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Research Article

Plants associated with water towers in the Saharan environment: Floristic diversity and therapeutic virtues

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Abstract

Water in arid regions plays a vital role in the existence and development of living beings. The main aim of this work is to study the diversity and therapeutic properties of plant species that grow in the vicinity of water towers (constructions used to store and distribute drinking water) in the Saharan environment (south-western Algeria). Twenty-two floristic surveys were carried out in five representative sites to study the floristic diversity. The biological and phytogeographical spectra were established, and the therapeutic properties were determined for each plant species inventoried. The results show that the floristic richness is of the order of 41 species belonging to 39 genera and 16 botanical families, the most represented of which are the Asteraceae (19.51%) and Poaceae (17.07%). The biological spectrum showed the existence of 20 species of therophytes, and the phytogeographic spectrum indicated that most of the inventoried plant species belonged to the Saharo-Arabian biogeographic element (31.7%). The leaves (51.22%) are the most used for therapeutic aspects, while decoction is the most commonly used preparation method (60.98%). The plants with the highest importance values are *Calotropis procera* (27.78%), *Phoenix dactylifera* (16.67%), *Cynodon dactylon* and *Tamarix gallica* (15.56% each). This study shows that the various plant species inventoried offer important therapeutic properties for treating various pathologies.

Keywords: arid zones; medicinal plants; pathologies; plant diversity; valorisation

Introduction

According to Ramade (2008), the term biodiversity is a new term that appeared in the early 1970s within the World Conservation Union (IUCN). According to Triplet (2023), this term represents the diversity of life and ecosystems: fauna, flora, bacteria, environments, but also breeds, genes and domestic varieties. The term aims to describe the erosion of the living world as a result of human activities, as well as protection and conservation activities, whether manifested in the creation of protected areas or changes in development behaviour (the concept of sustainable development).

Algeria's incredible diversity of biotic and abiotic ecological factors presents a significant floristic richness; its flora comprises 3139 species (Quézel and Santa, 1962-1963). Endemic taxa are 464 species, or 11.61% of Algerian vascular plants (Catullo *et al.*, 2011). These plants constitute a vital biological resource with multiple uses, including food, medicinal, cosmetics and the environment (Pouget, 1980; Baba-Aissa, 1991; Le

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Houérou, 1995; Beloued, 1998; Baba Aissa, 2000; Longo-Hammouda *et al.*, 2007; Chehma and Djebar, 2008; Bouallala *et al.*, 2011; Boukerker *et al.*, 2012; Kemassi *et al.*, 2014; Kadri *et al.*, 2018; Kemassi *et al.*, 2019).

In the Algerian Sahara, which is a very harsh desert environment that is very restrictive for the survival of life (Ozenda, 2004), plant species are well adapted to the arid environmental conditions (low and irregular rainfall, high thermal variation, strong winds and skeletal soil poor in organic matter) (Bouallala *et al.*, 2020; Souddi and Bouallala, 2021; Souddi and Bouallala, 2022). Many previous studies have focused on several aspects (medicinal, food and others) of phytogenetic resources that develop in the different ecosystems of the Algerian Saharan zones (Benhouhou *et al.*, 2001; Benhouhou *et al.*, 2003; Ould El Hadj *et al.*, 2003; Ozenda, 2004; Chehma and Djebar, 2008; Kemassi *et al.*, 2014; Benmeddour *et al.*, 2015; Lakhdari *et al.*,2016; Yabrir *et al.*, 2018; Bradai *et al.*, 2020; Bouallala *et al.*, 2020; Azizi *et al.*, 2021; Chelalba *et al.*, 2021; Nouidjem *et al.*, 2021, Bouallala *et al.*, 2022; Fandougouma *et al.*, 2022; Bouallala *et al.*, 2023; Souddi and Bouallala, 2023; Merchela *et al.*, 2023; Souddi and Bouallala, 2024). Despite these studies, the phytogenetic heritage near water towers remains unknown for therapeutic purposes. The excess and seepage water from these towers, which are constructions for storing and distributing drinking water, favours the installation of certain plants well adapted to the conditions of the arid environment.

In this context, this work aims to study the phytogenetic resources associated with water towers in the Algerian Sahara at the biological, chorological and therapeutic levels (parts used, forms of use and diseases treated).

Materials and Methods

Study area

The study area is the daïra of Zaouiet Kounta (The daïra is a *s*ubdivision of wilaya in the Algerian territorial administration; each daïra is divided into one or more municipalities), which is located 77 km south of the city of Adrar (Algerian Sahara). It covers an area of 14 830 km^2. It is limited to the north by the daïra of Fenoughil, to the east by the daïra of Aoulef and to the south by the daïra of Reggane (Figure 1). The climate of the region of Adrar is hyperarid (Souddi and Bouallala, 2022). The average maximum temperature is 45.9 °C in July, and the minimum temperature in January is 5.2 °C. The average annual precipitation does not exceed 10.2 mm for the period (1981-2021).

Sampling method and floristic surveys

For this study, five representative sites near the water towers in the daïra of Zaouiet Kounta (Figure 1) were chosen according to a subjective sampling. The floristic surveys were carried out at each site from February to March 2022. Each survey area was 100 m^2, and a list of all species present was recorded with their abundance-dominance coefficients. The abundance-dominance coefficient gives the importance of the species in the plant cover studied and is used to determine the average cover of the species inventoried. The abundance-dominance coefficients were converted into a numerical scale ('+'=2, '1'=3, '2'=4, '3'=5, '4'=6, '5'=7) to calculate the Shannon-Weaver diversity (H') and evenness (E) of the different sites studied (Bouallala *et al.*, 2020; Souddi and Bouallala, 2023). The species were identified using reference works (Quézel and Santa, 1962-1963; Ozenda, 2004).

Biological and phytogeographic spectra

The biological types of the inventoried plant species were determined according to the definitions of Raunkiaer (1934), which are based on the position of the renewal buds in relation to the soil surface during unfavourable periods. The principal life forms are: therophytes, geophytes, hemicryptophytes, chamaephytes and phanerophytes.

Phytogeography is the study of the distribution of plants on the earth's surface and the causes of this distribution. To establish the biological and phytogeographical spectra, the following reference works on the flora of Algeria (Quézel and Santa, 1962-1963) and the flora of the Sahara (Ozenda, 2004) were used.

Importance and medicinal use of inventoried plants

Published articles and documents describing the importance and use of medicinal plants (part used, form of use and diseases treated) found in arid and hyper-arid zones were used to assess the medicinal importance of the inventoried species.

Data analysis

To study biodiversity, Shannon-Weaver and evenness indices are widely used, according to the following formulae (Roselt/Oss, 2008):

$$H' = -\Sigma Ni/\log_2 Ni/N \quad (1)$$

Where Ni is the population of species i and N is the total number of individuals of all species present in the phytocenoses.

$$E = H'/ H_{max} \quad (2)$$

Where: $H_{max} = \log_2 S$, evenness is the ratio between the Shannon-Weaver diversity index "H'" and the maximum diversity "H_{max}".

To show the importance of using the plant organs of the inventoried plants and the importance value of the species based on the following indices:

Frequency, which is the percentage of the number of samples in which the species (F1) is found compared to the total number of samples (F2):

$$Fr = F1/F2 \times 100 \quad (3)$$

Where Fr = relative frequency, F1 = number of samples in which the species was found, F2 = total number of samples (Triplet, 2023) and the importance value (VIsp) of the species, which represents the ratio between the number of different uses of the species (vi) and the number of different uses of all listed species (∑vi) (Badjaré *et al.*, 2018).

$$VIsp = vi/\sum vi \times 100 \quad (4)$$

Results

Floristic composition and richness

The floristic composition of species in the study area showed the existence of 41 plant species belonging to 39 genera and 16 families (Table 1). The two most important botanical families are Asteraceae (6 genera and 8 species) and Poaceae (7 genera and 7 species). Amaranthaceae and Fabaceae have the same number of recorded species (4 species each).

Depending on the site (Figure 1), the most important families at site 1 are Apocynaceae (3 species), Asteraceae and Poaceae (2 species each). The most important families at site 2 are Asteraceae (4 species), Apocynaceae, Fabaceae and Poaceae (3 species each). The most important families at site 3 are Poaceae (5 species) and Amaranthaceae, Asteraceae (4 species each). The most important families at site 4 are Asteraceae (8 species) and Amaranthaceae, Apocynaceae (3 species each). The most important families at site 5 are Amaranthaceae, (4 species) and Apocynaceae, Poaceae (3 species each).

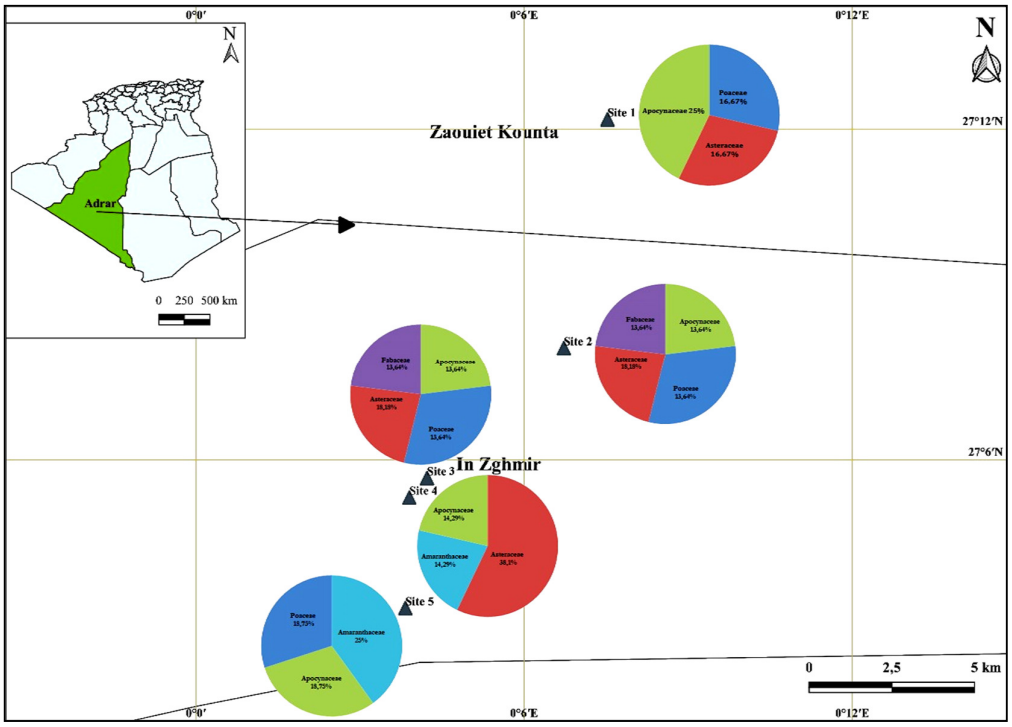

Figure 1. Geographical location of study sites and distribution of the dominant plant families (Source: Authors)

Table 1. List of plant species inventoried in the study area, their importance value, their biological and phytogeographic characteristics and their therapeutic properties (parts used, form of use and diseases treated)

Family	Species	Overall VC	Value imp. (%)	Life form	Chorology	Parts used	Form of use	Diseases treated	Reference
Amaranthaceae (9.75%)	*Bassia muricata* (L.) Asch.	0.4%	6.68%	Ther	Sah	Leaves and aerial parts	Decoction Maceration	Infectious, dermatosis, pustules, furuncles and infected wounds, hypocholesterolemia, renal and rheumatic diseases	Idm'hand *et al.* (2020), Hammiche and Maiza (2006), Hemmami *et al.* (2023), Al-Obeidyeen *et al.* (2023)
	Cornulaca monacantha Del.	0.9%	4.44%	Cham	SA	Leaves and aerial parts	Decoction	Digestive, liver pain, jaundice, liver disease and scabies	Chehma and Djebar (2008), Hammiche and Maiza (2006), Ashour and Alsuwayt (2019)
	Salsola foetida Del.	0.7%	1.11%	Cham	SA	Leaves	Decoction	Digestive	Ghourri *et al.* (2012)
	Chenopodium murale L.	0.3%	3.33%	Ther	Cosmop	Leaves	Decoction	Digestive, treats infertility, mouth ulcers	Ghourri *et al.* (2012), El-Newary *et al.* (2023)
Apocynacea (7.32%)	*Calotropis procera* (Aiton) W.T. Aiton	58.4%	27.78 %	Phan	Tr-SA	Leaves, latex and flowers	Infusion Decoction	Dermatology, syphilis, cough, tonsillitis, jaundice, helminthiases, bilharziasis, rheumatism, leprosy, elephantiasis, menorrhagia, malaria, snakebite, purgative and anthelmintic effects, neuropsychiatric disorders, joint pain, muscle spasms and constipation, fever, asthma, eczema, indigestion, diarrhea, elephantiasis and dysentery	Hammiche and Maiza (2006), Djerdjouri *et al.* (2021), Iqbal *et al.* (2005), Kinda *et al.* (2020), Mossa *et al.* (1991)

	Cynanchum acutum L.	96.2%	3.33%	Hemi	M-As.	Leaves and aerial parts	Decoction	Dermatology, chronic hepatitis, diuretics	Sayed *et al.* (2003), Fawzy *et al.* (2008), Abdelhameed *et al.* (2021)
	Pergularia tomentosa L.	5.7%	13.33 %	Cham	SA	Aerial part, Roots	Decoction	Dermatology, abortive helminths, chills, bronchitis, constipation and asthma., diarrhea, ocular instillation, headaches, tuberculosis, diabetes	Hammiche and Maiza (2006), Hosseini *et al.* (2019)
Arecaceae (2.44%)	*Phoenix dactylifera* L.	1.1%	16.67 %	Phan	N. Afr	Fruits, Seeds, Leaves and Pollen	Infusion	Cardiovascular, memory disorders, diarrhea, fever, inflammation, paralysis, loss of consciousness, nerve disorders, Intestinal disorders, sore throat, colds, bronchial catarrhs, fevers, gonorrhea, liver edema and abdominal disorders, Infertility treatment	Bradai *et al.* (2020), Fandougouma *et al.* (2022), Al-daihan (2012), Farag *et al.* (2023)
Asteraceae (19.51%)	*Aster squamatus* (Spreng.) Hieron.	0.1%	2.22%	Ther	Amer	Leaves, stems and roots	Infusion	Digestive, healing	Sperotto *et al.* (2002)
	Centaurea pungens Pomel.	17.8%	2.22%	Hemi	Sah	Seeds	Powder	Cardiovascular, respiratory infections	Labed *et al.* (2019)
	Launaea glomerata (Cass.) Hook. f.	27.6%	10%	Ther	M-SA	Aerial part	Decoction	Digestive, stomach and liver diseases, scorpion stings and snake bites, diuretic, colds and urinary tract infections.	Boukerker *et al.* (2012), Chelalba *et al.* (2021), Benmeddour *et al.* (2015), Zeghoud *et al.* (2023), Hemmami *et al.* (2023)
	Launaea nudicaulis (L.) Hook. f.	0.1%	4.44%	Ther	SA	Leaves	Herbal tea	Digestive, gastric and skin diseases, injuries	Boukerker *et al.* (2012), Kumar *et al.* (2020)
	Launaea resedifolia O.K.	0.7%	12.22 %	Ther	M-SA	Leaves and roots	Herbal tea	Digestive, liver pain, toothache, fever, itchy skin, cuts, ulcers, swelling, bilious fever, eczema rashes and rheumatism.	Boukerker *et al.* (2012), Auzi *et al.* (2007), Rashid *et al.* (2000), Zellagui *et al.* (2012)
	Pulicaria arabica (L.) Cass.	0.2%	10%	Hemi	SA	Aerial part	Decoction	Diarrhea,schistosomiasis, digestive disorders, ulcers, anti-smoking and skin diseases, treatment of diabetes and Alzheimer's disease	Sassoui *et al.* (2022), Djermane *et al.* (2016) , Djermane *et al.* (2023)
	Senecio massaicus (Maire) Maire	0.3%	1.11%	Ther	SA	Aerial part	Decoction	Cardiovascular	El Rhaffari and Zaid (2002)
	Sonchus oleraceus L.	0.7%	4.44%	Ther	Cosmop	Leaves	Decoction	Digestive, stomach and gastric disorders, rheumatism	Bellakhdar (1997), Vecchia *et al.* (2022), Adli *et al.* (2021)
Brassicaceae (7.32%)	*Brassica tournefortii* Gouan.	5%	1.11%	Ther	M	Leaves	Cooked	Chronic	Rahmani *et al.* (2019)
	Farsetia aegyptiaca Desv.	5.2%	5.57%	Cham	SA	Leaves	Decoction	Digestive, diabetes and antispasmodic, rheumatic pain and fevers	IUCN (2005), Atta *et al.* (2013)
	Schouwia purpurea (Forssk.) Schw.	0.4%	1.11%	Ther	South Sah	Leaves	Infusion	Impotence	Yebouk *et al.* (2020)
Cucurbitacea (2.44%)	*Colocynthis vulgaris* (L.) Schrad.	0.1%	5.57%	Ther	Trop. Med	Aerial part	Infusion	Dermatology, diabetes, constipation, hemorrhoids, gastrointestinal disorders	Chehma and Djebar (2008), Adli *et al.* (2021), Li *et al.* (2021)
Euphorbiacea (2.44%)	*Euphorbia granulata* Forssk.	0.1%	4.44%	Ther	SA	Latex	Dilution	Digestive, helminthiasis, purgative, anthelmintic and diuretic	El Rhaffari and Zaid (2002), Hammiche and Maiza (2006), Mahdavi *et al.* (2022)

Fabaceae (9.75%)	*Acacia farnesiana* (L.) Willd.	0.2%	3.33%	Phan	CA	Roots	Infusion	Digestive, dysentery and tuberculosis	Estrada-Castillón *et al.* (2018), Hernández-García *et al.* (2019)
	Cassia aschrek Forssk.	0.3%	14.44 %	Cham	Sahelo-Sudan	Whole plant	Decoction	Digestive, treatment of stomach ache, asthma and diuretic, dysmenorrhea, nausea and liver problems, burns, skin diseases and ulcers, diarrhea, elephantiasis and eye diseases	Zibaee *et al.* (2023), Osunga *et al.* (2023)
	Leucaena leucocephala (Lam.) de Wit.	0.1%	3.33%	Phan	CA	Leaves and seeds	Decoction	Digestive, contraception and treatment of diabetes	Zayed and Samling (2016), Chowtivannakul *et al.* (2016)
	Melilotus indica (L.) All.	0.2%	5.57%	Ther	M-As.	Whole plant	Decoction, Infusion	Digestive, dermatology, cataplasm or plaster for swelling, treatment of intestinal disorders and infantile diarrhea	Lakhdari *et al.* (2016), Iftikhar *et al.* (2019)
Heliotropiace (2.44%)	*Heliotropium bacciferum* Forssk.	5.7%	4.44%	Cham	SA	Leaves	Powder	Dermatology, abscesses, boils and tonsillitis	Bellakhdar (1997), Hammiche and Maiza (2006), Fathalipour-Rayeni et al. (2022), Aïssaoui *et al.* (2019)
Asphodelacea (2.44%)	*Asphodelus tenuifolius* Cav.	0.2%	7.79%	Ther	M	Whole plant	Decoction	Dermatology, constipation, measles, anemia, colds and hemorrhoids, diuretic agent and wound healing	Hammiche and Maiza (2006), Khatri *et al.* (2018), Khalfaoui *et al.* (2021)
Poaceae (17.07%)	*Cutandia dichotoma* (Forssk.) Trab.	0.1%	1.11%	Ther	M	Seeds	Infusion	Uro-genital	Chaachouay *et al.* (2020)
	Cynodon dactylon (L.) Pers.	28%	15.56 %	Hemi	Cosmop	Rhizomes	Decoction	Uro-genital, acute renal failure, dysuria, renal lithiasis, colic, treatment of dropsy, syphilis and diabetes, hydrops, cancer, convulsions, coughs, cramps, diarrhea, dropsy	Chehmaand Djebar (2008), Yabrir *et al.* (2018), Adli *et al.* (2021), Nair *et al.* (2018), Nagoriand Solanki (2011)
	Imperata cylindrica (L.) Raeusch.	5%	11.11 %	Hemi	Tr-M-SA	Leaves and Rhizome	Decoction	Respiratory, hematuria, jaundice, vomiting, haemorrhage and fever, diuretic, colic, tonsillitis and laryngitis gargle	Mahmoud and Gairola (2013), Jung and Shin (2021), Razafindrakoto *et al.* (2021)
	Phalaris minor Retz.	0.1%	1.11%	Ther	PSTr	Seeds	Poudre	Digestive	Ahmad *et al.* (2020)
	Phragmites communis Trin.	50.5%	2.22%	Hemi	Cosmop	Roots	Infusion	Cardiovascular and pulmonary diseases	Bellakhdar (1997), Farouk *et al.* (2023)
	Aristida pungens Desf.	0.3%	1.11%	Hemi	Sah South Africa	Aerial part	Decoction	Digestive	Boukerker *et al.* (2012)
	Polypogon monspeliensis (L.) Desf.	5.2%	1.11%	Ther	PSTr	Leaves	Infusion	Cardiovascular	Ahmad *et al.* (2020)
Primulaceae (2.44%)	*Anagallis arvensis* L.	0.1%	7.79%	Ther	Cosmop	Leaves	Decoction	Dermatology, liver and kidney diseases, diuretics, cirrhosis of the liver, pulmonary problems, gallstones, kidney stones, urinary tract infections and activities.	López *et al.* (2011), Shabbir *et al.* (2022)

Sapindaceae (2.44%)	*Dodonaea viscosa* (L.) Jacq.	0.1%	14.44 %	Phan	Tr-STr	Leaves	Decoction	Dermatology, dermatitis, smooth muscles, hemorrhoids, sore throats, fractures and snake bites, treatment of rheumatism, skin infections, diarrhea, stomache, hepatic pain, Uterine colic and sore throat, Gastrointestinal diseases	Khan *et al.* (2023), Venkatesh *et al.* (2008), Al-Snafi (2017), Malik *et al.* (2022), Herrera-Calderon *et al.* (2023)
Solanaceae (2.44%)	*Hyocyamus muticus* L.	0.5%	2.22%	Hemi	SA	Leaves	Cooked	Joint pain and renal disease	Ayari-Guentri *et al.* (2022)
Tamaricaceae (2.44%)	*Tamarix gallica* L.	42.9%	15.56 %	Phan	M-SA	Leaves	Decoction, Infusion	Liver disease, abdominal pain, diuretic and diarrhea, chills, colds, tonsillitis, sudorific, leucoderma, spleen cyst, eye diseases, rheumatism and gingivitis	Adli *et al.* (2021), Nisar *et al.* (2022)
Zygophyllaceae (7.32%)	*Fagonia glutinosa* Del.	0.4%	1.11%	Ther	SA	Whole plant	Decoction	Infectious	Nouidjem *et al.* (2021)
	Seetzenia africana R. Br.	0.1%	1.11%	Ther	SA	Whole plant	Decoction	Dermatology	Ali *et al.* (2023)
	Zygophyllum album L.	0.3%	13.33 %	Cham	SA	Whole plant, Latex and roots	Decoction	Digestive, gastric pain, liver attack, colic, cardiovascular disease, diabetes, dysmenorrhea, rheumatism, gout and asthma, local anesthesia and obesity	Zeghoud *et al.* (2023), Hammiche and Maiza (2006), Feriani *et al.* (2020), Belmimoun *et al.* (2017), Abdelhameed *et al.* (2021)

Life forms: (Cham: Chamaephyte, Hemi: Hemicryptophyte, Phan: Phanerophyte, Ther: Therophyte).
Chorological types: Sah: Saharan, SA: Saharo-Arabian, Cosmop: cosmopolitan, Tr-SA: Tropical Saharo-Arabian, M-As: Mediterranean-Asian, N. Afr: North African, Amer: America, M-SA: Mediterranean Saharo-Arabian, South Sah: South Sahara, Trop. Med: Tropical Mediterranean, CA: Central America, Sahelo-Sudan: Sahelo-Sudanian, M: Mediterranean, Tr-M-SA: Tropico-Mediterranean Saharo-Arabian, PSTr: Paleo-subtropical, Sah South Africa: Sahara South Africa, Tr-STr: Tropico-subtropical.
VC: Vegetation Cover.

Site 3 is the richest in species (26 species) and records the highest diversity index (3) with an evenness of 0.77 (Table 2). On the other hand, site 1 is the least rich in species (12 species) and records the lowest diversity index (2.36) with an evenness of 0.88.

Table 2. Richness and diversity indices of the sites studied

Site No.	Taxa (S)	Shannon (H')	Evenness (E)
Site 1	12	2.36	0.88
Site 2	22	2.84	0.78
Site 3	26	3	0.77
Site 4	21	2.90	0.87
Site 5	16	2.61	0.85

The dominant species by their vegetation cover are: *Cynanchum acutum* (96.2%), *Calotropis procera* (58.4%) and *Phragmites communis* (50.5%).

Biological spectra

The biological spectra (Figure 2) show a good representation of therophytes (48.79%) with 20 species compared with the other biological types. Hemicryptophytes are represented by eight species (19.51% of total species), while chamaephytes are represented by seven species (17.07% of total species) and phanerophytes are represented by 6 species (14.63% of total species).

Phytogeographic spectra

According to the analysis of the phytogeographic spectra (Figure 3), the most significant number of recorded taxa is represented by the Saharo-Arabian element (13 species). The cosmopolitan element occupies second place (5 species), followed by the Mediterranean element (3 species) and the Mediterranean-Saharo-Arabian elements (3 species). The other elements represent less than half of the species recorded, with two or one species per biogeographic type

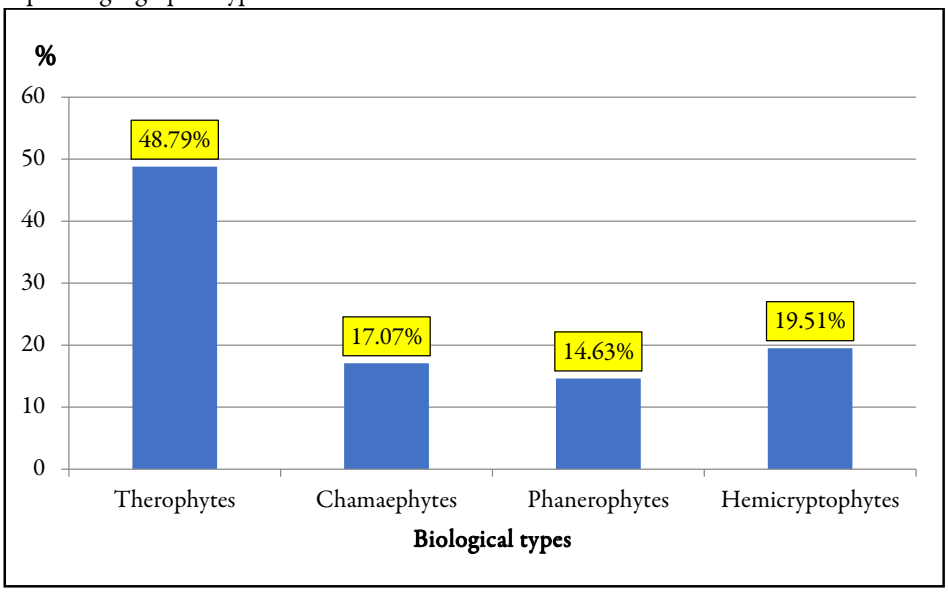

Figure 2. Biological spectra of the study area

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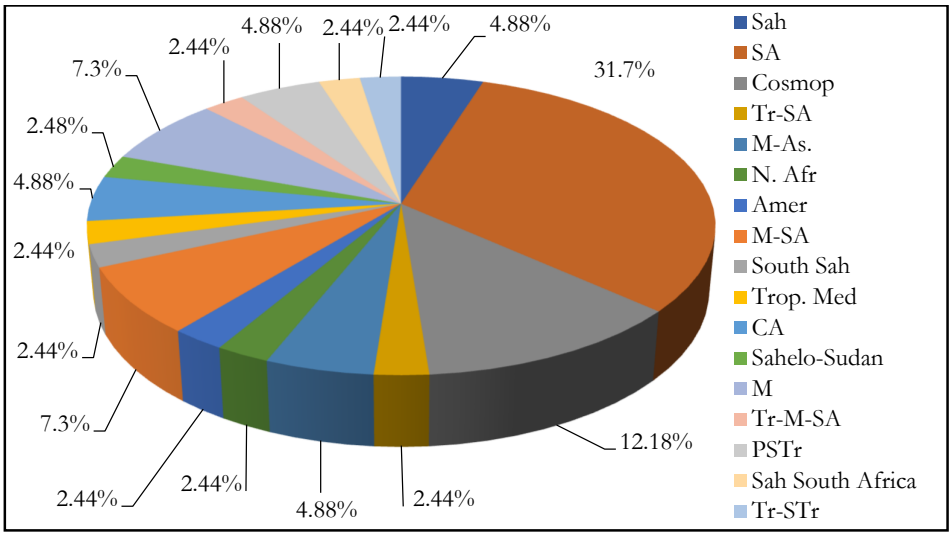

Figure 3. Spectrum of phytogeographic types in the study area

Sah: Saharan, SA: Saharo-Arabian, Cosmop: cosmopolitan, Tr-SA: Tropical Saharo-Arabian, M-As: Mediterranean-Asian, N. Afr: North African, Amer: America, M-SA: Mediterranean Saharo-Arabian, South Sah: South Sahara, Trop. Med: Tropical Mediterranean, CA: Central America, Sahelo-Sudan: Sahelo-Sudanian, M: Mediterranean, Tr-M-SA: Tropico-Mediterranean Saharo-Arabian, PSTr: Paleo-subtropical, Sah South Africa: Sahara South Africa, Tr-STr: Tropico-subtropical

Therapeutic properties

Parts used and products used

The frequency of the parts used shows that leaves are the most commonly used (51.22%), followed by aerial parts (21.95%), whole plants, and roots (14.63% for each). However, latex and rhizomes (4.88% for each) are the rarely used products and parts. Finally, the very few used parts are flowers, fruits, pollens and stems (2.44% each).

Forms of use

Various methods of preparing remedies are used to treat diseases: decoction, infusion, maceration, powder, dilution, herbal teas and cooking. The frequencies of use show that decoction and infusion are the most commonly used methods, with 60.98% and 21.95% respectively, followed by powder with 7.32%, then herbal teas and cooked with 4.88% each, and in the last position, dilution and maceration with 2.44% each.

Symptoms and diseases treated

The analysis of the results obtained allowed us to identify the different diseases treated by the plants inventoried. These plants are used to treat the digestive system (46.34%). Then there are dermatological diseases (21.95%) and cardiovascular diseases (12.19%). Other diseases less treated by plants are listed: infectious diseases, urogenital diseases and respiratory diseases. In addition, some plants are poorly used to treat chronic diseases (breast cancer) and sexual problems (impotence).

The importance value (Table 1) shows that the most commonly used plant in the treatment of diseases is *Calotropis procera* with an importance value of 27.78%, followed by *Phoenix dactylifera* (16.67%), *Cynodon dactylon* and *Tamarix gallica* with 15.56% each. On the other hand, the importance value shows that plants that are little used in disease treatments are *Salsola foetida*, *Senecio massaicus*, *Brassica tournefortii*, *Schouwia purpurea*, *Cutandia dichotoma*, *Phalaris minor*, *Aristida pungens*, *Polypogon monspeliensis*, *Fagonia glutinosa* and *Seetzenia africana* with 1.11% each.

Discussion

The dominance of the Asteraceae and Poaceae families has been reported in several studies on the Saharan flora (Bouallala, 2013; Souddi and Bouallala, 2022; Bouallala *et al.*, 2022). Furthermore, Quézel (1978) indicated the importance of Asteraceae, Poaceae and Fabaceae as the most frequent families in the Mediterranean flora of North Africa.

Roselt/Oss (2008) state that a higher index value corresponds to higher species diversity. Its evaluation helps detect changes in community structure, and in some cases, it has proved effective in detecting anthropogenic changes.

The dominance of *Cynanchum acutum*, *Calotropis procera* and *Phragmites communis* through their vegetation cover can be explained by the fact that these species are adapted to the Saharan environment and are dispersed by wind, which plays a key role in the dissemination of the diasporas of plants in Saharan zones (Souddi and Bouallala, 2022).

The high percentage of therophytes in the study area may be related to their ability to resist drought and sand accumulation (Bouallala, 2013). Also, therophytes present a form of resistance to drought and high temperatures in arid environments (Barbero *et al.*, 1990) and according to Dahmani-Megrerouche (1996), the difficult climatic conditions favour the development of short-cycle species at the expense of woody plants, which require more water and nutrient requirements. Hemicryptophytes are species adapted to strong environmental disturbances (Souddi and Bouallala, 2022) and are classically considered to be preferential to disturbances caused by zoopopulations (Vidal, 1998). The presence of Chamaephytes shows their good

adaptation to the ecological conditions of arid and hyperarid environments by developing of specific strategies (Azizi *et al.*, 2021).

The importance of the Saharo-Arabian element can be explained by the adaptation of its plants, which develop well to the severe environmental conditions of hot and arid lands (Quézel, 1965; El-Sheikh *et al.*, 2021). The cosmopolitan element occupies the second position, which can be explained by the fact that the studied biotopes are very open and disturbed environments (Souddi and Bouallala, 2022).

The predominance of leaves has been reported by several studies (Ould El Hadj *et al.*, 2003; Bouallala *et al.*, 2014; Bradai *et al.*, 2020). The ease and speed of harvesting could explain this high frequency of leaf use, but also and above all the fact that these organs are the site of photosynthetic and metabolic reactions that provide the majority of the secondary metabolites of the plant, namely alkaloids, glycosides and essential oils (Ould El Hadj *et al.*, 2003). The use of the leaves does not represent any danger to the regeneration of plants and will ensure the conservation of floristic richness; indeed, there is a clear relationship between the part of the plant used and the effects of this exploitation on its existence (Cunningham, 1996).

Decoction is the most used method to treat diseases. This preparation method is useful for extracting the maximum quantity of active compounds (Chevalier, 2001). The use of decoction has been reported in several studies in the Algerian Sahara (Ould El Hadj *et al.*, 2003; Kemassi *et al.*, 2014; Bouallala *et al.*, 2014). The infusion is applied to the sensitive organs of the plant (flowers, leaves and flowering tops), which is the method of preparation that preserves the plant's active components. In contrast, decoction is applied to the hard organs (roots, branches, and bark) (Kemassi et al., 2014). Therapeutically, some families treat many diseases due to the ability of plants to own many active compounds. In contrast, others only act on a well-defined disease category due to an appropriate active compound (Adli *et al.*, 2021). Most studies on medicinal plants in the Saharan regions have shown that digestive diseases are most treated by Saharan plants (Ould El Hadj *et al.*, 2003; Bouallala *et al.*, 2014).

Conclusions

The analysis of plant biodiversity in the vicinity of water towers in southwest Algeria revealed 41 species belonging to 39 genera in 16 families, with a predominance of Asteraceae, Poaceae, Amaranthaceae and Fabaceae compared to other botanical families. Therophytes constitute the dominant group in the biological spectrum, and species of Saharo-Arabian origin dominate the phytogeographic spectrum. The analysis of the therapeutic properties of plants has shown that leaves and aerial parts are the parts most used in traditional medicine preparations. The decoction is the most practiced method, followed by the infusion. In addition, the study's results also showed a diversity of therapeutic indications of the species, with dominance for diseases of the digestive system and dermatological diseases. With various usage importance values, the most important plants are *Calotropis procera*, *Phoenix dactylifera*, *Cynodon dactylon* and *Tamarix gallica*. On the other hand, the plants that record the lowest importance values are *Salsola foetida*, *Senecio massaicus*, *Brassica tournefortii*, *Schouwia purpurea*, *Cutandia dichotoma*, *Phalaris minor*, *Aristida pungens*, *Polypogon monspeliensis*, *Fagonia glutinosa* and *Seetzenia africana*. This research can be used as a database for other complementary scientific research in the ethnobotanical field in southwest Algeria, to establish a detailed inventory of medicinal plants and to collect as much information as possible on the therapeutic uses practiced by the Saharan population. Indeed, this work can help researchers in the field of medicinal and aromatic plants to develop an agro-pharmaceutical industry in arid zones.

Authors' Contributions

MS: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Software; Supervision; Validation; Visualization; Writing - original draft; Writing - review and editing. OF: Formal analysis; Visualization; Writing - original draft; Writing - review and editing. MB: Conceptualization; Data curation; Formal analysis; Methodology; Resources; Software; Supervision; Validation; Visualization; Writing - original draft; Writing - review and editing. All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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