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Diversity of Plant Communities Associated with Urban Green Spaces in Southwestern Algeria

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Abstract. Urban green spaces are essential to assuring the quality of life. This study aims to study the diversity of plant communities associated with urban green spaces in southwestern Algeria. Based on data collected from 57 phytoecological surveys with an area of 1 m², plant communities were analyzed using diversity parameters (specific richness, biodiversity indices and similarity) and plant functional traits (life forms, morphological, phytogeographical and dispersal types). 32 species belonging to 31 genera in 13 families have been identified. According to the real spectrum (data based on abundance) of plant functional traits, plant species are mainly geophytes (48.27%) which adopt various dispersal strategies, including barochores (71.55%) and anemochores (17.24%). Phytogeographic analysis revealed the dominance of the cosmopolitan element (41.55%) which is well adapted to the Saharan climate. Agglomerative hierarchical clustering of species based on their abundance by Minitab 17 revealed six groups. This work provides important information that can serve as a basis for the management and conservation of biodiversity in southwestern Algeria.

Keywords. Plant communities, Diversity, Urban, Green spaces, Southwestern Algeria.

I. INTRODUCTION

In an urbanized environment, the need for green spaces has become necessary for aesthetic and ecological reasons [1,2]. Today, cities are home to a large number of cultivated or natural plant formations [3, 4]. These plant formations are represented by public gardens, alignment trees and green spaces [5-7]. Green spaces provide many services to humans called ecosystem services [8]. Ecosystem services include improving air quality, reducing energy consumption and regulating running water [9-11]. Urban people plant green spaces; this is called urban agriculture [12]. Urban agriculture is defined as the assembly of works that applies to the soil to produce plants of interest to humans [2]. Urban and peri-urban agriculture represents an important impact in terms of food security [13-15] and in terms of improving the environment and quality of life in cities [2]. It is necessary to understand the potential of urban centers in terms of green spaces in the context of climate change [16]. Green spaces with high ecological value are the subject of agricultural practices that lead to changes in the floristic composition and structure of plant formations [17]. Integrating agriculture under trees into the urban landscape can improve food security and complement traditional food security strategies [15].

In southwest Algeria, the green spaces are home to remarkable plant formations and a rich heritage that offer attractive landscapes. Therefore, it is necessary to make an inventory of urban green spaces in order to know the floristic diversity and the characteristics of plant communities associated with urban green spaces.

The objective of the study is to (i) establish phytoecological groups of vegetation associated with urban green spaces; (ii) determine floristic diversity (specific richness, biodiversity indices and similarity); (iii) explore various functional traits of plants (life forms, morphological, phytogeographic and dispersal types).

II. MATERIAL AND METHODS

- *Study Area*

The study area is part of the Wilaya of Adrar (southwest Algeria). It is limited on the north by the municipality of Aougrout, on the south by the municipality of Fenoughil, on the east by the municipality of Timokten and on the west by the municipality of Adrar (Fig. 1).

The climate of Tamentit is the same as that of the city of Adrar, which is characterized by a hot climate and rare precipitation [18- 20]. Based on meteorological data collected between 2004 and 2014, the average climate data for the Adrar

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region are as follows: Summer temperatures are high (46.4°C) in July. In winter, it is (5.53°C) in January. Precipitation is low and irregular with an average of 15.72 mm. The winds are very frequent and their speed can reach 24.5 m/s in May.

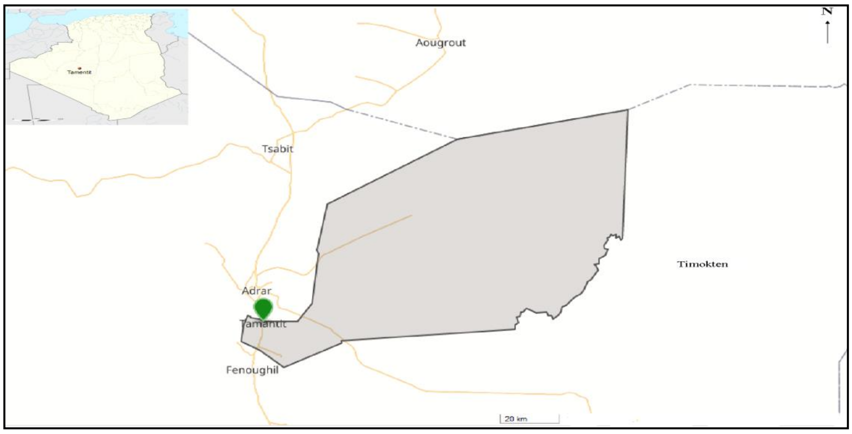

FIGURE 1. Location of the study area.

- ## *Collection of Data*

We have delimited plots with a fixed surface (1 X 1 m^2), which are sufficient to obtain exhaustive representativeness of the plants. The choice of this surface was based on studies of plant communities in urban and cultivated areas [21, 22]. In each plot, the name of the species and the number of individuals of each species were determined. A total of 57 surveys were carried out during the month of August 2021.

Plant species were identified and named according to the flora of Algeria [23]. Biological types of the plant species inventoried were determined according to Raunkiaer (1934) [24] which is based on the position of the renovation buds in relation to the soil surface during unfavorable periods.

The biogeographical origin of the species was established from the flora of Algeria [23]. The dispersal of species was determined according to the classification of van der Pijl (1982) [25] who classified plants into anemochores, barochores, hydrochores, zoochores and autochore. Plants are classified as perennial or annual, depending on the persistence of the aerial vegetative part during the unfavorable season [20].

- ## *Data Analysis*

The agglomerative hierarchical clustering (AHC) using Minitab 17 software was applied to obtain floristically homogeneous ecological groups. AHC was carried out on the basis of abundance in order to highlight the main groups of surveys that appear. The AHC takes into account the similarities between surveys of the same group to accurately distinguish between similar subgroups of surveys [26]. For each phytoecological group characterized by using the raw biological spectra (qualitative data: specific richness) and real biological spectra (quantitative data: abundance). The raw spectrum takes into account proportions of specific richness, while the real spectrum uses the cumulative abundances of these species in the group [20].

Alpha diversity was determined by calculating of:

Specific richness (S) is the total number of species present in each phytoecological group and the study area in general;

Shannon diversity index (H') was calculated using the formula:

$$\mathbf{H' = -\Sigma\ pi\ log_2\ pi}$$

where pi = ni/N is the relative abundance of species i in the sample;

ni is the number of individuals of a given species, i ranging from 1 to S (total number of species) and N is the total number of individuals [27].

Pielou's equitability (E) was calculated using the formula:

$$\mathbf{E = H'/\ H_{max}}$$

H': represents the Shannon diversity index;

$H_{max} = \log_2 S$: the theoretical value of the maximum diversity.

It varies between 0 and 1, with E = 1 when individuals are evenly distributed among species [28].

Simpson diversity index was calculated using the formula:

$$SDI = 1 - D \text{ Ou } SDI = 1 - \sum_{i=1}^{S} p^2_i \quad \text{avec } 0<SDI\leq 1$$

The maximum diversity will then be represented by the value 1 and the minimum diversity by the value 0 [29].

III. RESULTS AND DISCUSSION

- *Floristic Composition*

In total, 32 plant species belonging to 13 families and ٣1 genera were recorded (Table 1). The number of species recorded in green spaces is due to the types of agricultural techniques, the type of soil, the type and quality of irrigation water, and space management methods [30, 31]. According to [32, 33], that green spaces are highly invested environments and could constitute potential reservoirs of interesting species and environments.

The most representative families were Asteraceae (21.87%) and Poaceae (18.75%). These two families have been reported as the most representative families in cultivated areas around the world [34]. They are also characterized by the capacity to produce high quantities of seeds in a way favorable to dispersal and the ability to colonize different environments [35, 36, 37].

The majority of species were perennial species (63.79%) and annuals with (36.21%). The proliferation of perennial species is due to favorable conditions of the environment and the absence of herbicide treatments [30]. The presence of annual species may be related to their short life cycle, which allows them to resist maintenance labor [30, 38].

TABLE 1. List of plant species present in the study area.

Family	Species	Forme life	Dispersal types	Morphological types	Phytogeographical type
Cyperaceae	*Cyperus rotundus* L.	Geophytes	Barochore	Perennial	Subtropical
Zygophyllaceae	*Zygophyllum album* L. f.	Champhyte	Barochore	Perennial	Saharo-Arabian.
	Tribulus terrestris L.	Therophytes	Zoochore	Annual	Old World
Poaceae	*Phragmites communis* Trin.	Geophytes	Anemochore	Perennial	Cosmopolitan
	Phalaris brachystachys Link.	Therophytes	Zoochore	Annual	Mediterranean
	Dactyloctenium aegyptium (L.) Willd.	Therophytes	Barochore	Annual	Pantropical
	Setaria viridis (L.) P. Beauv	Therophytes	Zoochore	Annual	Temperate Subtropical
	Cynodon dactylon (L.) Pers.	Geophytes	Barochore	Perennial	Cosmopolitan
	Imperata cylindrica (L.) Räusch.	Geophytes	Barochore	Perennial	Cosmopolitan
Amaranthaceae	*Chenopodium album* L.	Therophytes	Barochore	Annual	Cosmopolitan
	Salsola vermiculata L.	Champhyte	Anemochore	Perennial	Saharo-Mediterranean
	Amaranthus retroflexus L.	Therophytes	Zoochore	Annual	North American
	Bassia muricata (L.) Asch.	Therophytes	Zoochore	Annual	Saharan
	Suaeda fruticosa L.	Champhyte	Hydrochore	Annual	cosmopolitan
Asteraceae	*Sonchus oleraceus* L.	Therophytes	Barochore	Annual	cosmopolitan
	Erigeron bonariensis L.	Therophytes	Anemochore	Annual	American
	Pulicaria arabica (L.) Cass.	Hemicryptophytes	Anemochore	Perennial	North African
	Launaea nudicaulis (L.) Hook. f.	Therophytes	Anemochore	Annual	Mediterranean Saharo Arabian
	Launaea resedifolia O.K.	Therophytes	Anemochore	Annual	Mediterranean Saharo-Arabian
	Lactuca Serriola L.	Therophytes	Anemochore	Annual	Paleo-temperate
	Reichardia picroides (L.) Roth	Therophytes	Barochore	Annual	Mediterranean
Portulacaceae	*Portulaca oleracea* L.	Therophytes	Barochore	Annual	Cosmopolitan
Polygonaceae	*Polygonum aviculare* L.	Therophytes	Barochore	Annual	Cosmopolitan
Apocynaceae	*Cynanchum acutum* L.	Geophytes	Barochore	Perennial	Mediterranean-Asian
	Calotropis procera Act.	Phanerophyte	Anemochore	Perennial	Sahelo-Saharan
Euphorbiaceae	*Euphorbia granulata* Forsk.	Therophytes	Barochore	Annual	Saharo-Arabian.
Solanaceae	*Solanum nigrum* L.	Therophytes	Zoochore	Perennial	Cosmopolitan
	Datura stramonium L.	Therophytes	Zoochore	Annual	Cosmopolitan
	Hyoscyamus muticus L.	Therophytes	Zoochore	Annual	Saharo-Arabian.
Cucurbitaceae	*colocynthis vulgaris* (L.) Schrad	Therophytes	Zoochore	Annual	Tropical Mediterranean
Malvaceae	*Malva parviflora* L.	Therophytes	Barochore	Annual	Mediterranean
Apiaceae	*Seseli tortuosum* L.	Hemicryptophytes	Zoochore	Perennial	Mediterranean

- *Discrimination of Different Plant Formations*

The Agglomerative hierarchical clustering made it possible to discriminate the principal vegetation groups. Each vegetation group includes an ensemble of surveys with similar vegetation. The (AHC) individualized six different groups of plants (G1, G2, G3, G4, G5 and G6) (Fig. 2).

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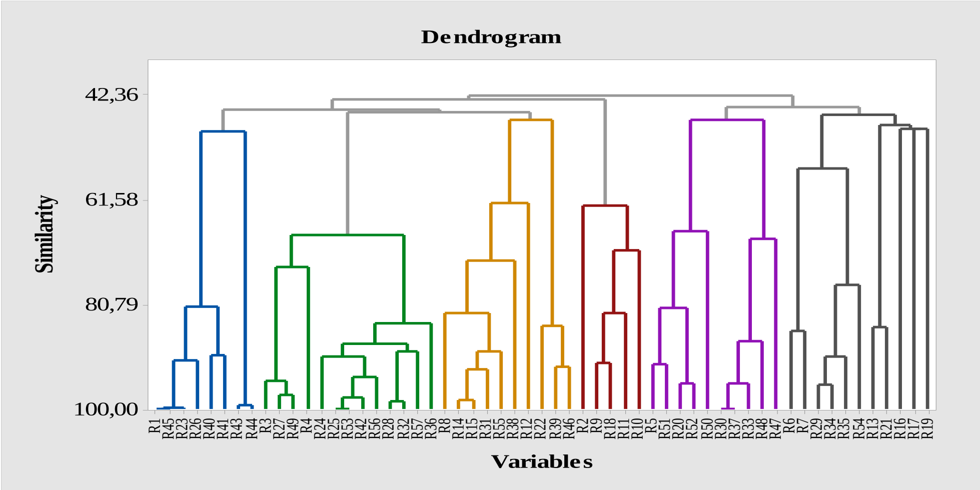

FIGURE 2. Dendrogram of the phytoecological groups of plant communities associated with urban green spaces in southwest Algeria.

The characteristics of these six vegetation groups as well as the abundance of species for each group are given in Table 2; this table also includes the values of species richness, the Shannon index and the Simpson index.

TABLE 2. Characteristics of the six vegetation groups.

Species	Abundance of G1	Abundance of G2	Abundance of G3	Abundance of G4	Abundance of G5	Abundance of G6
Cyperus rotundus L.	112	-	-	-	-	-
Zygophyllum album L. f.	-	-	4	5	23	2
Tribulus terrestris L.	-	-	-	-	1	-
Phragmites communis Trin.	1	2	7	16	6	7
Phalaris brachystachys Link.	-	-	-	3	-	-
Dactyloctenium aegyptium (L.) Willd.	4	5	43	2	2	53
Setaria viridis (L.) P. Beauv	-	5	-	-	-	-
Cynodon dactylon (L.) Pers.	16	-	106	-	-	-
Imperata cylindrica (L.) Räusch.	70	-	3	-	-	-
Chenopodium album L.	-	3	-	-	-	-
Salsola vermiculata L.	2	-	-	-	8	-
Amaranthus retroflexus L.	1	-	4	-	-	19
Bassia muricata (L.) Asch.	2	2	2	4	7	-
Suaeda fruticosa L.	3	-	-	-	-	-
Sonchus oleraceus L.	-	15	-	-	-	1
Erigeron bonariensis L.	1	1	2	1	1	1
Pulicaria arabica (L.) Cass.	-	-	-	-	-	10
Launaea nudicaulis (L.) Hook. f.	-	-	1	-	-	1
Launaea resedifolia O.K.	-	-	2	-	-	-
Lactuca Serriola L.	12	-	-	2	-	5
Reichardia picroides (L.) Roth	-	-	-	-	1	-
Portulaca oleracea L.	5	-	5	4	2	3
Polygonum aviculare L.	-	-	-	-	-	1
Cynanchum acutum L.	-	2	8	2	-	-
Calotropis procera Act.	-	3	5	25	2	-
Euphorbia granulata Forsk.	2	-	-	-	-	3
Solanum nigrum L.	-	1	-	-	7	-
Datura stramonium L.	-	-	2	1	-	4
Hyoscyamus muticus L.	-	-	-	1	-	-
colocynthis vulgaris (L.) Schrad	-	-	-	1	4	-
Malva parviflora L.	-	-	-	-	2	-
Seseli tortuosum L.	-	-	1	-	-	-
Species richness	13	10	16	13	13	13
Shannon index	2.10	2.79	2.32	2.80	3.03	2.52
equitability	0.57	0.84	0.58	0.76	0.82	0.68
Simpson index	0.66	0.80	0.65	0.79	0.82	0.70

The most abundant species in all phytoecological groups are *Dactyloctenium aegyptium* (109 individuals), *Phragmites communis* (39 individuals) and *Erigeron bonariensis* (7 individuals). *Dactyloctenium aegyptium* is a very invasive annual species, associated with sandy soils and the use of animal fertilizers [39]. In addition, *Dactyloctenium aegyptium* is characterized by early emergence [40]. *Phragmites communis* adapt to humid and very salty environments [41]. *Erigeron bonariensis* is a particularly invasive species [42]. The seeds of this species are light, which facilitates the dispersal of seeds at low wind speed and therefore a fort invasion [43].

The principal characteristics of each group and their component surveys are as follows (Fig. 3, Fig. 4 and Fig. 5):

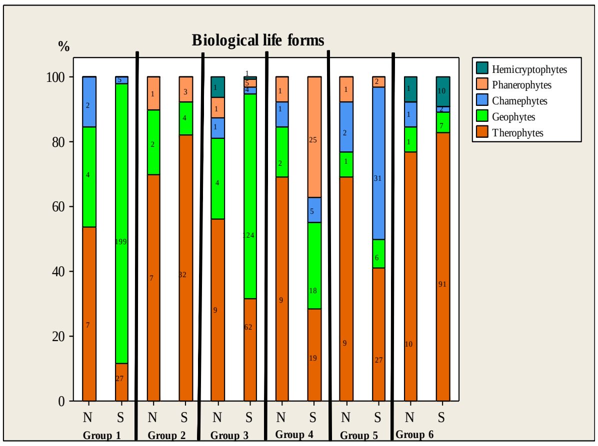

FIGURE 3. Spectra of biological types.

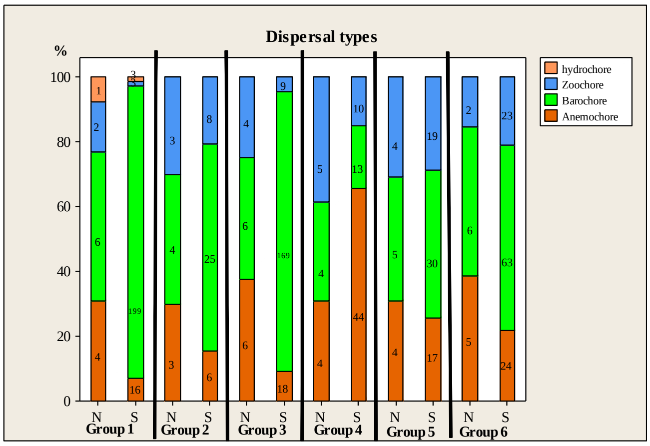

FIGURE 4. Dispersion spectrum.

N: Raw; S: Real

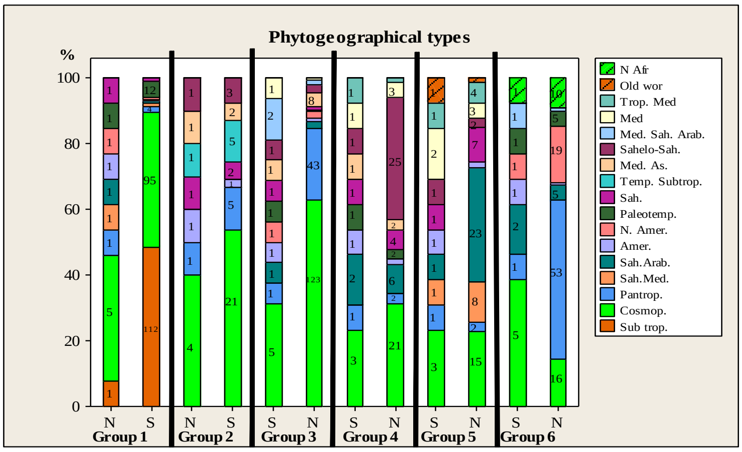

FIGURE 5. Phytogeographic spectrum.

Sub trop: Subtropical; Sah. Arab: Saharo-Arabian; Old wor: Old World; Cosmop; Cosmopolitan; Med: Mediterranean; Pantrop: Pantropical; Temp. Subtrop: Temperate Subtropical; Sah. Med: Saharo-Mediterranean; N. Amer: North American; Sah: Saharan; Amer: American; N Afr: North African; Med Sah. Arab: Mediterranean Saharo Arabian; Paleotemp: Paleo-temperate; Med. As: Mediterranean-Asian; Sahelo. Sah: Sahelo-Saharan; Trop. Med: Tropical Mediterranean

Group 1 consists of 8 surveys in which 13 species were recorded. The most abundant species are *Cyperus rotundus* (48.48%) and *Imperata cylindrica* (30.30%). The most representative families are Amaranthaceae and Poaceae (30.77%) and Asteraceae (15.38%). In the raw spectrum of biological types, Therophyte shows a good representation with (53.85%) followed by Geophytes (30.77%). In the real spectrum, Geophytes show a fort presence (86.15%) followed by Therophytes (11.69%). For chorological types, the cosmopolitan element dominated the raw spectrum with (38.46%). In the real spectrum, the Subtropical element shows a fort presence (48.50%) followed by the cosmopolitan elements (41.12%). plant dispersal is dominated by Barochores species (90.47%) followed by Anemochores species (6.93%). In the raw spectrum of morphological types, annual species show a high representation (61.54%), Perennial species show a high representation (87.01%) in the real spectrum. The Shannon diversity index is 2.10 bits, the Pielou Equitability is 0.57 and the Simpson index is 0.66.

Group 2 consists of 5 surveys where 10 species were recorded. The most abundant species are *Sonchus oleraceus* (38.46%), *Dactyloctenium aegyptium* and *Setaria viridis* (12.82%). The most represented families are Poaceae (30%), followed by Amaranthaceae, Asteraceae and Apocynaceae (20%). The raw and real biological spectrum shows a fort presence of Therophytes (70%; 82.05%) followed by Geophytes (20%, 10.26%) and Phanerophytes (10%; 7.69%). The flora of this group is dominated by cosmopolitan elements (40%; 53.85%) for the raw and real spectrum. The dispersion of plants is dominated by the Barochores type (40%; 64.11%) followed by the Zoochores species (30%, 20.51%) and the Anemochores (30%; 15.38%) for the raw and real spectrum. For morphological types, Annual species shows a fort presence in the raw spectrum with (70%), and in the real spectrum (79.49%). The Shannon diversity index is 2.79 bits, the Pielou Equitability is 0.84 and the Simpson index is 0.80.

Group 3 consists of 13 surveys with 16 species. The most abundant species are *Cynodon dactylon* (54.08%), *Dactyloctenium aegyptium* (21.94%). The Asteraceae with (25%) is the most represented family, followed by Amaranthaceae and Apocynaceae (12.5%) each. In the raw spectrum of biological types, Therophytes show good representation with (56.25%) followed by Geophytes (25%). In the real spectrum, Geophytes show a fort presence (63.27%) followed by Therophytes (31.63%). The two spectra of this group show that the flora of this group is dominated by cosmopolitan elements (31.25%; 62.76%). The raw and real spectrum shows that the flora of this group is dispersed by the Barochore type (37.5%; 86.23%) followed by the Anemochores species (37.5%, 9.18%) and the Zoochores species (25%; 4.59%). In the raw spectrum of morphological types, the Annuals show a good representation (56.25%). The Perennials show a good representation (68.37%) in the real spectrum. The Shannon diversity index is 2.32 bits, the Pielou equitability is 0.58 and the Simpson index is 0.65.

Group 4 consists of 10 surveys with 13 species. The most abundant species are *Calotropis procera* (37.31%), *Phragmites communis* (23.88%). The most represented family is the Family Poaceae (23.1%), followed by Asteraceae, Solanaceae and Apocynaceae (15.38%). In the raw spectrum of biological types, Therophytes show good representation with (69.24%). Phanerophytes (37.31%) dominated the real spectrum. The raw chorological spectrum of this group is dominated by the cosmopolitan element (23.1%), the Sahelo-Saharan element (37.32%) followed by the cosmopolitan element (31.35%) dominated the real spectrum. Zoochores species are dominated by the raw dispersal spectrum with (38.46%), the Anemochores dominate the real spectrum (65.68%). In the raw spectrum of morphological types, annuals show a good representation (69.23%). In the real spectrum, perennials show a good representation (71.64%). The Shannon diversity index is 2.80 bits, the Pielou equitability is 0.76 and the Simpson index is 0.79.

Group 5 consists of 11 surveys with 13 species. The most abundant species are *Zygophyllum album* (34.85%) and *Salsola vermiculata* (12.12%). The most represented families are: the family Zygophyllaceae, Poaceae, Amaranthaceae and Asteraceae (15.38%). In the raw spectrum of biological types, Therophyte shows good representation with (69.24%) followed by Chamephyte (15.38%). in the real spectrum, Chamephyte shows a fort presence with (46.97%) followed by Therophyte (40.91%). For chorological types, the cosmopolitan element dominated the raw spectrum with (23.1%). In the real spectrum, the Saharo-Arabian element shows a good presence (34.85%) followed by the cosmopolitan elements (22.73%). Plant dispersal is dominated by the Barochore type (38.46%; 45.45%) in two spectra. The raw spectrum of morphological types shows a good presence of annuals (61.54%). In the real spectrum, the Perennials show a good presence (69.7%). The Shannon diversity index is 3.03 bits, the Pielou equitability is 0.82 and the Simpson index is 0.82.

Group 6 consists of 10 surveys with 13 species. The most abundant species are *Dactyloctenium aegyptium* (48.18%), *Amaranthus retroflexus* (17.27%). The most represented families are: the family Asteraceae (38.48%), Poaceae (15.38%). In the raw and real spectrum, the biological spectrum shows an excellent presence of Therophytes (76.93%, 82.73%). For chorological types, the cosmopolitan element dominated the raw spectrum with (38.48%). In the real spectrum, the pantropical element shows a fort presence (48.19%) followed by the cosmopolitan elements (14.54%). The dispersion of plants is dominated by the Barochore type (46.16%; 57.27%) in two spectra. In the raw and real spectrum of morphological types, the annual shows a fort presence (76.92%; 82.73%). The Shannon diversity index is 3.03 bits, the Pielou equitability is 0.82 and the Simpson index is 0.82.

According to the life forms classification of Raunkiaer (1934), the G2 and G6 were dominated by Therophytes. The dominance of Therophytes is explained by their adaptation to agrarian ecosystems and the availability of water [44]. The G1 and G3 are dominated by the Geophytes; this dominance is probably related to their adaptation to superficial plowing practices [45, 34]. The pressure of working of soil favors the abundance of geophytes [31]. Vegetative propagation is their only mode of survival, as sexual reproduction is very infrequent for most of these species [46]. Phanerophytes dominated G4, indicating that they are found especially in green spaces without maintenance [30]. In general, Phanerophytes are rare in the Sahara and hot deserts [47, 48, 49]. The fort presence of Chamephytes in the G5 shows the good adaptation of Chamaephytes to the ecological conditions of hot arid and hyper-arid environments through the development of specific strategies [49].

The G1 dominated by the Subtropical element is explained by the effect of climate change in Mediterranean Africa since the Miocene, which will probably favor the installation of subtropical species, or the replacement of the range of native species [50, 51]. The G2 and G3 dominated by the cosmopolitan species can be explained by the fact that, the cultural biotope is a very open environment, regularly disturbed; accommodating many species introduced accidentally during the introductions of new crops or improved varieties [52]. In terms of the geographic distribution of species, the dominance of Sahelo-Saharan species in the G4 is probably due to systems of resistance to disturbances in this locality. This dominance can be explained by the fact that these species are more adapted to the bioclimatic conditions of the environment than other exotic species [53]. The Saharo-Arabian element is well represented in the G5, this may be because the region is considered a

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transition zone between the Mediterranean and Saharo-Arabian flora [54]. The abundance of pantropical species in the G6 confirms the loss of local biodiversity in our urban environments [55].

Dissemination by barochore dominated G1, G2, G3, G5 and G6 can be explained by its low spatial dispersion. The dominance of anemochore species in the G4 is probably due to the high frequency of winds in arid environments and particularly in Saharan areas [56]. The differences observed in floristic composition and biodiversity between the phytoecological groups are attributed to the micro-environmental conditions characterizing the associated surveys of each group, in particular soil properties, microclimate and irrigation [20].

CONCLUSION

This work has highlighted the importance of studying plant communities associated with urban green spaces in southwestern Algeria. The specific richness of these green spaces is composed of 32 species represented mainly by perennial species. This floristic richness is due to the microclimate of the green spaces, the diversity of the trees planted, the use of organic fertilizer. The vegetation studied is characterized by the dominance of Geophytes and Therophytes, this situation favors the installation of plants of barochore and anemochore dispersal strategies. Phytogeographically, the most abundant of cosmopolitan plants reflect the adaptation of plants to anthropogenic activities. Finally, urban green spaces constitute a reservoir of plant biodiversity and a protected area for spontaneous species.

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