Wild plants diversity in two Wadi beds in the Ouargla region (Northern Sahara of Algeria)

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Abstract

In the Sahara, rangelands, offer favorable conditions for vegetation survival. The present study focused on estimating the diversity and determining the functional traits of spontaneous plants established in two Wadi beds, the Wadi N'Sa bed and the Wadi Mya bed, in the Ouargla region (northern east of the Algerian Sahara). For each Wadi bed, 23 phytosociological surveys were selected to study the diversity parameters, plant functional traits, and soil analyses to study the vegetation–soil relationships.

The inventoried plants included 56 species, divided into 49 species from 24 families on the Wadi N'Sa bed and 15 from 10 families on Wadi Mya bed. The plant species are mainly therophytes (45%) in the Wadi N'Sa bed and chamephytes (60%) in the Wadi Mya bed. Phytogeographical analysis revealed the dominance of the Saharo Arabian element, which was 36.7% of the Wadi N'Sa bed and 53.33% of the Wadi Mya bed.

Our study revealed that the Wadi N'Sa bed exhibited greater alpha diversity than the Wadi Mya bed, with ANOVA confirming significant differences between the two Wadi beds. As shown in the Principal Coordinate Analysis (PCoA) plots, the beta diversity further highlighted the distinctiveness between the two riverbeds and their respective sites.

The soil analysis of two Wadi beds allowed us to determine the relationship between vegetation and soil. psammophilous, halophilous, and gypsophilous species were predominated.

Soil characteristics influence floristic composition diversity in sites of two Wadi beds and even between the two environments, and the distribution of plants according to the soil-vegetation relationship.

Keywords: Diversity, Wild plants, Wadi bed, Soil, Sahara Desert, Ouargla.

1. *Introduction*

Deserts are defined by their arid conditions (WARD 2016), where these arid areas occupy 75 million km^2 or approximately 30% of the world's land surface (ABD EL-GHANI et al., 2017). The Sahara Desert is considered the largest of the hot deserts, and the foremost, most aggressive, and most common aridity is characterized by edaphic-climatic conditions exceptionally limiting the spontaneous survival of living beings. Despite the harshest desert conditions determined by high heat and low downfall, this environment includes different Saharan camel rangelands and living surroundings for a specific and tailored vegetation cowl (CHEHMA et al., 2005).

The Ouargla region is located in the Northern Sahara, Southeast of Algeria, in the basin of the Wadi Mya Valley, at an altitude of 128 m. This region has one of the harshest climates in the North Eastern Sahara. Despite the relatively northern latitude, the climate is very contrasting (ROUVILLOIS-BRIGOL 1975). It is characterized by a dry period that lasts throughout the year, a hyperarid climate of xeric character, and is located in the Saharan bioclimatic stage with mild winters (MEDJBER et al., 2013).

The hydrographic system of the Ouargla region is essentially constituted of three major hydrological elements: Wadi Mya, Wadi N’Sa, and Wadi M’Zab (ROUVILLOIS-BRIGOL 1975). The Wadi Mya bed is the Quaternary bed of the low fossil valley that descends from the Tademaït Plateau, located 700 km to the south and ends at Sebkhet-Sefioune 40 km north of Ouargla (DUBIEF 1963). The Wadi N'Sa bed is one of the eastern watersheds of the Mozabite Ridge that constitutes the large Melrhir basin in the northern Sahara (OULD BABASY 2005).

CHEHMA (2005) stated that the geomorphological formations of Wadi bed types are the richest and most diverse of the species compared to the six types of Saharan routes. In this context of floristic richness, we have chosen two Wadi beds from the Ouargla region, namely, the Wadi N'Sa and the Wadi Mya.

According to CHEHMA (2005), Wadi bed geomorphological formations are the wealthiest and most diversified in terms of species compared to the six types of Saharan rangelands. In this context, to study how floristic richness and variation diversity control soil factors, we selected two Wadi beds from the Ouargla region: Wadi N'Sa and Wadi Mya.

The research hypothesis: the diversity and distribution of wild plants in the two biotopes is based essentially on the soil and its characteristics.

2. Materials and methods

2.1. Study area

This study was conducted on two Wadi beds in the Ouargla region (Wadi N'Sa and Wadi Mya). Four sites from each bed were selected to explore their floristic and pedological characteristics (Map 1, Figure. 1).

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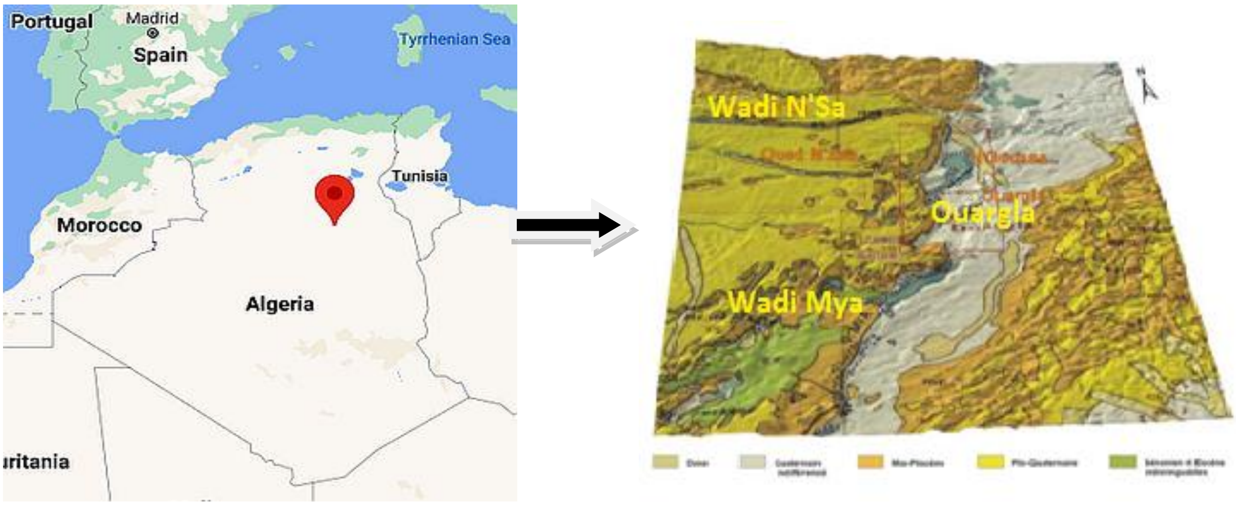

Figure 1. Map of Ouargla region localization.

The climate is BWh (B: arid climate, W: desertic with precipitation<250 mm, h: dry and hot with average annual temperature> 18°C) according to the Koppen and Geiger classification (www.climat-data.fr), which includes a high and extensive temperature range, severe and prolonged drought episodes, large inter- and intra-annual variability in rainfall, very intense evapotranspiration, and extreme weather events such as heat waves and extreme wind events. According to the ombrothermic diagram of Bagnouls and Gaussen, the drought period extended more than 12 months a year (Figure. 2). The minimum temperature in January did not drop below 3.2-4.4°C. However, July was the hottest month, with the average maximum temperature exceeding 44°C. The monthly sunshine frequency was greater than 70%. Rainfall was deficient (39 mm/year), with 17 days of effective rainy days, and the potential evapotranspiration very significantly exceeded the precipitation all year round. The climate data analysis provided by www.climat-data.fr over 30 years (1991–2021) indicates that precipitation is rare and has a marked intermittent irregularity.

The mean temperature and precipitation are averages of long-term monthly climatic data.

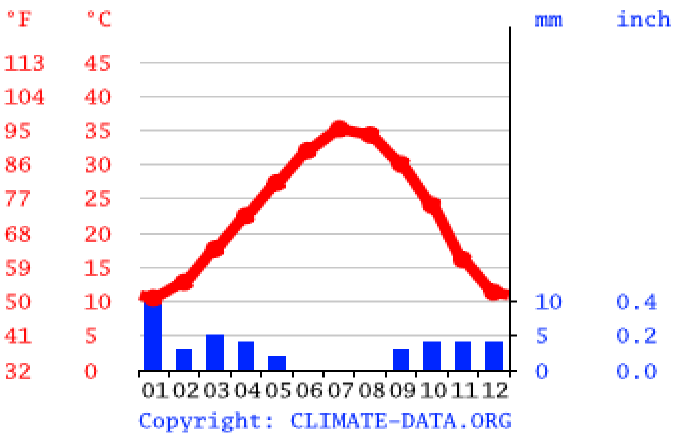

Figure 2. Ombrothermic diagram of Bagnouls and Gaussen of Ouargla (1991-2021)

2.2. Biodiversity and pedo floristic study

2.2.1. Vegetation sample

Thirty-two sample stands were selected along the two studied Wadi from December 2017 to November 2018. Stands measuring 20x20 m were selected to represent a wide range of physiographic and environmental variations at each site. The sampling process was carried out during all seasons, especially spring and autumn, when most species were expected to grow (CHEHMA 2005). The vegetation sampling involved listing all the plant species in the sample stands. The plant cover of each species was estimated as an abundance (MEDDOUR 2011). The plant specimens collected were identified according to OZENDA (2004) and CHEHMA (2006). Species life forms were determined according to (RAUNKIAER 1934).

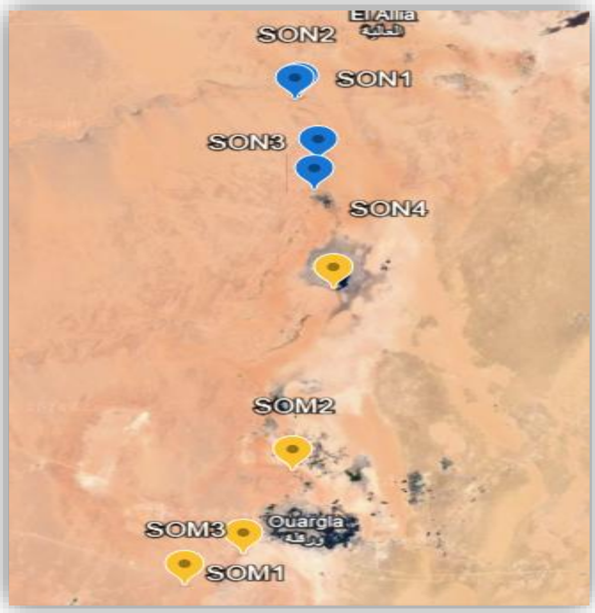

Figure 3. Sampling site locations in the study area (by Google Earth)

2.2.2. Floristic composition and diversity

The floral composition was determined: the list of sampled plant species (floristic richness), the frequency, the coefficient of abundance dominance, the Simpson index, and the coefficient of floristic similarity of Jaccard (IJ).

The identification of the phytogeographical types was based on QUEZEL (1965). The establishment of the gross phytogeographical spectrum was based on counting the species by phytogeographical type, which was carried out based on the totality of the inventoried species. The taxonomic names were updated according to the Tela Botanica site (2022).

The diversity of the plant species was estimated using the following nonparametric biodiversity indices (Magurran, 2004): specific richness (S), Shannon diversity index (H'), Shannon index (H), and Piélou's equitability index (E). The specific richness (S) is the total number of species in the study area. Based on the specific abundances (number of individuals, ni), the Shannon diversity index (H) was calculated using the formula $H = -\Sigma(pi \times \log2pi)$, where $pi = ni/N$ represents the relative specific frequency of species i, ni is the population size of species i and N is the total abundance of S species composing the studied community. The evenness index ''E" was computed as the ratio between the Shannon diversity index and the theoretical maximum diversity, 'Hmax = log2S'. Evenness values vary between 0 and 1, with maximum evenness recorded (i.e., _1) when all plant species have similar densities. The assessment of evenness is useful for detecting the structure of a community, as it helps effectively detect anthropogenic changes (NEFFAR et al. 2013, 2016).

Beta diversity measures the gradient of change in diversity between different habitats, sites, or communities and is represented by Jaccard's index and the Bray–Curtis dissimilarity index.

2.2.3. Soil analysis

Soil samples were collected from 0-30 cm depths at three random stands at each site in each Wadi. The organic matter content was determined by the ANNE method. The soil texture was determined via the hydrometer method. Soil water extracts were prepared (1:5) for measuring the pH, electrical conductivity (EC) (as mS cm1), and soil nutrient elements (e.g., cations (Ca, K, and Na)) by spectrophotometry and by titration (Mg), anions (CO_3 and HCO_3) using 0.01 N HCl, Cl by precipitation as AgCl, and $CaCO_3$. $CaSO_4$ was estimated by calcination (BAIZE 1995 and AUBERT 1978).

2.3. Statistical analysis

R software was used to examine the biodiversity of the two Wadi beds (alpha diversity and beta diversity). These nonparametric biodiversity indices were used to estimate plant alpha diversity.

According to the counts at each site determined by Bray and Curtis, the index of dissimilarity, the Bray–Curtis dissimilarity, which was named after J. Roger Bray and John T. Curtis, is a statistic used to assess the compositional dissimilarity between two separate sites. A box plot of the Shannon index was constructed for two Wadi beds.

3. Results

3.1. Floristic composition

Fifty-six wild species from the study area were recorded, belonging to 48 genera in 24 families. The strains were divided into 49 species belonging to 24 families on the Wadi N'Sa bed and 15 species belonging to 10 families on the Wadi Mya bed (Table 1, Figure. 4).

The number of species and their families at all sites varied between 31 species belonging to 18 families (site 1) and 26 species belonging to 17 families (site 2) (Figure. 3) on the Wadi Nsa bed. However, in the Wadi Mya bed, Amaranthaceae (33%) and Tamaricaceae (13%) were the most common families. The remaining families were represented by only one species (Figure. 4). In addition, the Brassicaceae (14% species, 05 genera) and Asteraceae (14% species, 05 genera) families were the most common families in the Wadi N'Sa bed. Moreover, 16 families were represented by only one taxon (Figure. 4).

The dominance of Brassicaceae, Asteraceae, and Fabaceae was inconsistent with the findings reported by OZENDA (2004) and BOUALLALA et al. 2020, who studied flora and vegetation in the Adrar region. The dominance of these families may be due to their wide ecological range of tolerance to abiotic stress.

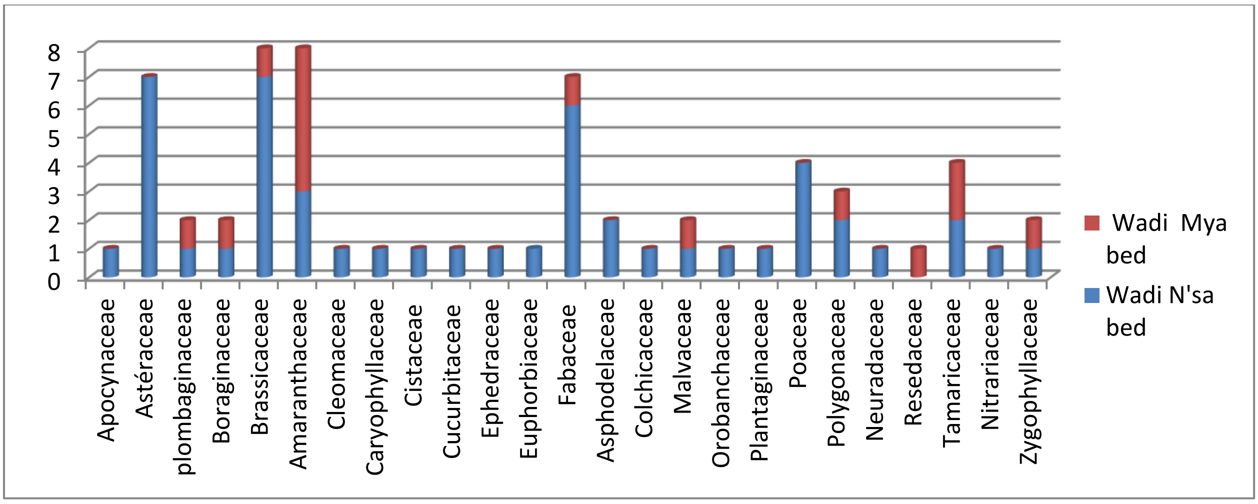

Figure 4. Families of species inventoried in the two Wadi beds

Life forms: Cham: Chamaephyte, Thero: Therophyte, Crypt: Cryptphyte, Hemi: Hemicryotophyte, Geo: Geophyte, Phan : Phanerophyte. Chorotype abbreviations: Endem: Endemic, Sah-Ara: Saharo-Arabian, Sah-Med: Cosmo: Cosmopolitan, Ende-North-African: North African Endemic, Med: Mediterranean.

Table 1. List and describe the characteristics of inventoried species and their families.

Inventoried Families	Inventoried Species	Wadi N'Sa bed	Wadi Mya bed	Abundance dominance Coefficient in Wadi N'Sa bed	Abundance dominance Coefficient in Wadi Mya bed	Morphological types	Life forms	Phytogeographical types
Amaranthaceae	*Anabasis articulata (Forssk.) Moq.*	+	-	3	/	Perennial	Cham	Endem- Sah-Ara
	Bassia muricata (L.) Asch.	+	-	+	/	Ephemeral	Thero	Sah-Ara
	Caroxylon tetrandrum (Forssk.) A. & R.	-	+	/	2	Perennial	Cham	Sah-Med
	Halocnemum strobilaceum (Pall.) M.	-	+	/	1	Perennial	Cham	Cosmo
		+	-	1	/	Perennial	Cham	Medit

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	B. *Salsola longifolia Forssk.* *Caroxylon imbricatum (Forssk.) A. & R.* *Traganum nudatum Del.* *Cornulaca monacantha Del.*	- - -	+ + +	/ / /	1 1 1	Ephemeral Perennial Perennial	Cham Cham Cham	Sah-Ara Sah-Ara Sah-Ara
Apocynaceae	*Pergularia tomentosa L.*	+	-	1	/	Perennial	Cham	Sah-Ara
Asphodelaceae	*Asphodelus tenuifoliusCav.* *Asphodelus refractusBoiss.*	+ +	- -	1 +	/ /	Ephemeral Ephemeral	Thero Thero	Med Sah-Med
Astéraceae	*Pulicaria Undulata L.* *Picris asplenioides L* *Launaea Capitata (Spreng.) Dandy* *Launaea Fragilis (Asso) Pau* *Launaea Arborescens (Batt.) M.* *Rhanterium adpressus Coss. & Dur.* *Scorzoneroides muelleri (Sch.Bip.)*	+ + + + + + +	- - - - - - -	1 1 1 1 1 1 1	/ / / / / / /	Perennial Ephemeral Ephemeral Ephemeral Perennial Perennial Ephemeral	Crypt Thero Hemi Hemi Cham Cham Hemi	Sah-Ara Medit-sah Sah-Ara Medit-Sah- Ara Medit-sah Ende-North-African. Medit
Boraginaceae	*Ogastemma pusillum Cross. et Dur.* *Miltoniopsis Ciliata (Forssk.) I.M.*	+ -	- +	1 /	/ +	Ephemeral Perennial	Thero Cham	Ende-Nord Sah Sah-Ara
Brassicaceae	*Eruca Vesicaria (L.) Cav.* *Oudney Africana R. BR.* *Savignya parviflora subsp. longistyla (Boiss. &Reut.) M.* *Diplotaxis Pitardiana M.* *Eremobium aegyptiacum subsp. longisiliquum (Coss.) M.* *Eremobium aegyptiacum subsp. aegyptiaca (Spreng.)* *Zilla spinosa subsp. macroptera (Coss.) M. & W.*	+ + + + + + +	- - - - - + -	+ 1 + 1 1 1 2	/ / / / / + /	Ephemeral Perennial Ephemeral Ephemeral Perennial Ephemeral Perennial	Thero Cham Thero Thero Thero Hemi Cham	Medit Endem Endem Endem Sah-Ara Sah-Ara Endem
Caryophyllaceae	*Polycarpaea repens (Forssk.) Asch. et Schw.*	+	-	1	/	Ephemeral	Thero	Sah-Ara
Cistaceae	*Helianthemum lippii (L.) Dum.Cours.*	+	-	+	/	Ephemeral	Thero	Sah-Ara
Cleomaceae	*Cleome arabica L.*	+	-	2	/	Ephemeral	Thero	Sah-Ara

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Colchicaceae	*Colchicum gramineum (Cav.) J.C.*	+	-	+	/	Ephemeral	Geo	Sah-Med
Cucurbitaceae	*Citrullus colocynthis (L) Schrad.*	+	-	2	/	Perennial	Crypto	Medit- Sah-Ara
Ephedraceae	*Ephedra alata DC.*	+	-	3	/	Perennial	Phan	Sah-Ara
Euphorbiaceae	*Euphorbia guyoniana Boiss. et Reut.*	+	-	1	/	Perennial	Hémi	End-Sah
Fabaceae	*Astragalus gombo Coss. et Dur.* *Astragalus arpilopus subsp. hauarensis (Boiss.)* *Astragalus vogelii (Webb) Bornm.* *Calobota saharae (Coss. & Dur.)* *Trigonella anguina Del.* *Retama raetam (Forssk.) Webb*	+ + + + + +	- - - - - +	+ + + 1 + 1	/ / / / / 2	Ephemeral Ephemeral Ephemeral Perennial Ephemeral Perennial	Hemi Thero Thero Phan Thero Phan	Ende Sah-Ara Ende-Sah Ende Sah-Ara Sah-Ara
Malvaceae	*Malva aegyptica L.*	+	+	+	+	Ephemeral	Thero	Medit- Sah-Ara
Nitrariaceae	*Peganum harmala L.*	+	-	1	/	Perennial	Hemi	Cosmo
Neuradaceae	*Neurada procumbens L.*	+	-	+	/	Ephemeral	Thero	Sah-Ara
Orobanchaceae	*Cistanche Tinctoria (Desf).Beck.*	+	-	+	/	Ephemeral	Thero	Sah-Med
Plantaginaceae	*Plantago ciliata Def.*	+	-	+	/	Ephemeral	Thero	Sah-Ara
Plombaginaceae	*Limoniastrum Guyonianum Dur.*	+	+	2	3	Perennial	Cham	Ende-North-African
Poaceae	*Stipagrostis plumosa L.* *Stipagrostis ciliata Def.* *Cynodon Dactylon (L) Pers.* *Stipagrostis obtusa Del.*	+ + + +	- - - -	+ + 1 +	/ / / /	Perennial Perennial Perennial Ephemeral	Hemi Hemi Hemi Thero	Sah Sah-Ara Thermo-cosmo Ende-Sah
Polygonaceae	*Calligonum comosum L'Her.* *Emex Spinosa (L.) Camp.*	+ -	+ -	2 1	+ /	Perennial Ephemeral	Phan Hemi	Sah-Ara Medit
Resedaceae	*Randonia africana (Coss.)*	-	+	/	2	Perennial	Cham	Sah
Tamaricaceae	*Tamarix aphylla (L.)* *Tamarix gallica L.*	+ +	+ +	4 +	2 1	Perennial Perennial	Phan Phan	Sah-Ara Medit- Sah-Ara
Zygophyllaceae	*Tetraena alba (L.f.)*	+	+	2	3	Perennial	Cham	Sah-Med
Total families = 25		24	10					
Total species =56		49	15					
Total common species =08								

3.2. Plant functional traits

3.2.1. Life forms (biological spectrum)

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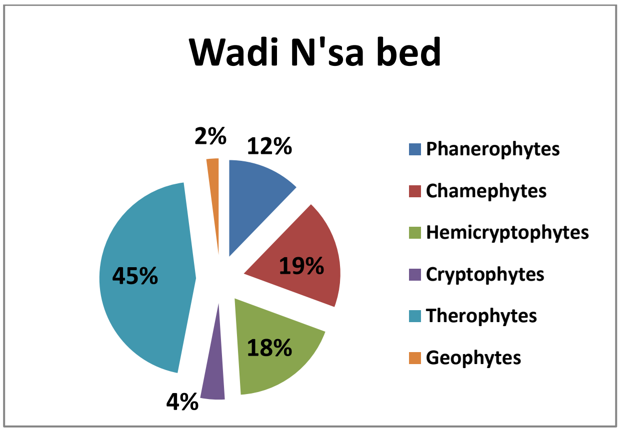
The spectrum of life forms showed high scores for therophytes (45%), followed by chamaephytes (18%) and hemicryptophytes (19%) in the Wadi N'Sa bed. However, in the Wadi Mya bed, chamephytes (perennials) predominated at 60%, followed by phanerophytes (27%) (Figure. 5).



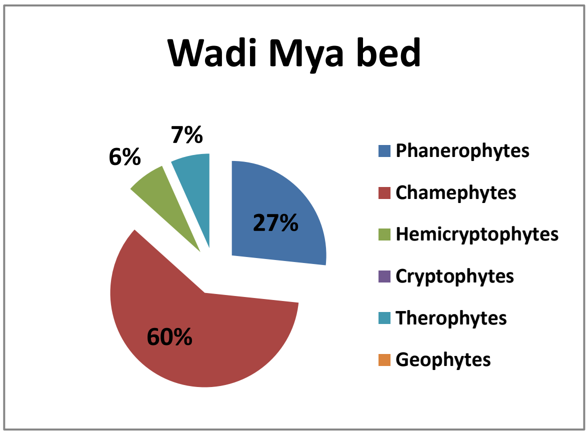


Figure 5. Biological spectrum of two Wadi beds.

3.2.2. Morphological types

The spectrum showed the dominance of annual (ephemeral) plants (53%) in the Wadi N'Sa bed (53%), while perennial species (permanent) were represented by 47%.

However, in the Wadi Mya bed, perennial plants were dominant (94%), whereas annual species represented only 6% of the total (Figure. 6).

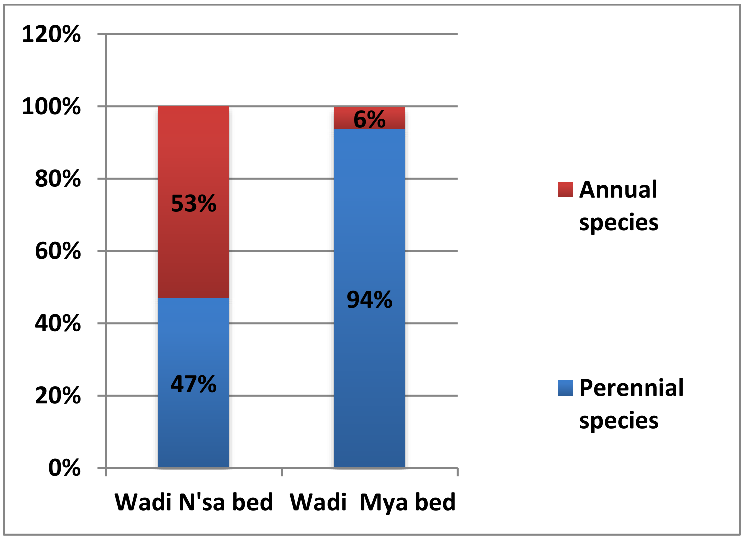


Figure 6. Morphological types in two Wadi beds.

3.2.3. Phytogeographical types

QUEZEL (1978) has classified the study area as part of the Holarctic Empire, Mesogean sub empire, Saharan region, Saharan-Arabic subregion, and Northern Sahara domain. Within this domain, several phytogeographic elements of different origins exist and are adapted to the conditions of the Saharan environment. The determination of phytogeographic elements in this study was based on the work of QUEZEL (1965).

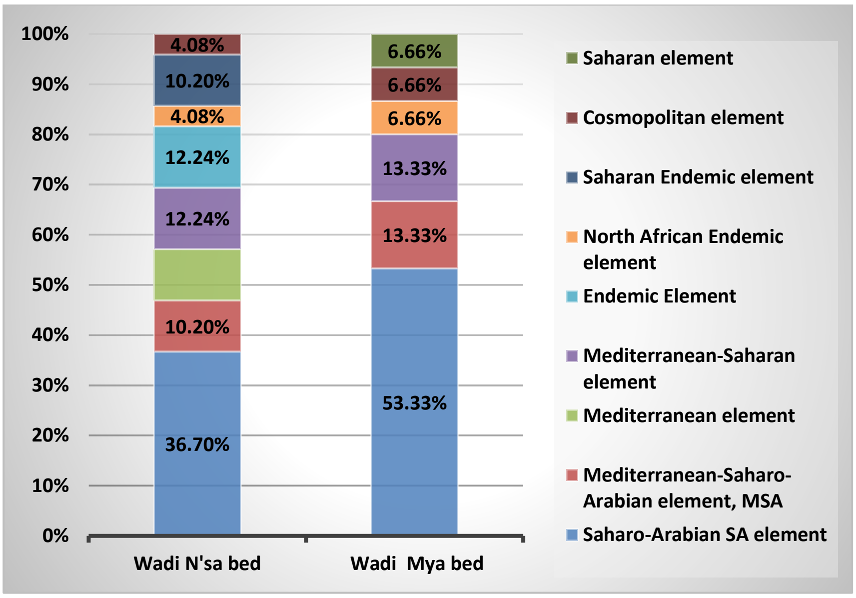


Figure 7. Phytogeographical types in two Wadi beds.

The phytogeographical spectrum of the recorded plant species is shown in (Figure. 7). The spectrum revealed that high levels of Saharo-Arabian species constituted 20 species in both Wadi beds (36.7% in the Wadi N'Sa bed and 53.33% in the Wadi Mya bed). However, the Mediterranean element (32.65%) and cosmopolitan species (04.08%) represented the Wadi N'Sa bed. Endemism (26.5%) was represented by the Wadi N'Sa bed, where the endemic element was represented by 12.24%, the Saharan endemic element was represented by 10.20%, and the North African endemic element was represented by 4.08%. However, the Wadi Mya bed represents North African endemic, Saharan, and cosmopolitan elements (6.66%).

3.3. Diversity study

3.3.1. Alpha diversity

Specifically, the richness was more significant on the Wadi N'Sa bed than on the Wadi Mya bed, and a difference was noted between the Wadi N'Sa bed sites, where site 4 was the least diversified (fewer than 20 species). All the sites on the Wadi Mya bed had less than ten species diversity. (Figure. 8)

The Shannon diversity index (H') is considered high at the sites of the Wadi N'sa bed where it is in the interval (1.5< H' <3); this index expresses the importance of the specific diversity in this Wadi bed. However, a less specific diversity was detected in the Wadi Mya bed, for which the index value was 1< H' <1.5. (Figure. 8)

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The box plot (Figure. 9) of the Shannon index (H') expresses the difference in specific diversity between the studied Wadi bed sites; it shows a marked difference between sites 2, 3, and 4 and a similarity between sites 1 and 3 at the Wadi N'sa bed. At the Wadi Mya bed, the difference between site 1 and the 3 other sites was detected, as was the similarity between sites 2, 3 and 4.

The difference between the two Wadi beds is significant.

The values of this index (E) at the Wed Mya site are between 0.58 and 0.85 (Figure. 8), whereas sites 1, 3, and 4 have values of approximately 0.8, except for site 2, where the value of the index (E) is close to 0.6; therefore, the distribution is less equitable, and the population is less balanced than those at the other sites. (Figure. 8)

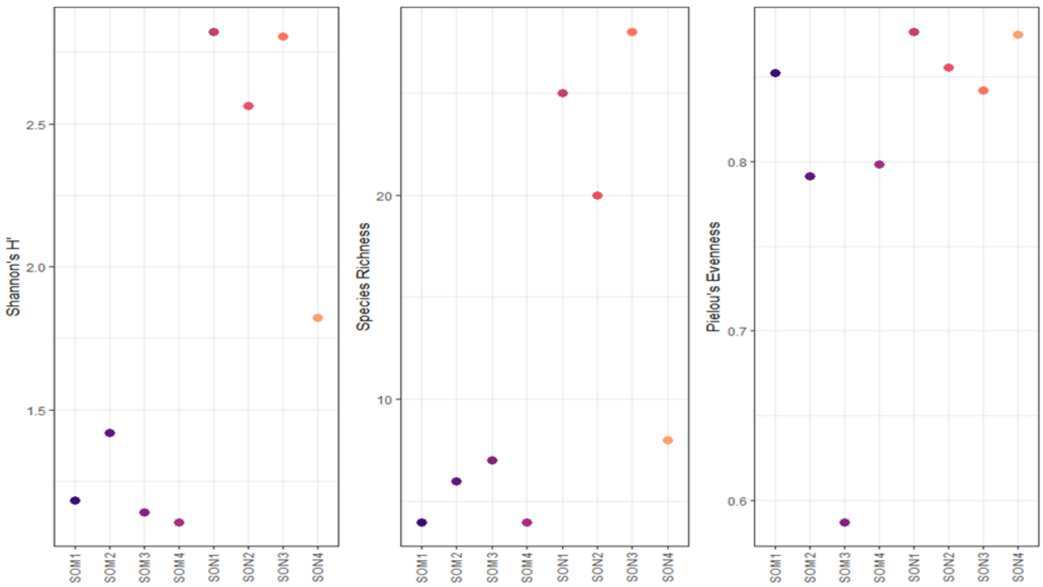

Figure 8. Alpha diversity indices of two Wadi beds.

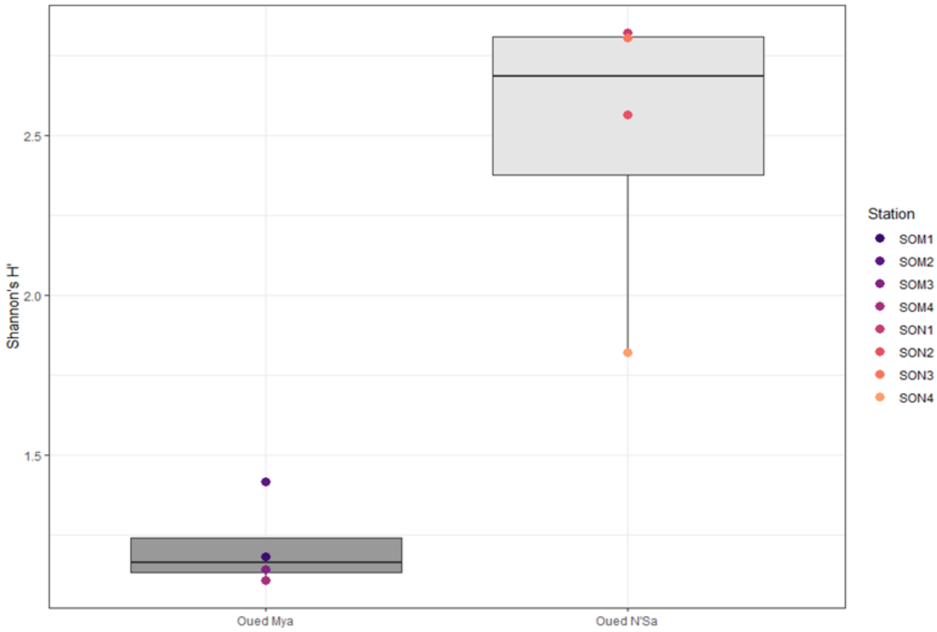

Figure 9. Box plot of the Shannon indices for two Wadi beds.

3.3.2. Beta diversity

Beta diversity was calculated using the Jaccard index and the dissimilarity index of Bray–Curtis. Both indices have values close to 0 for sites 1, 2, and 3 of the Wadi N'Sa bed; thus, the compositions and habitats of these sites are similar to those of site 4. (Figure. 10)

Sites 1 and 4 of the Wadi Mya bed had similar values compared to sites 2 and 3; thus, stations 2 and 3 were similar, and the degree of dissimilarity increased for sites 1, 2, and 4 (Figure. 10).

The distances between the Jaccard and Bray–Curtis beds show the dissimilarity between the two Wadi beds.

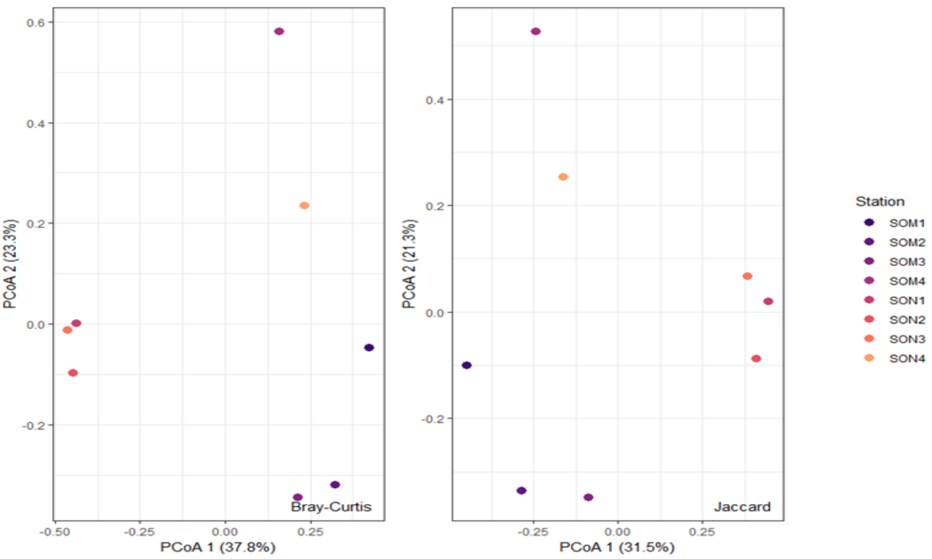

Figure 10. Beta diversity indices in two Wadi beds.

3.4. Soil Study

The soil analysis results for the sampled sites are shown in Figure. 10.

The results of the soil analysis (Figure. 11) suggest that the soil of the Wadi N'Sa bed site is sandy-silty with a dominance of fine sand, slightly alkaline, not salty, not calcareous (low limestone content), poor in organic matter (low content), slight gypsum, and a remarkable percentage of potassium in the ionic balance. On the other side, the soil of Wadi Mya bed sites is a sandy-silty texture soil with a dominance of fine sand and a remarkable rate of silt, neutral to slightly alkaline, little salty to extremely salty (site n°4: ‘’sebkha’’), low in limestone, poor in organic matter (low content), slightly to moderately gypseous, a remarkable rate of calcium and a high rate of sodium in the ionic balance (Figure. 11).

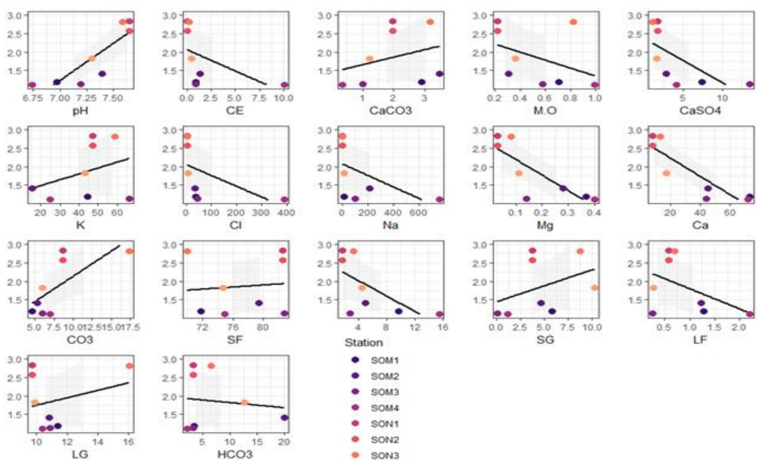

Figure 11. Soil analysis results for the sampled sites.

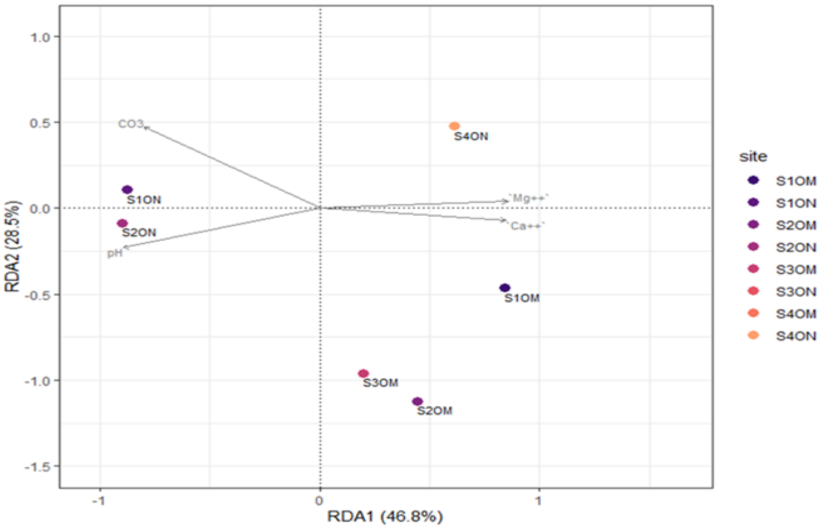

Figure 12. Distance-based redundancy analysis (dbRDA) plot of the DistLM based on Bray–Curtis distance with the studied sites and soil parameters that significantly affect ($P < 0.05$) vegetation diversity (vegetation diversity–soil parameter relationship). pH, CO3

Vectors indicate the direction of the parameter in the ordination plot. CA++ and Mg++ displayed significant positive linear relationships with plant diversity (positive correlation), while pH and CO3 had significant negative relationships (negative correlation). Ca and Mg impact local soil pH (GRAY et al., 2014).

3.5. Relationships between plant diversity and soil characteristics

The relationships between vegetation and soil variables were studied based on the dominant species and soil characteristics;

The dominant species at the Wadi N'Sa bed site are the **hygrophilous** species *Tamarix aphylla*, which is characteristic of the Wadi N'Sa bed (with moisture and water), which colonizes unsalted soils; the **psammophilous** *Anabasis articulata*, *Ephedra alata*, and *Cleome arabica*, which colonize a large surface of the sandy area of the Wadi N'Sa bed.

The soils of the Wadi Mya bed sites are sandy, gypsum, slightly salty to highly salty, and moderately to extremely salty, with a remarkable percentage of sodium and chloride. These substrata are colonized and dominated by psammophilous species, such as Tetraena alba; halophilic species, such as Limoniastrum guyonianum; and gypsophila species, such as Randonia africana and Traganum datum.

4. Discussion

The present study focused on plant biodiversity in two Wadi beds in the Saharan arid region (Ouargla region, Eastern Sahara of Algeria).

In this study, we characterized wild Saharan plants in Wadi N'Sa and Wadi Mya using a floristic approach (species composition and biodiversity assessment), plant functional characterization (life forms, morphological, phytogeographical, etc.), and vegetation–soil relationship information.

Ecologically, deserts may be characterized as areas with scant vegetation of adapted plants with specific characteristics that empower them to dodge, resist, or endure extraordinary environmental conditions. They extend over large zones of uncovered soil and low vegetation cover (BOUALLAL, 2013; BRADAI et al., 2013; 2015a).

We interpret our results and support them with the results of similar previous studies:

4.1. Floristic composition

On the Wadi N'Sa bed, we counted 36 genera and 49 species belonging to 24 botanical families; at the Wadi Mya bed, we counted 13 genera and 15 species belonging to 10 botanical families.

According to CHEHMA (2005), the abundance of Wadi beds is linked to favorable conditions, essentially the presence of water and alluvial material generated by floods, even irregular floods, which cross these areas.

According to ANRH (2017), Oued N'Sa is a living Wadi that experiences floods from time to time (ANRH,2017), which can explain the high floristic richness at the level of its bed; conversely, Wadi Mya, which is considered poor in plant species, is a fossil Wadi, and its last recorded flood was in 1950. According to history, this Wadi only travels halfway (from its lover to 700 km).

Monod (1992) reported that Asteraceae, Poaceae, Fabaceae, and Chenopodiaceae (Amaranthaceae) dominate almost everywhere in desert flora. Moreover, based on the studies of CHEHMA (2005) and BOUALLALA (2013), these three families (Brassicaceae, Asteraceae, and Fabaceae) are among the families most represented in the Saharan flora. Generally, Asteraceae, Poaceae, and Fabaceae are the most represented families and are often found in mainland and island areas of Algeria (BENHAMICHE-HANIFI and MOULAI 2012).

The typical plant families of the sandy habitats of the study area are Poaceae, Brassicaceae, and Amaranthaceae; these families are well suited to the ecological conditions of most Saharan environments (AZIZI et al., 2021).

Additionally, our results agree with those of SALLAM et al. (2023).

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4.2. Plant functional traits

4.2.1. Morphological types

The dominant biological category in the Wadi N'Sa bed was annual species (acheb or ephemeral) (53%), while perennial species (permanent) were represented by 47%. This is a result of the absence of floods and low rainfall. According to OZENDA (1977), these two categories represent a mode of adaptation to drought in Saharan plants, where he defined ephemeral plants (achebs) as those that appear only after the rainy period and carry out their entire vegetative cycle before the soil is dry. Permanent plants (perennials) are constantly present and adapt physiologically and morphologically to the conditions of the Saharan environment.

4.2.2. Phytogeographical types

The chronological spectrum of the recorded plant species exhibited diverse phytogeographic types, with a dominance of the Saharan-Arabic component within the two Wadi beds (36.7%) within the Wadi N'Sa bed and 53.33% within the Wadi Mya bed. In accordance with QUEZEL (1960, 1965), the Saharan-Arabic component is best adjusted to the conditions of leaf locales. Most of the time, it is foremost overwhelming within the courses regarding number and scope (BOUALLALA 2013). EL KHOULY and SHAWKY (2017) suggested that Saharo Arabian species are good indicators of desert environmental conditions, as the Saharo-Arabian chorotype is the significant component of the floristic structure.

Following QUEZEL (1983), the flora of Mediterranean Africa is differentiated at the phytogeographic level after climatic alterations since the Miocene, which has promoted the relocation of tropical vegetation. This flora is currently adapted to the conditions of the Saharan districts (BOUALLALA and CHEHMA 2014).

4.2.3. Life forms (biological spectrum)

The spectrum of life forms showed high scores for therophytes, followed by chamaephytes and hemicryptophytes in the Wadi N'Sa bed. While, in the Wadi Mya bed, chamephytes (perennials) predominated, followed by phanerophytes This may be related to soil characteristics, soil moisture and microclimate.

According to BOUALLALA (2013), therophytes are the most overwhelming of all the examined courses at the slightest in number. The nearness of these particles in parched situations is connected to their adjustment methodology, and the nearness of therophytes is strongly connected to rainfall. The lavishness of therophytes speaks to a sign of aridity in the environment (NÈGRE 1966), and the wonder of therophytes is considered by DAGET (1980) as a methodology for avoiding unfavorable periods. According to BOUGHANI et al. (2013), this tall extent of therophytes appears in a few works in the bone-dry Mediterranean zone (AIDOUD-LOUNIS 1984, 1997; FLORET et al., 1990).

In accordance with RAUNKIAER (1934) and FLORET et al. (1990), chamephytes are best adjusted to temperature and aridity. BOUGHANI et al. (2013) reported that chamephytes are also well represented (29%) because they can develop various forms of adaptation to drought, reducing leaf area and developing a robust root system. Phanerophytes are uncommon in arid lands and often colonize valleys and aqueduct beds of the Saharan environment (BRADAI et al., 2015b). The high chamaephytic count can be related to the species' resistance to dryness, salinity, sand accumulation and overgrazing (EL KHOULY and SHAWKY 2017).

BOUALLALA et al. (2020) reported that the biological spectra of bunches are heterogeneous, likely due to the specific local ecological conditions.

It is well known that when the lavaness and equity of species in a community have moderately high values, this indicates high species diversity in the region (MAGURRAN 2004).

BARBARO et al. (2001) remarked that the utilitarian characteristics that describe dry plant networks fluctuate following transient varieties of ecological conditions, such as the amount of accessible water, soil richness, and available light.

4.3. Soil characteristics

The soil of the Wadi N'Sa bed site is sandy-silty with a dominance of fine sand, slightly alkaline, not salty, not calcareous, poor in organic matter, slight gypsum, and a remarkable percentage of potassium in the ionic balance. On the other side, the soil of Wadi Mya bed sites is a sandy-silty texture soil with a dominance of fine sand and a remarkable rate of silt, neutral to slightly alkaline, salty, low in limestone, poor in organic matter, slightly to moderately gypseous, a remarkable rate of calcium and a high rate of sodium in the ionic balance. We think that the difference in some soil properties in the two environments can affect the diversity and abundance of plants, depending on the ecology of each species.

The soil's physicochemical characteristics control plant communities' distribution, and these factors also appear to play a determining role in implementing certain types of microbial communities (LACOSTE and SALANON 2001). Furthermore, edaphic differences influence plant diversity more than the climate in desert regions (DANIN 1978).

BAMMEUR (2015) mentioned that Ephedra alata, Tamarix aphylla, and Calligonum Comosum dominate the Wadi N'Sa station.

The richness and diversity of Wadis beds are principally due to favorable and edaphic conditions that help spontaneous vegetation grow, protect, and survive (BENHOUHOU et al., 2005).

DJILI et al. (2005) concluded that, for their study in the middle region of the Northern Sahara Génire East, there is a relationship between the ecological excellence of plants and the ordinary conditions offered by the stations. In addition, BAMMEUR (2015) suggested a relationship between plants and the ground in the Northern Sahara Eastern Algeria (Ghardaia and Ouargla regions).

The distribution of plant associations is not random; somewhat, it is affected by soil, climatic, and biotic factors (GUINOCHET 1973).

4.4. Relationships between plant diversity and soil characteristics

As a result of soil-vegetation relationship, the dominant species at the Wadi N'Sa bed site are the **hygrophilous** species *Tamarix aphylla*, which is characteristic of the Wadi N'Sa bed (with moisture and water), which colonizes unsalted soils; the **psammophilous** *Anabasis articulata*, *Ephedra alata*, and *Cleome arabica*, which colonize a large surface of the sandy area of the Wadi N'Sa bed.

The soils of the Wadi Mya bed sites are colonized and dominated by psammophilous species, such as Tetraena alba; halophilic species, such as Limoniastrum guyonianum; and gypsophila species, such as Randonia africana and Traganum datum.

The study of SALLAM et al. (2023) confirmed the results obtained by ABDELAAL (2017) that soil texture, salinity, and organic carbon could affect the phytodiversity of wild plants.

In areas where water is not a limiting factor, spontaneous flora is divided into associations ranging from Gypso neutrophils, which look for rocky soils, to hygro-halophytic vegetation colonizing salty, sandy soil. (BAMMEUR 2015)

According to ABD EL-GHANI and AMER (2002), soil parameters, especially pH, calcium carbonate content, gravel content, fine soil fraction, soil saturation, electrical conductivity, and gypsum, highly differ among the distribution plant groups.

The species distributions in phytoecological groups and subgroups, such as psammophils, hygrohalophils, halophytes, and gypsophils, are linked to the influence of two ecological factors (geomorphological forms and edaphic factors). (MEDJBER 2014)

KOULL (2015) noted the presence of halo-gypsophiles (*Zygophyllum album* and *Limoniastrum guyonianum*) and halophytes (*Traganum nudatum and Halocnemum strobilaceum*), where she described *Halocnemum strobilaceum* (a hyperhalophilic species), which occupies the most salty and humid soils and is the most tolerant species to harsh edaphic conditions.

The distribution of halophilic plants is essentially influenced by salinity gradients, humidity, soil texture, air temperature, water depth, and flooding period (ABD-EL-GHANI 2000).

SALAMA et al. (2013) reported that vegetation–soil relationships are closely related to soil factors. These authors considered gravel, coarse sand, fine sand, silt, clay, sodium, and chlorides to be the most important variables affecting the distribution of plant communities in the inland Wadis of South Sinai.

According to previous pertinent studies in the Wadis of arid and semiarid areas, the soil-vegetation relationships of inland Wadis showed that gravel, coarse sand, fine sand, silt, clay, sodium, and EC were the main soil factors. (EL KHOULY and SHAWKY 2017).

4.5. Diversity

The Wadi N'Sa bed was more diversified and riche than the Wadi Mya bed. generally, it is the result of the interaction of edaphic, geomorphological, hydric (presence of water) and geomorphological factors.

The heterogeneity of local topography, edaphic factors, and microclimatic conditions leads to the diversity and variation in the distributional behavior of the plant associations in the study area. (ABD EL-GHANI AND AMER 2002; BARAKAT et al. 2014)

According to BOUALLA et al. (2020), natural components, such as climate, soil, and disturbance, play a significant role in the variance of biodiversity components (both specific and functional diversity).

The distinctions between wild plant life forms, richness, and diversity along the studied desert roadsides and the soil differences indicate plant biodiversity (SALLAM et al., 2023)

Conclusion

Floristic diversity in the Saharan environment is considerable at specific points, such as in Wadi beds and depressions where water is a limiting factor, and other factors, such as soil and climate, control the distribution of spontaneous plants. This work evaluated plant diversity and differences between two Wadi beds (the Wadi N'Sa bed and the Wadi Mya bed) in the same region (the Ouargla region). It evaluated the relationship between plant diversity and soil content.

The vegetation studied was characterized by high diversity at the Wadi N'Sa bed (49 species in 24 families) compared to (15 species in 10 families), the dominance of therophytes (ephemerals) in the Wadi N'Sa bed, the presence of chamaephytes (perennials) in the Wadi Mya bed, and the dominance of the Saharan-Arabic element in the two Wadi beds, which are the most adaptable to the climatic conditions of arid regions.

For biodiversity studies, alpha and beta diversity showed differences between the floristic compositions of two Wadi beds and between the two environments.

On the other hand, the soil study showed a similarity between parameters and differences between the other biotopes, which influenced the floristic composition of the stations and the distribution of plants according to the relationship between soil and vegetation.

In conclusion, the results obtained confirm our hypothesis, soil characteristics influence the distribution and diversity of wild plants by the soil-vegetation relationship in two Wadi Bed, but in interaction with other factors: water, geomorphology, and microclimate.

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