b). Values related to the allergenic potential (ap), type of pollen emissions (pe), and principal pollination period (ppp) parameters were used to determine PAVs (Table 2; Eq. 1).

$$PAV = ap_i \times pe_i \times ppp_i \quad (1)$$

PAV = potential allergenic value of the  $i$ th species, allergenic potential of the  $i$ th species (0, 1, 2, 3, or exceptionally 4 for main local allergens) ( $ap_i$ ), type of pollen emission of the  $i$ th species (0, 1, 2, 3) ( $pe_i$ ), duration of the principal pollination period of the  $i$ th species in weeks (1, 2, 3) ( $ppp_i$ ).

After calculating PAV values for each species, the allergenic levels of these species were classified

**Table 2** Parameters and values to be assigned for obtaining PAV (Cariñanos et al., 2016a, 2016b)

| Parameters                         | Values                                                                                                                                                        |
|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Allergenic potential (ap)          | 0 = Non-allergenic or not reported as allergenic<br>1 = Low allergenicity<br>2 = Moderate allergenicity<br>3 = High allergenicity<br>4 = Main local allergens |
| Type of pollen emissions (pe)      | 0 = Only female individuals<br>1 = Entomophilous<br>2 = Amphiphilous<br>3 = Anemophilous                                                                      |
| Principal pollination period (ppp) | 1 = 1–3 weeks<br>2 = 4–6 weeks<br>3 ≤ 6 weeks                                                                                                                 |

**Table 3** Ranks of PAV applicable to urban tree species in Aydin urban parks (Cariñanos et al., 2016a, 2016b)

| PAV (rank) | Allergenicity |
|------------|---------------|
| 0          | Nil           |
| 1–6        | Low           |
| 8–12       | Moderate      |
| 16–24      | High          |
| 27–36      | Very high     |

as nil, low, moderate, high, and very high using the ranges presented in Table 3.

To estimate  $I_{UGZA}$ , detailed field surveys were conducted, including estimating the crown volume of each individual, in addition to an inventory of all flower-producing tree individuals in all the parks examined. The tree crown height and two vertical diameters were measured using a laser altimeter. The tree crown shape was identified as a sphere, cylinder, cone, and hemisphere, and the crown volume was calculated using standard mathematical formulae, considering the flattening of the figures (Eq. 2).  $I_{UGZA}$  was calculated using Eq. 3.

$$V_i = S_i \times H_i \quad (2)$$

$V_i$ =volume of pollen-producing vegetation (the turf volume/the tree and shrub crown volume), the

surface area of the plant in square meters ( $S_i$ ), and the crown height of the  $i$ th species in meters ( $H_i$ ).

$$I_{UGZA} = \frac{1}{a \times S_T} \times \sum_{i=1}^k n_i \times PAV_i \times V_i \quad (3)$$

The relevant variables for  $I_{UGZA}$  are the total area of the examined green space in square meters ( $S_T$ ), the number of species ( $k$ ), the number of individuals belonging to the  $i$ th species ( $n_i$ ),  $PAV$ =potential allergenic value of the  $i$ th species,  $V_i$ =volume of pollen-producing vegetation (the turf volume/the tree and shrub crown volume), and  $a$  is calculated as  $PAV_{imax} \times H_{imax}$  for each park. The variable depends on the maxima of  $ap_i$ ,  $pe_i$ ,  $ppp_i$ , and  $H_i$ . (In this study, 30 m was taken in all parks as  $H_{imax}$  adapted to the local growing conditions.  $PAV_{imax}$  was taken as 36 in Aytepe Recreation Area, Ismet Sezgin Park, and Pinarbasi Recreation Area and as 27 in Nevzat Bicer Park.)

The resulting  $I_{UGZA}$  value between 0 and 1 represents the possible allergenic risk for visitors with pollen allergies at certain times of the year. The  $I_{UGZA}$  value varies between 0 (zero allergenicity) and 1 (maximum allergenicity). A value of 0.3 is accepted as a threshold at which people with allergies experience discomfort. If  $I_{UGZA}$  exceeds 0.3, the park is considered to have a detrimental effect on humans (Cariñanos et al., 2017).

## 2.4 Data analysis

Ordination techniques explain the relationship between plant distribution and environmental factors. In this respect, ordination methods take an important place in modern ecological research (Li et al., 2017). Canonical correspondence analysis (CCA), one of the direct ordination methods, was employed to determine the correlation between plant distribution and environmental factors and reveal similarities in tree species distribution between the four parks. CCA was conducted using Canoco for Windows v4.5 (Ter Braak & Smilauer, 2002) software. Before the analysis, species data were transformed using the chi-square method and the environmental variables using the  $\ln(x+1)$  formula.

The Shannon Diversity Index (SHDI) (Shannon, 1948) is a measure of biodiversity based on the

number and ratio of species in an area. In the present study, the SHDI value for each park was calculated using Eq. 4:

$$SHDI_S = \sum_{i=1}^S p_i \times \ln(p_i) \text{ with } p_i = \frac{n_i}{N} \quad (4)$$

where the number of species is ( $S$ ), the relative frequency of the  $i$ th species is ( $p_i$ ), the number of individuals belonging to the  $i$ th species is ( $n_i$ ), and the number of individuals is ( $N$ ).

### 3 Results

Fifty-eight tree species belonging to 46 genera from 29 families were examined in the four parks. While the park with the highest species richness is Pinarbasi Recreation Area (34 species), the park with the lowest species richness is Aytepe Recreation Area (7 species). Although Aytepe Recreation Area hosts the lowest number of tree species, it has the highest number of trees (619 trees). The tree density (n/ha) in the parks varies from 159.96 (Pinarbasi Recreation Area) to 391.06 (Aytepe Recreation Area). The most common three species in Aytepe Recreation Area make up 99.03% of the total number of trees. When an examination is carried out throughout the park, the existing three species make up 51.25% of the total number of trees (Table 4).

Table 5 shows the species identified in Aydin urban parks, their reproductive and pollination characteristics, PAV values, and allergenicity. The highest values (PAV=36) were obtained in the species (*Cupressus macrocarpa* var. goldcrest Hartw., *C. sempervirens* var. horizontalis (Mill.) Loudon and *C. sempervirens* var. pyramidalis (O.Targ.Tozz.) Nyman) belonging to the *Cupressaceae* family. These species have the monoecious sexual system and anemophilous type of pollination. Most species with low or nill allergenicity exhibit entomophilous pollination characteristics. Although sometimes the species have abundant pollen production and long pollination time, their pollens are considered a minor cause of allergies in the literature (*Cedrus atlantica* (Endl.) Lindl. & Gordon, *C. libani* A.Rich., *Celtis australis* L., *Eucalyptus camaldulensis* Dehnh., *Picea pungens* Engelm., *Pinus brutia* Ten., *Pinus pinea* L.). In other cases, since they have low pollen release despite high allergenic values

**Table 4** Different attributes of trees in the parks of Aydin

| Attributes                                        | Parks                                                                                                                                                                       |                                                                                               |                                                                                                                              |                                                                                                                | Overall                                                                                                                                       |
|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
|                                                   | Aytepe Recreation Area                                                                                                                                                      | Ismet Sezgin Park                                                                             | Nevzat Bicer Park                                                                                                            | Pinarbasi Recreation Area                                                                                      |                                                                                                                                               |
| Family                                            | 6                                                                                                                                                                           | 15                                                                                            | 20                                                                                                                           | 22                                                                                                             | 29                                                                                                                                            |
| Genus                                             | 7                                                                                                                                                                           | 22                                                                                            | 27                                                                                                                           | 29                                                                                                             | 46                                                                                                                                            |
| Species                                           | 7                                                                                                                                                                           | 24                                                                                            | 31                                                                                                                           | 34                                                                                                             | 58                                                                                                                                            |
| No. of trees ( $n$ )                              | 619                                                                                                                                                                         | 143                                                                                           | 239                                                                                                                          | 515                                                                                                            | 1516                                                                                                                                          |
| Tree density ( $n/ha$ )                           | 391.06                                                                                                                                                                      | 177.78                                                                                        | 162.99                                                                                                                       | 159.96                                                                                                         | 214.43                                                                                                                                        |
| Top 3 species (%)                                 | 99.03                                                                                                                                                                       | 53.85                                                                                         | 38.49                                                                                                                        | 46.80                                                                                                          | 51.25                                                                                                                                         |
| Main contributory 3 species ( $n$ of individuals) | <i>Cupressus sempervirens</i> 'Horizontalis' (Mill.) Loudon (85)<br><i>Cupressus sempervirens</i> 'Pyramidalis' (O.Targ.Tozz.) Nyman (31)<br><i>Pinus brutia</i> Ten. (492) | <i>Morus alba</i> L. (47)<br><i>Pinus pinea</i> L. (15)<br><i>Platanus orientalis</i> L. (15) | <i>Acer negundo</i> L. (27)<br><i>Cupressocypariss leylandii</i> A.B.Jacks. & Dallim (49)<br><i>Tilia cordata</i> Mill. (16) | <i>Casuarina equisetifolia</i> L. (104)<br><i>Pinus brutia</i> Ten. (69)<br><i>Platanus orientalis</i> L. (68) | <i>Pinus brutia</i> Ten. (565)<br><i>Casuarina equisetifolia</i> L. (114)<br><i>Cupressus sempervirens</i> 'Horizontalis' (Mill.) Loudon (98) |

**Table 5** Tree species with PAV in Aydin urban parks (developed by Cariñanos & Casares-Porcel, 2011; Cariñanos et al., 2016a, 2016b; Maya Manzano et al., 2017; PFAF, 2021)

| Code  | Species                                                             | Sex <sup>a</sup> | Type of pollination <sup>b</sup> | PAV | Allergenicity |
|-------|---------------------------------------------------------------------|------------------|----------------------------------|-----|---------------|
| Acnef | <i>Acer negundo</i> f. flamingo Geerinck                            | D                | A                                | 18  | High          |
| Acne  | <i>Acer negundo</i> L.                                              | D                | A                                | 18  | High          |
| Acpl  | <i>Acer platanoides</i> L.                                          | H                | A                                | 18  | High          |
| Acsa  | <i>Acer saccharinum</i> L.                                          | H                | AE                               | 8   | Moderate      |
| Aehi  | <i>Aesculus hippocastanum</i> L.                                    | H                | AE                               | 8   | Moderate      |
| Aial  | <i>Ailanthus altissima</i> (Mill.) Swingle                          | D                | AE                               | 18  | High          |
| Alju  | <i>Albizia julibrissin</i> Durazz                                   | M                | E                                | 2   | Low           |
| Brpo  | <i>Brachychiton populneus</i> Schott                                | H                | E                                | 2   | Low           |
| Cabe  | <i>Carpinus betulus</i> L.                                          | M                | A                                | 27  | Very high     |
| Caeq  | <i>Casuarina equisetifolia</i> L.                                   | M                | A                                | 27  | Very high     |
| Cabi  | <i>Catalpa bignonioides</i> Walt                                    | H                | E                                | 3   | Low           |
| Ceat  | <i>Cedrus atlantica</i> (Endl.) Lindl. & Gordon                     | M                | A                                | 9   | Moderate      |
| Celi  | <i>Cedrus libani</i> A.Rich                                         | M                | A                                | 9   | Moderate      |
| Ceau  | <i>Celtis australis</i> L.                                          | H                | A                                | 12  | Moderate      |
| Chhu  | <i>Chamaerops humilis</i> L.                                        | D                | A                                | 18  | High          |
| Ciau  | <i>Citrus × aurantium</i> L.                                        | H                | E                                | 3   | Low           |
| Cili  | <i>Citrus × limon</i> (L.) Osbeck                                   | H                | E                                | 3   | Low           |
| Cire  | <i>Citrus reticulata</i> Blanco                                     | H                | E                                | 3   | Low           |
| Crja  | <i>Cryptomeria japonica</i> (L.f.) D. Don                           | M                | A                                | 27  | Very high     |
| Cule  | <i>Cupressocyparis leylandii</i> A.B.Jacks. & Dallim                | M                | A                                | 27  | Very high     |
| Cuarg | <i>Cupressus arizonica</i> cv. glauca (Woodall) Rehder              | M                | A                                | 24  | High          |
| Cumag | <i>Cupressus macrocarpa</i> var. goldcrest Hartw                    | M                | A                                | 36  | Very high     |
| Cuseh | <i>Cupressus sempervirens</i> var. horizontalis (Mill.) Loudon      | M                | A                                | 36  | Very high     |
| Cusep | <i>Cupressus sempervirens</i> var. pyramidalis (O.Targ.Tozz.) Nyman | M                | A                                | 36  | Very high     |
| Elan  | <i>Elaeagnus angustifolia</i> L.                                    | H                | E                                | 0   | Nil           |
| Erja  | <i>Eriobotrya japonica</i> (Thunb.) Lindl                           | H                | E                                | 2   | Low           |
| Euca  | <i>Eucalyptus camaldulensis</i> Dehnh                               | H                | AE                               | 12  | Moderate      |
| Fica  | <i>Ficus carica</i> L.                                              | M                | E                                | 0   | Nil           |
| Fror  | <i>Fraxinus ornus</i> L.                                            | H/male           | A                                | 18  | High          |
| Gltr  | <i>Gleditsia triacanthos</i> L.                                     | H                | E                                | 4   | Low           |
| Grro  | <i>Grevillea robusta</i> A.Cunn. ex R.Br                            | M                | E                                | 2   | Low           |
| Jami  | <i>Jacaranda mimosifolia</i> D. Don                                 | H                | E                                | 2   | Low           |
| Jure  | <i>Juglans regia</i> L.                                             | M                | AE                               | 18  | High          |
| Lain  | <i>Lagerstroemia indica</i> L.                                      | M                | E                                | 2   | Low           |
| Lior  | <i>Liquidambar orientalis</i> Mill                                  | M                | A                                | 18  | High          |
| Magr  | <i>Magnolia grandiflora</i> L.                                      | H                | E                                | 2   | Low           |
| Meaz  | <i>Melia azedarach</i> L.                                           | H                | E                                | 2   | Low           |
| Moal  | <i>Morus alba</i> L.                                                | M                | A                                | 18  | High          |
| Monip | <i>Morus nigra</i> f. pendula                                       | M                | A                                | 27  | Very high     |
| Oleu  | <i>Olea europaea</i> L.                                             | H                | A                                | 24  | High          |
| Pato  | <i>Paulownia tomentosa</i> Thunb                                    | H                | E                                | 2   | Low           |
| Phca  | <i>Phoenix canariensis</i> L.                                       | D                | A                                | 9   | Moderate      |
| Pipu  | <i>Picea pungens</i> Engelm                                         | M                | A                                | 9   | Moderate      |
| Pibr  | <i>Pinus brutia</i> Ten                                             | M                | A                                | 12  | Moderate      |

**Table 5** (continued)

| Code  | Species                                          | Sex <sup>a</sup> | Type of pollination <sup>b</sup> | PAV | Allergenicity |
|-------|--------------------------------------------------|------------------|----------------------------------|-----|---------------|
| Pipi  | <i>Pinus pinea</i> L.                            | M                | A                                | 12  | Moderate      |
| Ploc  | <i>Platanus occidentalis</i> L.                  | M                | A                                | 18  | High          |
| Plor  | <i>Platanus orientalis</i> L.                    | M                | A                                | 24  | High          |
| Plyor | <i>Platycladus orientalis</i> (L.) Franco        | M                | A                                | 27  | Very high     |
| Poni  | <i>Populus nigra</i> L.                          | D                | A                                | 18  | High          |
| Prcea | <i>Prunus cerasifera</i> cv. atropurpurea Rehder | H                | E                                | 1   | Low           |
| Prdo  | <i>Prunus domestica</i> L.                       | H                | E                                | 1   | Low           |
| Prpe  | <i>Prunus persica</i> (L.) Batsch                | H                | E                                | 1   | Low           |
| Pugr  | <i>Punica granatum</i> L.                        | H                | E                                | 0   | Nil           |
| Rops  | <i>Robinia pseudoacacia</i> L.                   | H                | E                                | 4   | Low           |
| Saba  | <i>Salix babylonica</i> L.                       | D                | A                                | 18  | High          |
| Soja  | <i>Sophora japonica</i> L.                       | H                | AE                               | 4   | Low           |
| Tate  | <i>Tamarix tetrandra</i> Pall. ex M.Bieb         | H                | AE                               | 12  | Moderate      |
| Tico  | <i>Tilia cordata</i> Mill                        | H                | AE                               | 8   | Moderate      |
| Trfo  | <i>Trachycarpus fortunei</i> (Hook.) H. Wendl    | D                | AE                               | 12  | Moderate      |
| Waro  | <i>Washingtonia robusta</i> H. Wendl             | H                | A                                | 6   | Low           |

<sup>a</sup>Sexual system (M: Monoecious, D: Dioecious, H: Hermaphrodite)

<sup>b</sup>Type of pollination (A: Anemophilous, E: Entomophilous, AE: Amphiphilous)

(*Phoenix canariensis* L., *Tamarix tetrandra* Pall. ex M.Bieb., *Trachycarpus fortunei* (Hook.) H. Wendl.), they were considered moderately allergenic (PAV 8–12).

Upon examining the distribution of trees in Aydin urban parks according to their characteristics, Aytepe Recreation Area was the park with the highest rate of native trees of 99.52%. The highest rate of exotic species is in Nevzat Bicer Park (83.26%). Except for Aytepe Recreation Area, over 35% of the species in the other parks are exotic species. There are no invasive species in Aytepe Recreation Area. The highest rate (20.50%) of invasive species (including *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle., *Albizia julibrissin* Durazz., *Cedrus atlantica* (Endl.) Lindl. & Gordon, *Grevillea robusta* A.Cunn. ex R.Br., *Lagerstroemia indica* L., *Melia azedarach* L. and *Robinia pseudoacacia* L.) is in Nevzat Bicer Park. Although exotic species constitute the majority in the park, monoecious and anemophilous species are less common than in the other parks. Over 75% of the trees in Aytepe Recreation Area, Ismet Sezgin Park, and Pinarbasi Recreation Area have a monoecious sexual system. While Aytepe Recreation Area hosts the highest number of monoecious species

(98.55%), Nevzat Bicer Park has the highest number of dioecious and hermaphrodite species. The majority (> 60%) of the species in the four urban parks have the anemophilous type of pollination (Fig. 2).

All trees in Pinarbasi Recreation Area are allergenic species. The park with the lowest number of allergenic tree species is Ismet Sezgin Park. Nevzat Bicer Park has the highest number of trees (29.71%) with low allergenicity. Over 50% of the species in Ismet Sezgin Park, Nevzat Bicer Park, and Pinarbasi Recreation Area have high and very high allergenic levels. The parks with the highest number of highly and very highly allergenic trees are Ismet Sezgin Park (44.75%) and Pinarbasi Recreation Area (32.43%). The highest  $I_{UGZA}$  value was observed in Ismet Sezgin Park (0.46) and Pinarbasi Recreation Area (0.56). It was revealed that the SHDI was high in other parks, except for Aytepe Recreation Area. Although Nevzat Bicer Park has the highest SHDI value, Aytepe Recreation Area has the lowest  $I_{UGZA}$  value (Table 6).

Upon examining the CCA plot, it was found that the species distribution differed between the parks. Species similarity is the highest in Ismet Sezgin Park and Pinarbasi Recreation Area. The other parks differ more in terms of species composition. Monoculture

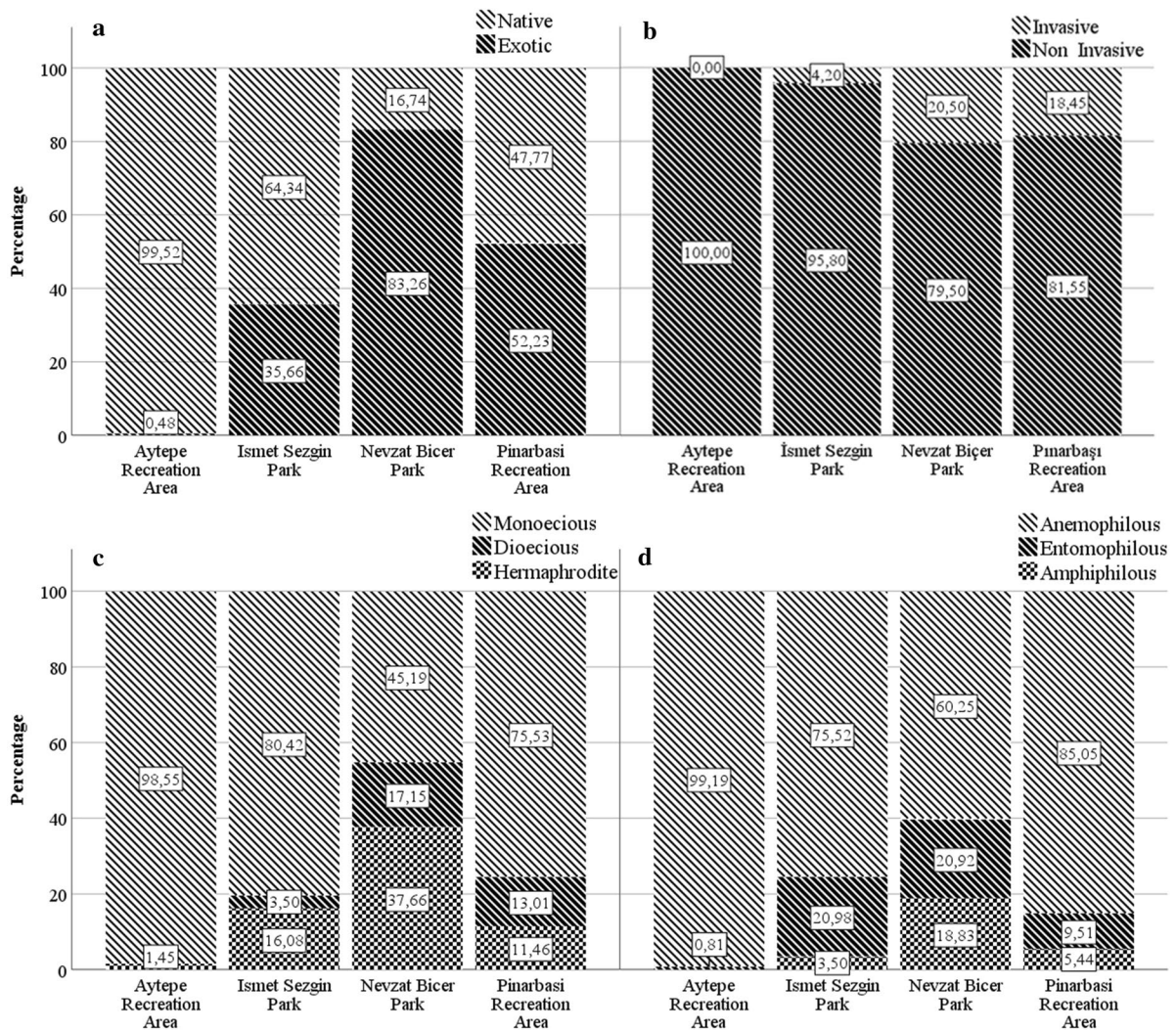


**Fig. 2** Proportion of trees by the native/exotic status (a), invasive/noninvasive status (b), sexual system (c), and the type of pollination (d) in the parks of Aydın

**Table 6** Percentage of allergenic trees, Shannon Diversity Index (SHDI), and  $I_{UGZA}$

| Parks                     | Allergenic trees (%) |       |          |       |           | SHDI | $I_{UGZA}$ value |
|---------------------------|----------------------|-------|----------|-------|-----------|------|------------------|
|                           | Nil                  | Low   | Moderate | High  | Very high |      |                  |
| Aytepe Recreation Area    | 0.16                 | 0.65  | 79.48    | 0.97  | 18.74     | 0.70 | 0.17             |
| İsmet Sezgin Park         | 2.10                 | 20.98 | 20.28    | 44.75 | 11.89     | 2.43 | 0.46             |
| Nevzat Bicer Park         | 0.42                 | 29.71 | 18.83    | 20.50 | 30.54     | 2.90 | 0.23             |
| Pınarbaşı Recreation Area | 0                    | 10.49 | 22.33    | 34.76 | 32.43     | 2.78 | 0.52             |

is common in Aytepe Recreation Area.  $I_{UGZA}$  is higher in İsmet Sezgin Park and Pınarbaşı Recreation Area. Tree density is associated with Aytepe Recreation Area, and the SHDI is associated with the other

parks. An inverse correlation was revealed between the SHDI and the number of species and tree density. The SHDI and the number of species were strongly

correlated with each other. There was no correlation between the SHDI and  $I_{UGZA}$  (Fig. 3).

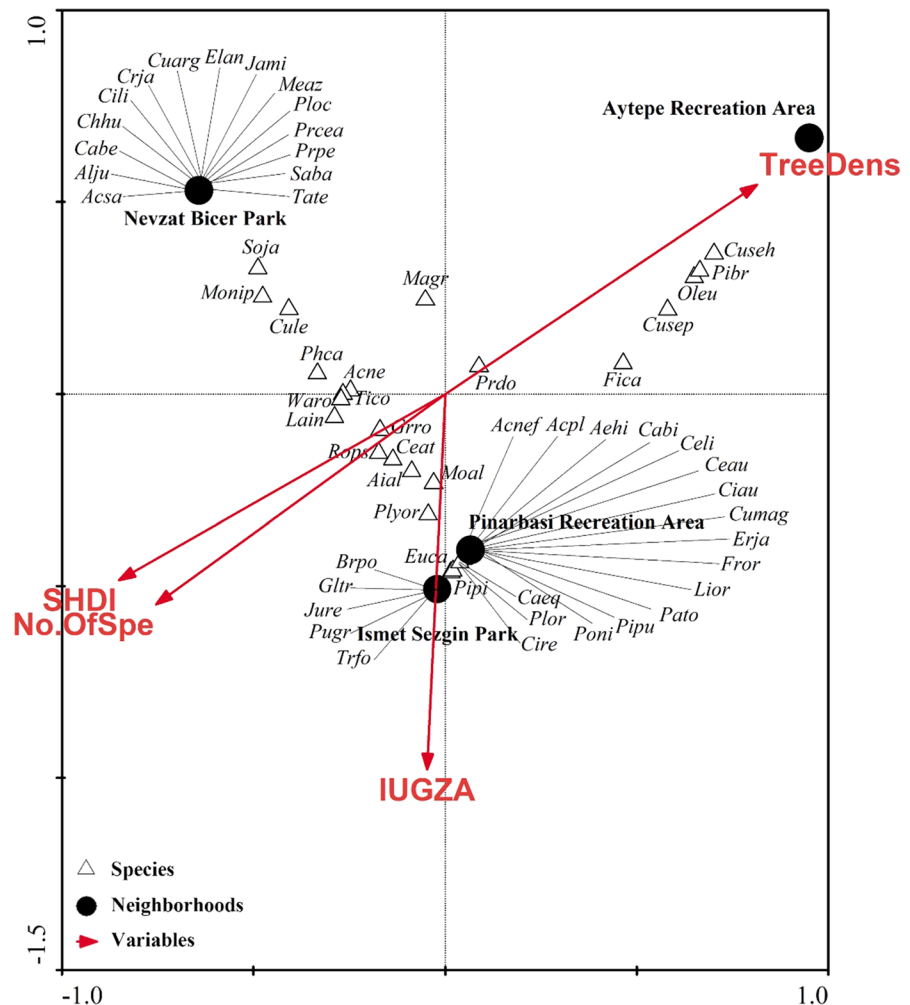
#### 4 Discussion

This study determined the allergenic status of the species and the allergenic level of each park and revealed the tree species composition in the four parks in the city of Aydin. According to the study by Cariñanos et al. (2014), the important factors influencing  $I_{UGZA}$  are species whose pollens are classified as allergenic and the existence of single-species stands. However, the lowest  $I_{UGZA}$  value was found in Aytepe Recreation Area, where monoculture was the most prevalent. (Three species make up 99.03 percent of the total number of trees.) The reason for this is that most

trees in Aytepe Recreation Area are native species, contain noninvasive species, and are mostly moderately allergenic. Differently, although monoculture is not common in Pinarbasi Recreation Area, most trees with high (34.76%) and very high (32.43%) allergenic levels cause the highest  $I_{UGZA}$  value. The reason why Nevzat Bicer Park has a low allergenic level (0.23), where monoculture is least common (three species make up 38.49% of the total number of trees), is that monoecious and anemophilous species are less common in the park and trees with a low allergenic level are abundant (29.71%).

The most common allergenic genus in the Cupressaceae family is *Cupressus* (D'Amato et al., 1998). Charpin et al., (1993, 2013) and Mari et al. (1997), and showed that exposure to cypress pollen was a strong risk factor for allergic asthma. In a study

**Fig. 3** Canonical correspondence analysis (CCA) plot, showing the correspondence of different variables with the tree composition in parks of Aydin



conducted in Southern France, Bousquet et al. (1993) stated that the incidence of conjunctivitis was very high (73.7–88.5%), and it might be severe in patients sensitive to cypress pollen allergens. The entire Cupressaceae family has an anemophilous character, abundant pollen production (Aboulaïch et al., 2008), and a broad flowering period (De la Guardia et al., 2006). In places where the Cupressaceae family is common, authorities should alert the public during the periods of pollination, which occurs in the winter months (Cariñanos et al., 2019). In the winter months, when pollination occurs, it is recommended that visitors to Aytepe Recreation Area and Pinarbasi Recreation Area reduce their visits because *Cupressus sempervirens* var. *horizontalis* (Mill.) Loudon and *C. sempervirens* var. *pyramidalis* (O.Targ.Tozz.) Nyman are abundant in these parks and have very high allergenicity. Since the pollens of the *C. arizonica* Greene are in the air not only seasonally but throughout the year, they pose a significant risk for susceptible individuals living in cities (Bicakci & Tosunoğlu, 2019). The high allergenicity of *Cupressus arizonica* cv. *glauca* (Woodall) Rehder can make visits to Nevzat Bicer Park risky throughout the year. Research shows that the genera *Juniperus*, *Platycladus*, *Cupressus*, and *Chamaecyparis* from the Cupressaceae family cross-react with each other and with the species belonging to the Pinaceae family (Schwietz et al., 2000). *Cryptomeria japonica* (L.f.) D. Don., *Cupressocyparis leylandii* A.B.Jacks. & Dallim, *Cupressus arizonica* cv. *glauca* (Woodall) Rehder, *C. macrocarpa* var. *goldcrest* Hartw., *C. sempervirens* var. *horizontalis* (Mill.) Loudon, *C. sempervirens* var. *pyramidalis* (O.Targ.Tozz.) Nyman and *Platycladus orientalis* (L.) Franco individuals from the Cupressaceae family, which are dense in Aytepe Recreation Area, Ismet Sezgin Park, Nevzat Bicer Park, and Pinarbasi Recreation Area, can cross-react with each other and *Cedrus atlantica* (Endl.) Lindl. & Gordon, *C. libani* A.Rich., *Picea pungens* Engelm., *Pinus brutia* Ten. and *P. pinea* L. belonging to the Pinaceae family.

The main allergenic pollens in China originate from the genera of the Pinaceae family and the genus *Populus* from the Salicaceae family (Man et al., 1992; Meng, 2005; Xie et al., 2003). In Greece, plants from the Cupressaceae and Oleaceae families are common allergenic pollen plants (Gioulekas et al., 2004). *Cryptomeria japonica* (L.f.) D. Don. is shown as

the cause of most pollinosis cases in Japan (Ishizaki et al., 1987). Since *Populus* species cause respiratory reactions by being exposed to seed trichomes, they have allergenic potential (Spieksma, 1990). The presence of *Cedrus atlantica* (Endl.) Lindl. & Gordon, *C. libani* A.Rich., *Picea pungens* Engelm., *Pinus brutia* Ten. and *P. pinea* L. from the Pinaceae family; *Cryptomeria japonica* (L.f.) D. Don., *Cupressocyparis leylandii* A.B.Jacks. & Dallim, *Cupressus arizonica* cv. *glauca* (Woodall) Rehder, *C. macrocarpa* var. *goldcrest* Hartw., *C. sempervirens* var. *horizontalis* (Mill.) Loudon, *C. sempervirens* var. *pyramidalis* (O.Targ.Tozz.) Nyman and *Platycladus orientalis* (L.) Franco from the Cupressaceae family; *Fraxinus ornus* L. and *Olea europaea* L. from the Oleaceae family; and *Populus nigra* L. from the Salicaceae family in the four parks where the study was conducted reveals that these species can cause pollinosis by producing allergenic pollens.

A study carried out in 26 parks in Spain revealed that the percentage of allergenic species fluctuated between 17 and 67%, their density between 100 and 300 trees/ ha, and the recorded index values varied between 0.07 and 0.87. A significant correlation was found between the  $I_{UGZA}$  value and both the number of trees and tree density. However, biodiversity (SHDI) did not have a significant impact on the  $I_{UGZA}$  value (Cariñanos et al., 2017). Another study showed that variables such as the density of trees and the number of species have a strong effect on  $I_{UGZA}$  (Cariñanos et al., 2019). Jochner-Oette et al. (2018) drew attention to the fact that the increase in biodiversity did not always lead to lower allergen potential of park vegetation cover. The percentage of allergenic trees in the parks examined in the current study varies between 97.90 and 100%, and their densities are between 159.96 and 391.06 trees/ha. The  $I_{UGZA}$  values vary between 0.17 and 0.52. Likewise, there was no correlation between the  $I_{UGZA}$  and SHDI values. Differently, no correlation was detected between  $I_{UGZA}$  and the density of trees and the number of species. In a study conducted in 26 green areas in 24 Spanish cities, Cariñanos et al. (2017) reported that 12 of the parks examined exceeded the 0.30  $I_{UGZA}$  value, and these parks were unhealthy at any time of the year. According to the current study, Ismet Sezgin Park and Pinarbasi Recreation Area pose a risk to human health at any time of the year because their  $I_{UGZA}$  exceeds 0.30.

Pollen susceptibility is limited to anemophilous plants, which make up 10–18% of all flowering plants (Songnuan, 2013). Anemophilous species are associated with higher allergenicity values (Cariñanos et al., 2016a, 2016b). Despite some exceptions, allergenic plants are anemophilous, whereas most entomophilous plants do not pose a community-level risk. The allergenic level of entomophilous species is low. Therefore, a general rule for plant selection is to use plants with showy, entomophilous flowers. Particular focus is placed on entomophilous plants that require insects as propagation vectors and produce smaller amounts of pollen than anemophilous species. *Cornus florida* L., various magnolias *Magnolia* spp. and *Liriodendron tulipifera* L. can be given as examples of entomophilous species (Green et al., 2018). In this study, 50% of the 58 tree species (29 species) in the four parks were anemophilous species, indicating the high allergenic level in the parks. The rate of entomophilous species with a low allergenic level, which is 36.21% (21 species) in the parks, should be increased. While most trees with a high and very high PAV value are anemophilous species, all trees with nil and low values are entomophilous species.

The major causes of pollen allergenicity are stated as the widespread use of species with high allergenic pollen distribution in urban areas (Bicakci & Tosunoğlu, 2019), low species diversity adapted to urban environmental conditions, invasive species and introducing exotic species, the use of monoecious species, the use of male individuals in dioecious species, the widespread use of anemophilous species (Cariñanos & Casares-Porcel, 2011), the emergence of cross-reactivity among phylogenetically related species, the interaction between pollens and air pollutants, and maintenance activities (Mrđan et al., 2017). The guidelines for designing green spaces with low allergy effects require adopting management, pruning, and maintenance strategies appropriate for avoiding the collective use of male individuals of dioecious species (avoiding botanical sexism)/replacing male individuals of dioecious species with females (Green et al., 2018; Ogren, 2000, 2002), selecting entomophilous species with low pollen production and low allergenic potential (Green et al., 2018; Kasprzyk et al., 2019; Kremen et al., 2007), using species with short pollen seasons, increasing plant biodiversity, ensuring the controlled introduction of exotic flora (Cariñanos & Casares-Porcel,

2011), control of invasive species, avoiding the promotion of cross-reaction between panallergens (Green et al., 2018), and ensuring the eradication of opportunistic and spontaneous species (Cariñanos & Casares-Porcel, 2011; Fam et al., 2008).

## 5 Conclusion

The present study draws attention to public health in the planning and design of urban parks. According to the findings of the current study, Pinarbasi Recreation Area has the highest number of species (34 species) and Aytepe Recreation Area has the highest number of trees (619 individuals). Invasive species are rarely used in parks. Monoecious and anemophilous species are common in parks. İsmet Sezgin Park and Pinarbasi Recreation Area have the highest  $I_{UGZA}$  values. Except for Aytepe Recreation Area, SHDI values are high in the other parks.  $I_{UGZA}$  and SHDI, as well as the number of species and tree density, showed no correlation. As a result, it was determined that there was a need for guidelines on the design and planning of urban green spaces with low allergenic effects. The method used shows the need to consider the potential allergenicity of a species when choosing plant material to be used in cities. It guides the planning and design of future green spaces by selecting the most suitable species against pollen allergy and opens new perspectives. However, establishing the pollination calendar in that region is useful to offer solutions to pollen allergy. After such a study is conducted, it is revealed which allergen pollens release pollens during which periods and what are the areas where they are concentrated. After this stage, the relevant health-care professionals will tell which plant their patients are allergic to, and the treatment will be provided. This study will contribute to preparing a pollination calendar in other regions, primarily in the city of Aydin. Considering the results will ensure that urban parks will become safer areas for public health. Future studies should include all plants (shrub, grass, etc.) to draw more comprehensive conclusions about the allergenic level in urban green zones.

**Author contributions** Both authors were involved in all phases of the work.

**Funding** The authors received no financial support for the research, authorship, and/or publication of this article.

**Availability of data and materials** Not applicable.

**Declarations**

**Conflict of interest** The authors declare no conflict of interest.

**Consent for publication** Not applicable.

**Ethics approval** Not applicable.

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