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Floristic diversity of plant communities in sandy wadis of the northern Algerian Sahara (Ghardaïa region)

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Abstract. Plant species diversity was studied in 20 sandy wadis of the northern Algerian Sahara (Ghardaïa region). Based on subjective sampling, 20 floristic surveys were carried out in the various sandy biotopes in February-April 2022. Through an ascending hierarchical analysis, we distinguished 3 phytoecological groups and assessed their functional, biogeographic, and abundance characteristics. The recorded plants represented 15 species (296 individuals) belonging to 15 genera of 10 botanical families. The most represented families were the Fabaceae, Anacardiaceae, Brassicaceae, and Poaceae. In terms of the real plant-life spectrum, hemicryptophytes (51.7% of individuals) dominated the sandy wadis, followed by chamaephytes (33.1%) and phanerophytes (15.2%). In the real dispersal spectrum, the barochores prevailed (60%). The real phytogeographic spectrum shows that the Saharan endemic element reached the highest share (32.7%). In terms of abundance, an analysis of the real spectrum revealed that very common species (52%) dominate in the Ghardaïa region, but some fairly rare plants were also found. Indeed, the sandy biotopes of the wadis of the Ghardaïa region are valuable habitats for the conservation of plant species in the northern Algerian Sahara.

Key words: Algeria, plant community, nature conservation, sandy wadi, plant diversity, flora, northern Sahara

1. Introduction

The Sahara occupies 10% of the surface of the African continent and is the largest hot desert in the world (Rognon 1994). It extends over more than 5000 km between the Atlantic Ocean and the Red Sea (Grenot 1968). The Algerian Sahara occupies more than 85% of the national territory and is characterized by particularly hostile edapho-climatic conditions: soil poor in organic matter, very low and irregular rainfall, large differences in temperature, and long periods of drought (Ozenda 2004; Bouallala & Chehma 2014). These environmental conditions are constraining the spontaneous survival of organisms (Ozenda 2004; Chehma 2005). This immense area includes multiple landscapes, such as: hamadas (rocky plateaus), regs (flat surface covered with a thin layer of sand or gravel), ergs (sand dunes with little or no plant cover), sebkhas and chotts (salt depressions, lakes, and salt marshes), dayas (smaller depressions than sebkhas) and wadi beds (temporary watercourses) (Monod 1992; Fabre 2005; Chenchouni 2010). These geomorphological forms are favourable environments for the development of a specific flora (Bouallala 2013). The Saharan areas face the problem of sand encroachment that threatens the stability and sustainability of socio-economic and biological systems (Ichaou & Guibert 2009). The flora of sandy soils has been described as poor in terms of species richness, but well adapted to Saharan habitats, which are considered to be very fragile (Bouallala *et al*. 2020). In these ecosystems, the conservation of different taxa is a global scientific priority for the assessment and management of biodiversity (Cotterill 1995; Bouallala 2013; Médail & Quézel 2018). The objective of this study was to characterize the phytoecological groups of the sandy soils of the Sahara through the parameters of floristic

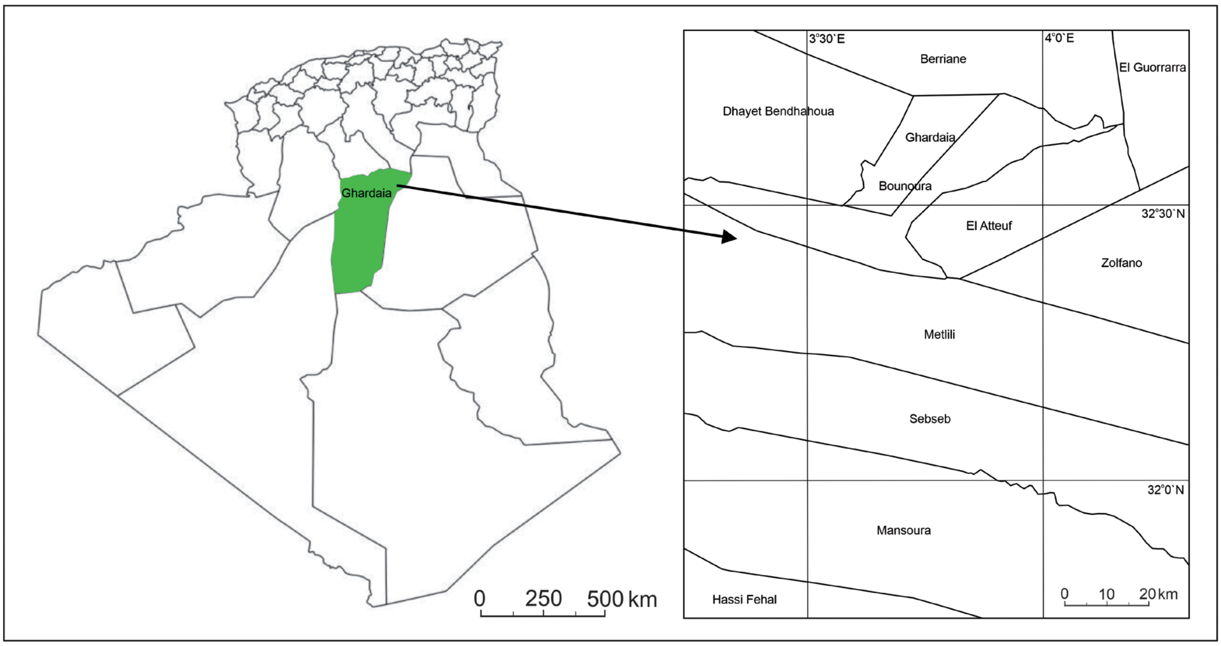

Fig. 1. Location of the study area (Ghardaïa region) and floristic surveys (R1-R20) in the northern Algerian Sahara

diversity (species richness, diversity indices), the various functional classifications (life-forms, i.e., morphological types, and dispersal types), phytogeography and abundance of plant species that develop in the sandy habitats of the wadis of northern Sahara.

2. Materials and methods

2.1. Study area

The Ghardaïa region is located in the centre of the northern Sahara (32°29'00" N, 3°41'00" E), at altitudes of up to 566 m (Fig. 1). The climate is of Saharan type, with mild winters and very hot, sunny summers. In 1990-2019, the average monthly temperature reached a maximum in July (34.8°C) and a minimum in January (11.2°C), with a cumulative precipitation of 66.3 mm (https://climatecharts.net/). According to the ombrothermic diagram of Bagnouls & Gaussen (1953), which determines the dry period on the basis of average temperature and precipitation (Fig. 2), this period lasts all the year round.

2.2. Sampling and floristic surveys

During several outings and field explorations in the wadis of the Ghardaïa region, we studied plant diversity in the sandy habitats. According to subjective sampling, 20 floristic surveys were carried out during the optimal period of vegetation development, in February–April 2022 (Table 1). The surface area of each survey was 100 m^2, because this area is considered sufficient to

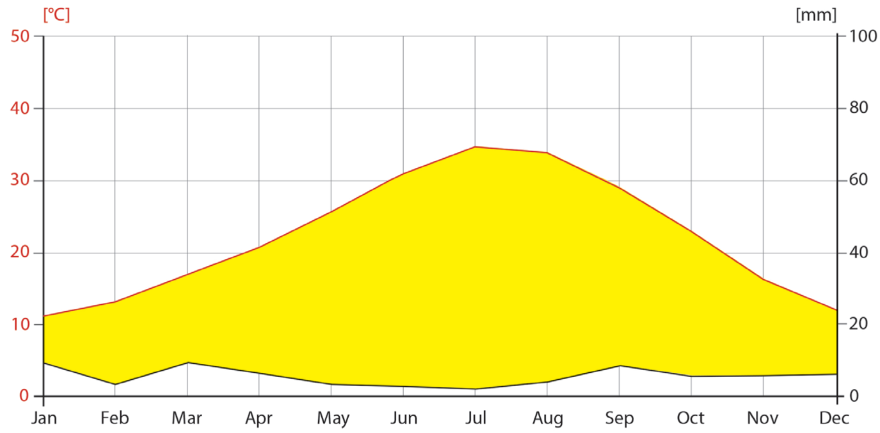

Fig. 2. Ombrothermic diagram of Bagnouls & Gaussen (1953) of the Ghardaïa region (1990-2019)

Table 1. Geographic location of floristic surveys in the Ghardaïa region (northern Sahara of Algeria)

R1: Alt. 421 m N: 32°56'03.3" E: 03°58'03.9"	**R5**: Alt. 470 m N: 32°43'50.3" E: 03°57'57.7"	**R9**: Alt. 357 m N: 32°38'57.5" E: 04°14'57.1"	**R13**: Alt. 347 m N: 32°38'17.6" E: 04°18'18.9"	**R17**: Alt. 396 m N: 32°05'03.5" E: 03°46'47.6"
R2: Alt. 467 m N: 32°50'01.8" E: 03°58'04.8"	**R6**: Alt. 355 m N: 32°39'06.0" E: 04°14'59.0"	**R10**: Alt. 356 m N: 32°38'55.3" E: 04°14'55.6"	**R14**: Alt. 348 m N: 32°38'07.2" E: 04°18'23.4"	**R18**: Alt. 401 m N: 32°05'02.0" E: 03°46'47.7"
R3: Alt. 465 m N: 32°50'01.1" E: 03°58'03.2"	**R7**: Alt. 357 m N: 32°39'06.4" E: 04°15'01.2"	**R11**: Alt. 346 m N: 32°38'50.8" E: 04°17'32.6"	**R15**: Alt. 346 m N: 32°37'55.3" E: 04°18'31.9"	**R19**: Alt. 400 m N: 32°05'00.5" E: 03°46'48.1"
R4: Alt. 464 m N: 32°50'00.8" E: 03°58'01.8"	**R8**: Alt. 357 m N: 32°38'59.0" E: 04°14'57.5"	**R12**: Alt. 345 m N: 32°38'33.1" E: 04°18'07.9"	**R16**: Alt. 386 m N: 32°05'04.8" E: 03°46'48.4"	**R20**: Alt. 400 m N: 32°05'02.3" E: 03°45'44.1"

assess plant diversity in Saharan environments, like in previous studies of Saharan flora and vegetation (Quézel 1965; Benhouhou *et al*. 2003; Chehma 2005; Bouallala & Chehma 2011; Bouallala 2013; Bouallala & Chehma 2014). In each survey, we noted the geographic coordinates (latitude, longitude) and altitude, the list of species, and the number of individuals of each species. The identification of the inventoried species was based on the book flora of Algeria and the southern desert regions (Quézel & Santa 1962-1963).

2.3. Phytoecological grouping (plant communities)

The ascending hierarchical classification (AHC) method is generally used in Algeria to analyse ecological data and identify groups of plant communities with similar characteristics (Bouallala *et al*. 2020). In this study, the AHC was applied to abundance data (number of individuals in surveys of 100 m^2 each) to distinguish phytoecological groups that are floristically homogeneous. The dendrogram resulting from the AHC takes into account the similarities between surveys of the same set, to discriminate between subsets of similar surveys (Macheroum *et al*. 2021).

2.4. Biodiversity of phytoecological groups

Species richness, Shannon index, and evenness were evaluated for each phytoecological group and for the whole Ghardaïa region. The Shannon index (H') was calculated using the formula $H'=-\Sigma\,((n_i/N) \times \log_2(n_i/N))$, where n_i is the number of individuals of a given species, and N is the total number of individuals (Shannon & Weaver 1949). The Pielou evenness (E) was calculated using the formula: $E = H'/H_{max}$, where H' represents the Shannon diversity index, $H_{max} = \log_2 S$, and S is species richness. E is used to measure the distribution of individuals within species, and varies between 0 and 1. A community is considered evenly composed when all its species have the same or very similar abundance. Thus the evenness of a community increases when it tends toward equipartition ($E > 0.5$) (Marcon 2016).

2.5. Similarity analysis of plant communities

The species richness of the phytoecological groups was compared using a Venn diagram, which is a visual organizational tool, making it possible to illustrate all the possible logical relationships between different groups (Macheroum *et al*. 2021).

2.6. Functional traits of plants

2.6.1. Plant life-forms

Raunkiaer (1934) classified plants according to the location of perennial elements (buds, seeds, etc.) during unfavourable periods, into several life-forms: chamaephytes, hemicryptophytes, cryptophytes, phanerophytes, and therophytes. Using his classification, we assessed raw plant-type spectra (based on species richness) and real plant-type spectra (based on the abundance of species of each type). The raw and real plant-type spectra served to compare on the biological level the different plant communities of the sandy wadis studied and the whole Ghardaïa region.

2.6.2. Dispersal types

Depending on seed dissemination mechanisms, plant species were divided into 5 major types: anemochores (seeds transported by wind), barochores (dispersed by weight), hydrochores (dispersed by water), autochores (more precisely: ballochores, with seeds ejected several tens of centimetres from the parent plant), and zoochores (dispersed by animals) (van der Pijl 1982). Using that classification, we assessed raw dispersal spectra (based on species richness) and real dispersal spectra (based on the abundance of species of each dispersal type). The raw and real dispersal spectra served to compare the different plant communities of the sandy wadis studied and the Ghardaïa region.

2.7. Phytogeographic spectrum

The phytogeographic types of taxa recorded in Ghardaïa region were determined according to Quézel and Santa (1962-1963), to assess raw phytogeographic spectra (based on species richness) and real phytogeographic spectra (based on the abundance of species of each phytogeographic type). They served to compare on the biogeographic level the different plant communities of the sandy wadis studied and the whole Ghardaïa region.

2.8. Assessment of abundance

The assessment of plant abundance in sandy wadis of northern Sahara was based on the work of Quézel and Santa (1962-1963) on the Algerian flora, according to the degree of rarity of plants in Algeria. Plant species were divided into the following categories: particularly common (CCC), very common (CC), common (C), fairly common (AC), fairly rare (AR), rare (R), very rare (RR) and extremely rare (RRR). The cited work specifies the status of plant abundance throughout Algeria and in the southern desert regions. Using that classification, we determined raw abundance spectra (based on species richness) and real abundance spectra (based on the abundance of species of each type). The raw and real abundance spectra served to compare in terms of abundance the different plant communities of the sandy wadis studied and Ghardaïa region.

3. Results

3.1. Taxonomic composition of the flora

The plant communities of the sandy wadis in the Ghardaïa region include 15 species grouped into 15 genera and 10 families (Table 2). The family Fabaceae accounted for 20% of the total number of species, followed by the Brassicaceae, Poaceae, and Anacardiaceae, with 13.3% each.

3.2. Diversity and structure of phytoecological groups

The ascending hierarchical classification distinguished 3 phytoecological groups: G1 includes surveys 1-2, 3, 5, 9, and 11-14, G2 includes surveys 4, 6-8, and 10, while G3 includes surveys 15-20 (Fig. 3).

Group 1 is located between 345 m and 670 m in altitude, with 10 plant species in 9 surveys (Table 3). Psammophytes are represented by only 3 species, with a total of 21 individuals (Table 4). The most abundant species in this group is *Zilla macroptera* (34 individuals), while the most poorly represented species in this group are: *Rhus tripartitum*, *Pistacia atlantica*, and *Oudneya africana* (1 individual each). The value of the Shannon index in this group is H'=1.78, and evenness E=0.77.

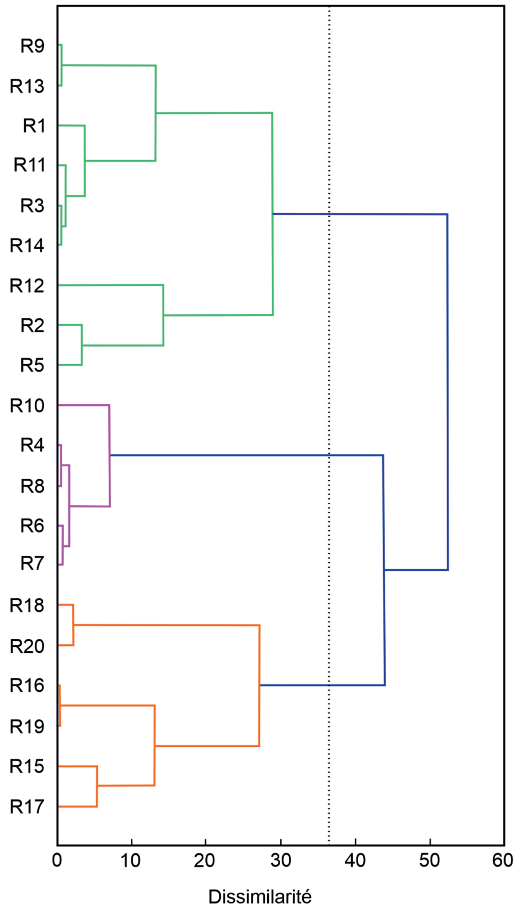

Fig. 3. Dendrogram of individual floristic surveys and the 3 phytoecological groups in sandy wadis of the northern Algerian Sahara

Group 2 is located between 355 m and 464 m in altitude, with 8 plant species in 5 surveys (Table 3). Psammophytes account for more than half of the species (5), with a total of 110 individuals (Table 4). The most abundant species in this group is *Peganum harmala* (66 individuals), while the most poorly represented spe-

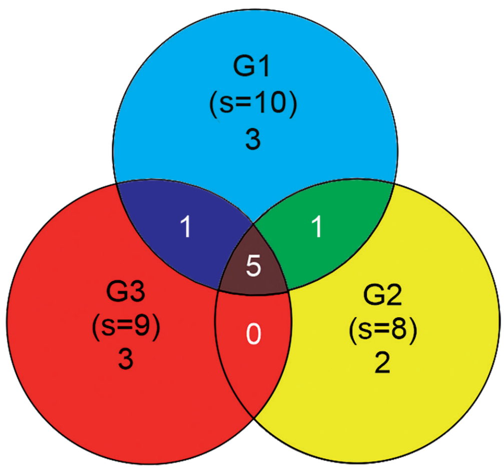

Fig. 4. Three-set Venn diagram showing the plant species richness (S) recorded in various phytoecological groups in sandy wadis of the northern Algerian Sahara

Table 2. List and characteristics of species identified in the sandy wadis of the northern Algerian Sahara

Species	Family	Life-form	Dispersal type	Phytogeographic type	Ecological type	Abundance in northern Algerian Sahara (Quézel & Santa 1962-1963)
Arthrophytum scoparium (Pomel) Iljin	Chenopodiaceae	Ch	anemo	Saharo-Mediterranean	gypsovague (Pouget 1980)	C
Astragalus gombo Bunge	Fabaceae	H	anemo	endemic to North Sahara	psammophyte (Pouget 1980)	AC
Cynodon dactylon (L.) People	Poaceae	H	baro	cosmopolitan	psammophyte (Pouget 1980)	C
Euphorbia guyoniana Drink. and Reut	Euphorbiaceae	H	baro	endemic to Sahara	psammophyte (Pouget 1980)	CC
Genista saharae Coss. & Hard	Fabaceae	Ph	zoo	endemic to Sahara	psammophyte (Pouget 1980)	AR
Nicotiana glauca Graham	Solanaceae	Ph	baro	North American	saxicolous (Tela Botanica)	AC
Oudneya africana R.Br.	Brassicaceae	Ch	baro	Endemic to Sahara	gypsophyte (Quézel 1965)	AR
Peganum harmala L.	Zygophyllaceae	H	baro	Irano-Turanian-European	eury-psammophyte (Duranton *et al*. 2012)	CC
Pergularia tomentosa L.	Asclepiadaceae	Ch	anemo	Saharo-Arabian	sandy-loamy soils, rocky or ±gravelly (Duranton *et al*. 2012)	CC
Pistacia atlantica Desf.	Anacardiaceae	Ph	zoo	endemic to North Africa	unsalted soils of medium texture, fine (Pouget 1980)	AC
Retama raetam (Forssk.) Webb	Fabaceae	Ph	zoo	Saharo-Arabian	psammophyte (Pouget 1980)	C
Rhus tripartitum (Ucria) DC.	Anacardiaceae	Ph	zoo	Saharo-Mediterranean	calciphile, heliophile (Le Houérou *et al*. 1975)	AR
Stipagrostis pungens (Desf.) de Winter	Poaceae	H	anemo	Saharo-Arabian	psammophyte (Pouget 1980)	CC
Zilla macroptera (Coss.) Maire & Weiller	Brassicaceae	Ch	zoo	Saharo-Arabian	sandy loamy soils (Duranton *et al*. 2012)	C
Zizyphus lotus (L.) Lam.	Rhamnaceae	Ph	zoo	Mediterranean	sandy loamy soils (Duranton *et al*. 2012)	C

Explanations: categories of abundance, CC – very common, C – common, AC – fairly common, AR – fairly rare; life-form, Ch – chamaephyte, H – hemicryptophyte, Ph – phanerophyte

cies are: *Astragalus gombo* and *Pergularia tomentosa*, (1 individual each). The value of the Shannon index in this group is *H*'=1.34, and evenness *E*=0.64.

Group 3 is located between 346 m and 401 m in altitude, with 9 plant species in 6 surveys (Table 3). Psammophytes account for more than half of the species (5), with a total of 47 individuals (Table 4). The most abundant species in this group is *Oudneya africana* (27 individuals), while the most poorly represented species are: *Nicotiana glauca* and *Pergularia tomentosa* (1 individual each). The value of the Shannon index in this group is *H*'=1.74, and evenness *E*=0.79.

With a total richness of 15 species, the Venn diagram showed that 5 plant species are omnipresent, i.e. present in all phytoecological groups (Fig. 4), whereas additional single species are shared by G1 and G2 and by groups G1 and G3. Besides, 3 plant species are present exclusively in group 1, another 3 in group 3, and 2 in group 2.

3.3. Plant-form spectrum

Overall, the raw plant-form spectrum shows a good representation of phanerophytes (40.0% of species),

Table 3. Phytoecological groups of vegetation in sandy wadis of the northern Algerian Sahara

	Group 1									Group 2					Group 3					
	R1	R2	R3	R5	R9	R11	R12	R13	R14	R4	R6	R7	R8	R10	R15	R16	R17	R18	R19	R20
Total no. of individuals	5	15	10	8	5	22	2	3	14	29	57	13	13	16	24	24	15	5	9	7
Arthrophytum scoparium	1	5	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Astragalus gombo	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Cynodon dactylon	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.
Euphorbia guyoniana	.	.	.	.	.	2	.	.	1	8	19	5	3	.	11	5	7	.	3	.
Genista saharae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	3
Nicotiana glauca	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Oudneya africana	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	15	3	1	6	1
Peganum harmala	1	1	2	.	.	4	.	.	3	19	26	6	8	7	4	.	.	.	.	.
Pergularia tomentosa	.	.	.	.	.	3	.	.	.	.	.	.	.	1	.	1	.	.	.	.
Pistacia atlantica	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Retama raetam	1	1	.	.	2	1	.	1	1	.	1	1	2	1	.	2	2	1	.	3
Rhus tripartitum	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Stipagrostis pungens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	1	.	.
Zilla macroptera	2	4	6	.	2	12	.	1	7	.	8	.	.	3	7	1	.	.	.	.
Ziziphus lotus	.	4	1	2	1	.	1	1	1	2	.	.	.	4	.	.	.	.	.	.

followed by hemicryptophytes (33.3%) and chamaephytes (26.7%). The real plant-type spectrum reveals the dominance of hemicryptophytes (51.7% of individuals), followed by chamaephytes (33.1%) and phanerophytes (15.2%). At the level of phytoecological groups, the raw spectrum shows that in group 1, chamaephytes and pha-

Table 4. Species richness and number of individuals of psammophytes in phytoecological groups (G1-G3) of plant communities in sandy wadis of the northern Algerian Sahara

	G1	G2	G3
Number of floristic surveys	9	5	6
Species richness	10	8	9
Richness of psammophytes	3	5	5
Total no. of individuals	84	128	84
No. of psammophytes	21	110	47

nerophytes have 40% each. In group 3, all plant types have the same values. In group 2, the highest percentage is recorded in hemicryptophytes (50%). As for the real spectrum, chamaephytes dominate group 1 (59.5%) and hemicryptophytes dominate group 2 (82%). In group 3, the contribution of chamaephytes (42.8%) is a little higher than that of hemicryptophytes (40.4%), and the percentage of phanerophytes is low (16.6%) (Fig. 5).

3.4. Dispersal spectrum

Overall, in the raw dispersal spectrum, zoochores have a high rate (40%), compared to other types. In the real dispersal spectrum, barochores reach the highest rate (60%). However, at the level of phytoecological groups and concerning the raw spectrum, zoochores (50%) occupy an important place, as compared to the other types, only in group 1. As for the real spectrum, anemochores (38.1%) prevail in group 3, barochores (81.2%) dominate in group 2, and zoochores (64.2%) dominate in group 1 (Fig. 5).

3.5. Phytogeographic spectrum

Overall, the analysis of the raw phytogeographic spectrum of the flora of the sandy soils in the northern Sahara shows a high contribution of the Saharo-Arabian element (26.6%), as compared to other biogeographic types. Concerning the real spectrum, the Saharan endemic element reached the highest rate (32.7%). At the level of the phytoecological groups and concerning the raw spectrum, the Saharo-Arabian element is the most

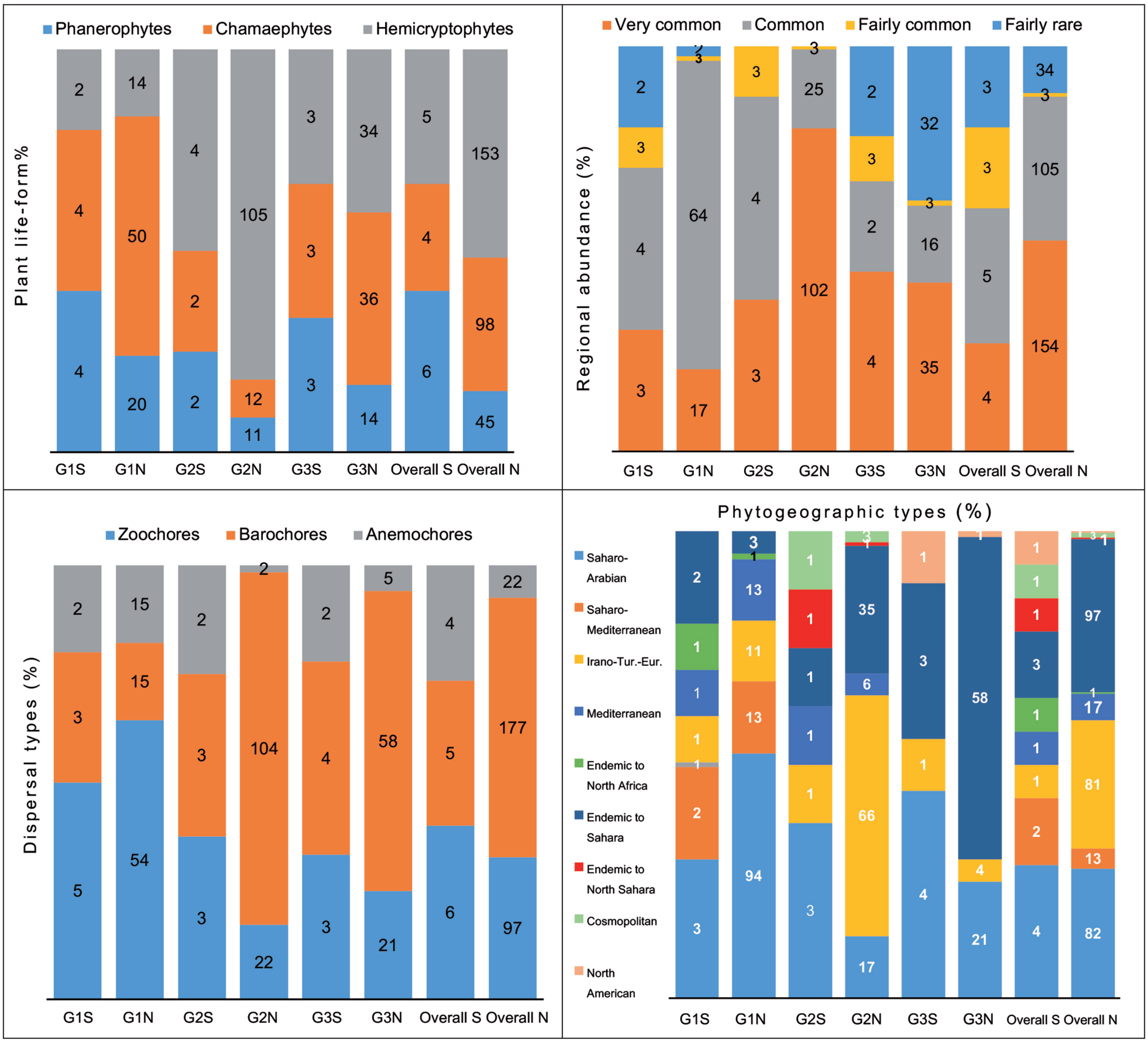

Fig. 5. Raw (based on specific richness, *S*) and real (based on the number of individuals, *N*) spectra of plant life-forms, dispersal types, chorological types, and abundance, characterizing phytoecological groups in sandy wadis of the northern Algerian Sahara

represented in all groups. In the real phytogeographic spectrum, the Saharo-Arabian element (52.3%) dominates in group 1, the Mediterranean element (56.2%) dominates in group 2, and the Saharan endemic element (69%) dominates in group 3 (Fig. 5).

3.6. Assessment of species abundance

The plant species of the sandy biotopes of the northern Algerian Sahara belong to 4 categories of abundance: very common (CC), common (C), fairly common (AC); and fairly rare (AR). The total number of individuals was 296. Overall, in terms of the raw dispersal spectrum, common species represent a high percentage (33.3%), as compared to the other types. However, very common species (52%) dominate the real spectrum (Fig. 5). Considering the phytoecological groups at the level of the raw spectrum, common species reached 40% and 50% in groups 1 and 2, respectively (Fig. 5). In group 3, very common species accounted for 44.4% of total richness. As for the real spectrum, very common species dominate in groups 2 and 3, with 79.6% and 41.6%, respectively. Common species (76.1%) dominate in group 1 (Fig. 5).

4. Discussion

In general, in the sandy wadis of the Ghardaïa region, the Fabaceae, Poaceae, Brassicaceae, and Anacardiaceae are the most represented families, thanks to their development strategies and adaptation to Saharan ecological conditions (Chehma 2005; Bouallala 2013; Gamoun *et al*. 2018). The variation in family contributions and floristic composition between plant communities depends to a large extent on the lithological substrate (Djebaïli 1984). In our study, psammophytes were represented by 7 species (46.6%) in the Ghardaïa region. Depending on the phytoecological groups studied, their importance varied according to the degree of sand encroachment.

Sand encroachment promotes the spread of psammophyte species because of their biological and morphological adaptation to the sandy environment (Benaradj *et al.* 2013). The plants have a well-developed root system, so the presence and sometimes high abundance of psammophytes in the sandy wadis studied plays an important ecological role in the stabilization of degraded sandy soils and the fixation of sand dunes by trapping aeolian sediments (Floret & Pontanier 1973; Rustamov 1994; Chenchouni *et al*. 2019, 2022; Bouallala *et al*. 2022).

Biological characterization of the communities studied, according to real plant-form spectra, shows a predominance of hemicryptophytes in the Ghardaïa region. This is explained by the good adaptation strategy of this plant form to sandy environments (Azizi *et al*. 2021). According to Barbéro and Quézel (1989), the abundance of hemicryptophytes in Maghreb is related to site-specific soil conditions, in particular soil moisture and organic matter levels.

The abundance of chamaephytes in the plant communities of the wadis studied is well explained in the phytoecological studies of dryland researchers. The presence of these plants throughout the year is ensured by their physiological abilities and their specific anatomical and morphological adaptations (Floret & Pontanier 1982; Monod 1992; Aidoud 2005; Azizi *et al*. 2021). Phanerophytes, which are rare in the Sahara and other hot deserts (Bouallala 2013; Gamoun *et al*. 2018), show a notable presence in the different groups of plants in the sandy wadi beds of the Ghardaïa region. This confirms that wadis are the most favourable habitats for the development of trees and shrubs in arid zones (Bradai *et al*. 2015; Bouallala *et al*. 2020).

The dispersal mode that dominates in the Ghardaïa region is the barochore, but at the level of the groups there is a variation between the dominance of the 3 major dispersal modes (anemochore, barochore, and zoochore). The anemochorous species find in the Saharan environment the adequate factor for their dispersal (Bradai *et al*. 2015). In addition, however, many of the recorded plant species need animals for the dispersal of their seeds (zoochores) away from the parent plant (Howe & Smallwood 1982; Willson 1992).

The phytogeographic characterization of plant communities of the sandy wadis of the northern Algerian Sahara shows a good representation of the endemic Saharan element, which finds optimal edapho-climatic conditions for its development in the Ghardaïa region. The Saharo-Arabian element, well adapted to the Saharan climate (Ozenda 2004; Bouallala 2013; Salama *et al*. 2014), finds optimal conditions especially in group 1.

With regard to the abundance of plants in all the sandy wadis studied, very common and common species prevail and reflect their adaptation to the Saharan environment (Quézel & Santa 1962-1963). The fairly rare plants develop well in group 3, where they rank second after very common plants, due to the specificity of the conditions of the silted wadis of this group. According to Quézel and Medail (2003), the specificity of habitats, the taxonomic originality, and the temporal persistence of species constitute useful criteria in the definition of rarity.

5. Conclusions

This work shows that the sandy wadis of the northern Algerian Sahara constitute favourable biotopes for the establishment and development of a particular diversity of plants and plant communities. The presence of sand determines a specific landscape and has caused the enrichment of the biodiversity of the wadis by perennial psammophytes belonging to various life-forms and dispersal types. These psammophytes of varied geographic origin include some endemic plants, well adapted to the edapho-climatic conditions of the Saharan zones. These plants, which deserve special attention in terms of valorization and conservation, constitute a phytogenetic resource for the rehabilitation of sandy ecosystems in drylands.

Author Contributions:
Research concept and design: M. Widad
Collection and/or assembly of data: M. Widad
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