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Bioclimate and diversity of Tamaricaceae in Oranie, West Algeria

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Abstract

Vegetation is a good indicator of the status of ecosystems that adapt to environmental changes. In this study, the diversity, floristic composition of Tamaricaceae and distribution of plant species under climate change were determined in West Algeria. Four sites were selected for performing phytoecological surveys using the sigmatist method along a north-south ecological gradient. In total, 195 plant species belonging to 41 families were identified, dominated by Asteraceae (15.90%) and Poaceae (15.38%). Analysis of biological types showed dominance of therophytes (49.74%) in this flora, which indicates the presence of therophytization in this region. Analysis of chorological types identified the dominance of the Mediterranean element (46.67%). The disturbance index was relatively high (75.54%) reflecting significant importance of disturbance in the formation of the characteristic vegetation of the region. The study concluded that the flora of Tamaricaceae is under the threat of climate change and anthropogenic pressure. These results underline the need for strict policies to maintain and conserve the ecosystems that are vulnerable.

Key words: climate, diversity, Oranie, Tamaricaceae, west Algeria.
Abbreviations: WBCS, Worldwide Bioclimatic Classification System.

Introduction

Tamarix L. is one of the largest genus in the family Tamaricaceae and is represented by 55 species worldwide (Heywood et al. 2007). Tamarix is native to the Mediterranean countries, former Soviet Union, China, India, North Africa, and southern Africa (Baum 1978; Heywood et al. 2007). The family Tamaricaceae is divided into five genera: *Hololachna* Ehrenb., *Myricaria* Desv., *Reaumuria* L., *Tamarix* L. and *Myrtama* Ovcz. and Kinzik (Crin 1989). In Algeria, 10 species of Tamarix have been reported: *Tamarix gallica, Tamarix africana, Tamarix aphylla, Tamarix boveana, Tamarix pauciovulata, Tamarix parviflora, Tamarix brachystylis, Tamarix anglica, Tamarix speciosa*, and *Tamarix balansae* (Quezel, Santa 1962; Quezel, Santa 1963).

Species of the Tamaricaceae in Algeria are found in arid and semi-arid environments that play a major role in the socioeconomic life of the local rural population. The species of *Tamarix* are used in animal feed, especially during the dry period, and as ornamental plants, they reduce desertification and have been used in traditional medicine (Villar et al. 2014). Thus, it is very important to study their diversity and species composition.

The study of floristic biodiversity, its spatial and temporal distribution and its interaction with the environment is very essential for the valuation and preservation of the natural ecosystems. In the global context of preserving biodiversity, the study of the flora of the Mediterranean basin presents great interest given the diversity of the historical, paleogeographical, paleoclimatic, ecological and geological factors that determine the secular impact of human pressure (Quezel et al. 1980).

In the region of Oranie, halophyte vegetation plays a strategic role both in pastoral and environmental terms; it constitutes a vast heritage by the diversity of ecological systems it integrates (Ghezlaoui 2011). Various studies have been conducted to assess halophyte diversity in western Algeria (Merzouk 2010; Sari-Ali et al. 2011), and, in particular, on the *Tamarix* in the region of Tlemcen (Bemmoussat 2004; Ghezlaoui 2011; Hadj-Allal 2013; Belkhoudja 2014). The aim of the present study was to obtain data about the species composition and diversity of Tamaricaceae, and to characterize the ecological gradients that govern their diversity and distribution in the region of Oranie in western Algeria. Because of the influence of the climate on plant composition, a climatic analysis updated by a global bioclimatic classification (Rivas Martinez 1993; 2004) was applied to the region.

Materials and methods

Study area and field sampling

The study area was located in northwestern Algeria between 0°32' to 02°00' W and 34°30' to 35°49' N. Administratively, it is located at the junction of the provinces of Tlemcen and Aïn Témouchent (Fig. 1).

Sampling was performed in 2014 to 2017 during spring, a period corresponding to optimum vegetation development in the studied area. In total, 70 phytoecological surveys at four sites were performed, which were chosen according to the sigmatist method (Braun-Blanquet 1952).

Site 1 (Rachgoun) was located at the junction of the National Route N° 22, which links Rachgoun to Beni-Saf. It was characterized by diverse vegetation formations with the presence of *Tamarix gallica* next to Oued Tafna and the presence of other plant species (*Atriplex halimus, Malva sylvestris, Pistacia lentiscus, Quercus ilex*, and *Withania frutescens*).

Site 2 (Remchi) was located north-west of Remchi. It was characterized by the presence of *Tamarix gallica* and *Atriplex halimus.*

Site 3 (Hammam Boughrara) was located 3 km east of the village of Hammam Boughrara. The site was dominated by *Tamarix gallica, Atriplex halimus*, and *Salsola vermiculata*.

Site 4 (El-Aouedj) was located southwest of the province of Tlemcen in the steppe zone. It was characterized by the presence of *Tamarix boveana* in the form of reforestation.

Data collection and plant identification

At each site, floristic surveys were carried out on a floristic homogeneous surface (Guinochet 1973). For each survey, floristic, geographical and environmental data were collected. The floristic surveys were carried out using the "minimal area" approach adapted to the type of vegetation. The minimum area of the stations varied between 64 m^2 (El-Aouedj) and 100 m^2 (Rachgoun, Remchi, Hammam Bougrhrara). This area varied significantly depending on the number of annual species present at the time of surveying and therefore precipitation and operating conditions (Djebaili 1984). Only the presence-absence of species was considered, as the objective was the discrimination and characterization of species inventoried in the study area (Ghezlaoui 2011). The botanical identification and classification into chorological types of the collected taxa was made using the flora of Quezel and Santa (1962; 1963). The classification of plants according to their life form sensu Raunkiaer (1934) was based on the position of the perennating buds, but this classification was adjusted according to the local characteristics of the environment. The perturbation index was used to quantify therophytisation. It was calculated according to Loisel and Gamila (1993) as the ratio of the sum of chamaephytes and therophytes from the full number of the species.

Bioclimatic synthesis

Climate can exert direct and indirect effects on all components of ecosystems (Khatibi et al. 2016). The bioclimatic concept is wide and from an ecologic viewpoint shows the combination of elements that determine plant and animal life (Mankolli et al. 2009). While most systems of bioclimatic classification depend on limited variables such as precipitation, temperature, and their combinations, describing the climate of a region requires the evaluation of more factors (Khatibi et al. 2016).

The present bioclimatic study was based on historical climatic data (1913 to 1938) that were obtained from the

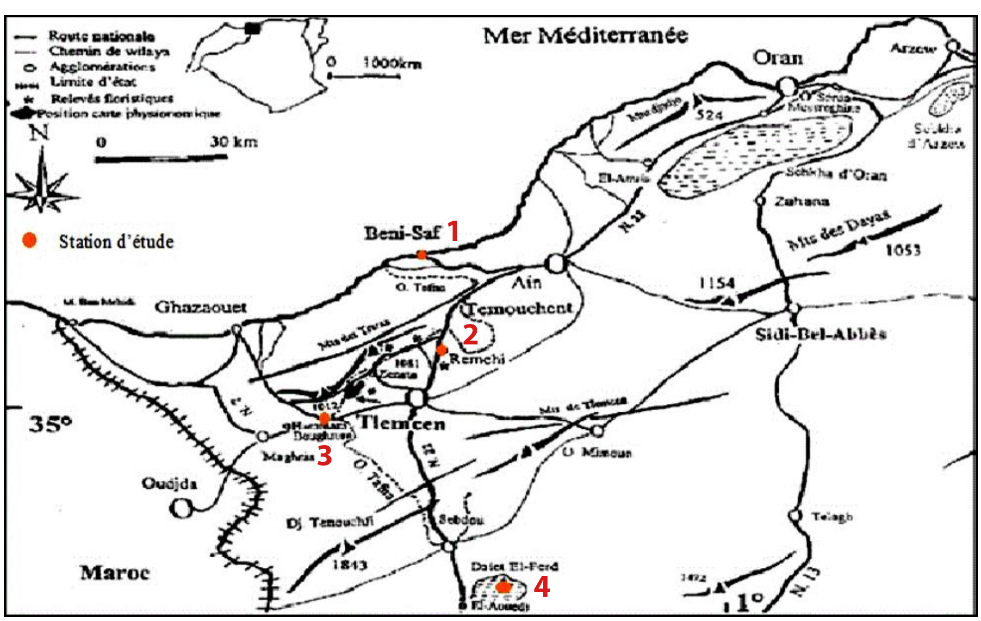

Fig. 1. Map of the study area with locations of study sites.

Table 1. Geographical coordinates of reference meteorological stations

Station	Latitude (north)	Longitude (west)	Altitude (m)	Wilaya
Béni Saf	35°18'	1°21'	68	Ain-Temouchent
Zenata	35°01'	1°27'	249	Tlemcen
Hammam Boughrara	34°81'	1°47'	426.5	Tlemcen
Sebdou	32°42'	1°18'	1100	Tlemcen
El Aricha	34°12'	1°16'	1250	Tlemcen

meteorological collection of Seltzer (1946) and recent meteorological reports that were taken from the National Office of meteorology from reference meteorological stations (Table 1). Many studies on climatology and bioclimatology have been carried out in Algeria in general and in the region of Tlemcen (Oranie) in particular (Benabadji, Bouazza 2000; Bestaoui 2001; Hasnaoui 2008; Merzouk 2010). All of these studies recognize that the Algerian climate belongs to the Mediterranean climate (Ghezlaoui, Benabadji 2018).

Recently, botanists and biogeographers have been using the bioclimatic classification system established by Rivas-Martinez (1981), known as the Worldwide Bioclimatic Classification System (WBCS). The WBCS is a bioclimatic classification system that is widely used in vegetation sciences, especially in geobotany and landscape ecology (Rivas-Martinez 1993). In this study, we applied the WBCS to five meteorological stations following the approach of Rivas-Martinez (1993; 2004).

The bioclimatic classification of the region of Tlemcen was derived by calculations of the bioclimatic indices necessary to define the bioclimate of each station. In particular, continentality, ombrotype and thermicity indices were obtained (Rivas-Martınez et al. 2011).

In the bioclimatic classification of Oranie, the simple continentality index was used. This continentality index expresses the difference between the average temperature of the hottest month and that of the coldest month of the year (Rivas-Martínez et al. 2011).

The thermicity index (I_t) is the sum of the mean annual temperature, mean minimum temperature of the coldest month and mean maximum temperature coldest monthly period multiplied by 10 (Rivas-Martínez et al. 2004a).

The compensated thermicity index (I_{tc}) was proposed to summarize the thermic constraints of climate to plant growth:

$$I_{tc} = (T + m + M) \times 10 + C,$$

where T is the mean annual temperature (°C), m is the mean minimum temperature of the coldest month of the year (°C), M is the average maximum temperature of the coldest month of the year (°C), and C is a compensation parameter, used if the climate is too continental or too oceanic, so that the I_{tc} values for any part of the world can be significantly compared (Rivas-Martínez et al. 2004 b).

The annual ombrothermic index (I_o) aims at expressing the average annual availability of water to plants, by including in its formulation the reduction in rainfall efficiency with increasing temperatures:

$$I_o = P_p / T_p,$$

where P_p is the total rainfall (mm) of all months with positive average temperature and T_p is the sum of the monthly average temperature of all months with positive average (°C) (Mesquita , Sousa 2009).

Positive temperature (T_p) is again a thermic index, used for defining thermotypes thresholds when the temperatures are particularly low:

$$T_p = \Sigma\, T_i,$$

where T_i is the monthly average temperature of any month with positive average temperature in tenths of degrees Celsius (Mesquita, Sousa 2009).

Multivariate analysis

Vegetation analysis was performed by correspondence analysis using Minitab 16 software. The variables were introduced in a form of codes in order to facilitate the reading of output ordinations. These codes were represented by lowercase letters taken from the vernacular name of the taxa present and identified from the flora of Quezel and Santa (1962). For example, species *Tamarix gallica* was assigned the code (Ta ga) (Ghezlaoui, Benabadji 2018). Presence and absence data were used in the correspondence analysis.

Two-dimensional (Axis 1 – 2) species ordinations were produced and eigenvalues and inertia values.

Results and discussion

Bioclimatic synthesis

The climatic characteristics at the meteorological stations used in this study are presented in Table 2. The Mediterranean macrobioclimate was the dominant pattern, with a wide range of bioclimate variation that included Mediterranean pluviseasonal-oceanic, Mediterranean xeric-oceanic and Mediterranean xeric continental types. Four thermotypic horizons and three ombrotypic horizons were identified (Table 2).

Almost all the meteorological stations in the Tlemcen region had an oceanic xeric Mediterranean bioclimate for both periods, which was characterized by high continentality, low rainfall during the growing season or months with average temperature > 0 °C, and long dry season duration of 4 to 12 months (Rivas-Martínez et

Table 2. Climatic data of the study area in the reference meteorological stations. T, mean annual temperature ; T_{min}, minimum temperature; T_{max}, maximum temperature; P_p, total rainfall (mm) of all months with positive average temperature; I_c, thermicity index; I_{tc}, compensated thermicity index; Io, annual ombrothermic index; T_p, sum of the monthly average temperature of all months with positive average

Station	Year	T (°C)	T_{min}	T_{max}	P_p	I_c	I_{tc}	I_o	T_p	Bioclimate	Ombrotype	Thermotype
Béni Saf	1913 – 1938	18.15	9.10	29.30	371.00	20.2	565.5	1.70	217.80	Mediterranean xeric-oceanic	Semiarid upper	Infra mediter-ranean lower
	1980 – 2013	18.93	10.34	30.30	389.07	19.96	595.7	1.71	227.16	Mediterranean xeric-oceanic	Semiarid upper	Thermotropical upper
Zenata	1913 – 1938	15.91	6.70	32.00	474.00	25.3	546.1	2.48	190.92	Mediterranean pluviseasonal oceanic	Dry lower	Infra mediter-ranean lower
	1980 – 2013	19.95	5.47	33.06	340.57	27.59	584.8	1.42	239.40	Mediterranean xeric-continental	Semiarid lower	Thermotropical upper
Hammam Boughrara	1913 – 1938	16.82	3.00	26.96	418.00	23.96	467.8	2.07	201.84	Mediterranean xeric-continental	Dry lower	Infra mediter-ranean upper
	1977 – 2013	17.09	3.46	34.89	297.28	31.43	554.4	1.45	205.08	Mediterranean xeric-continental	Semiarid lower	Infra mediter-ranean lower
Sebdou	1913 – 1938	16.71	3.80	36.70	326.00	32.90	572.1	1.62	200.52	Mediterranean xeric-continental	Semiarid upper	Infra mediter-ranean lower
	1981 – 2011	23.77	3.97	36.80	300.5	32.83	645.5	1.05	285.24	Mediterranean xeric-continental	Semiarid lower	Thermotropical lower
El Aricha	1913 – 1938	13.67	–1.50	35.60	296.80	37.10	477.7	1.81	164.04	Mediterranean xeric-continental	Semiarid upper	Infra mediter-ranean upper
	1984 – 2009	14.57	0.00	32.94	198.00	32.94	475.1	1.13	174.84	Mediterranean xeric-continental	Semiarid lower	Infra mediter-ranean upper

al. 1997). The exception was Zenata station, which had a bioclimatic Pluvi seasonal Mediterranean-continental, characterized by great continentality, relatively high rainfall during the growing season or months with average temperature > 0 °C, and at least two consecutive dry summer months (Rivas-Martínez et al. 1997). This type of climate results in lower plant cover and floristic diversity, and development of halophilic vegetation (Tamaricaceae). Halophytes can also inhabit drier bioclimatic environments (Benabadji, Bouazza 2000).

Floristic composition

In total, 195 taxa at the four sites were recorded (Table 3). This richness was similar to that in the region of Tlemcen (Ghezlaoui, Benabbadji 2018). The taxa belonged to 42 botanical families. The most represented families were Asteraceae (31 taxa, 15.9%), Poaceae (30 taxa, 15.38%), Chenopodiaceae (15 taxa, 7.69%) and Lamiaceae with a total of 13 taxa (6.67%) (Fig. 2). Other families like Brassicaceae, Fabaceae and Liliaceae were moderately represented with 11, 11 and eight taxa respectively. The other families were poorly represented and accounted less than seven taxa. Asteraceae, Poaceae and Chenopodiaceae species are adapted to the arid and semi-arid environment in the Mediterranean regions (Ozenda 1983). In Oranie, a study on the floristic composition of the halophilic and salt-resistant plant population mention, dominance of the these plant families was also observed in the region of Hammam-Boughrara (Sari-Ali et al. 2012).

Biological types

The abundance of species by Raunkiaer life form (1934) was as follows: therophytes > chamaephytes > hemicryptophytes > phanerophytes > geophytes, with a clear predominance of therophytes (97 species, or 49.74%; Fig. 3). Indeed, the dominance of therophytes indicates resistance to dry periods at high temperatures and is characteristic of Mediterranean vegetation in arid and semi-arid zones (Quezel 2000). It is thought that therophytes have a strategy of adaptation to adverse conditions by resistance to climatic extremes like summer drought in the Mediterranean context (Daget 1980; Madon, Medail 1997). Chamaephytes were the second most abundant life form with 49 species (25.13%). The prevalence of chamaephytes can be explained by good adaptation to arid conditions (Raunkiaer 1934; Floret et al. 1990). Grazing by animals favours establishment of species that are not grazed by the herds (Benabadji et al. 2004). Hemicryptophytes came in third place with 10.77%, which can be explained by low content of organic matter in soil (Le Houerou 1979). Phanerophytes and geophytes are less represented in the study area with respectively 7.69% and 6.67% of species, which could be explained by arid climatic conditions of the study area and the structural instability of the soil, which favours the development of species with

Table 3. List of plant species inventoried in the study area with their families, biological types, and biogeographical types

Families	Species according to Quezel and Santa (1962 – 1963)	Code	Biological type	Biogeographical type
Asteraceae	*Artemisia herba-alba* Asso.	Art her	CH	Asie-occid
	Astragalus pentaglottis L.	As pe	TH	Méd
	Asteriscus maritimus (L). Less	As ma	TH	Canaries.Eu. Mérid.N.A
	Atractylis cancellata (L).	At ca	CH	Circum-méd.
	Atractylis humilis L.	At hu	HE	Ibéro-Maur
	Atractylis serratuloides Sieb.	At se	CH	Sah
	Bellis annua L.	Be an	HE	Circum-Méd
	Bellis silvestris L.	Be sy	TH	Circum-Méd
	Calendula arvensis L.	Ca ar	TH	Sub-Med
	Centaurea pullata L.	Ce pu	TH	Méd
	Chrysanthemum coronarium L.	Ch co	TH	Méd
	Chrysanthemum grandiflorum (L.) Batt.	Ch gr	TH	End
	Echinops spinosus L.	Ec sp.	CH	Sub. Méd. Sah.
	Evax pygmaea (L.) Brot.	Ev py	TH	Circum méd
	Filago spathulata Presl	Fi sp	TH	Méd
	Galactites tomentosa (L.) Moench	Ga to	CH	Circum bor
	Launaea resedifolia O.K.	La re	HE	Méd.-Sah-Sind
	Micropus bombicinus Lag.	Mi bo	TH	Euras. N.A. Trip
	Pallenis spinosa (L.).Cass.	Pa sp	CH	Eur-Méd
	Scorzonera undulate Vahl.	Sc un	HE	Méd
	Taraxacum microcephalum Pomel.	Ta mi	TH	Méd
Poaceae	*Aegilops triuncialis* L.	Ae tr	TH	Méd-Irano-Tour
	Agropyrum repens (L.) P .B. p. p.	Ag re	TH	Circum-bor
	Ampelodesma mauritanicum (Poiret) Dur. et Sch.	Am ma	CH	W.Méd
	Anagallis arvensis L.	An ar	TH	Sub-Cosmop
	Avena alba Vahl	Av al	TH	Méd-Iran-Tour
	Avena sterilis L.	Av st	TH	Macar-Méd-Irano-Tour
	Brachypodium distachyum (L.) P .B.	Br di	TH	Paleo-sub-Trop
	Bromus rubens L.	Br ru	TH	Paleo-sub-Trop
	Cistus albidus L.	Ci al	CH	Méd
	Echinaria capitata (L.) Desf.	Ec ca	TH	Atl - Méd
	Glyceria fluitans (L.) R. Br.	Gl fl	TH	Sub-Cosmop
	Hordeum murinum L.	Ho mu	TH	Circum bor
	Koeleria phleoides (Vill.) Pers.	Ko ph	TH	Sub - cosm
	Koeleria pubescens (Lamk.) P. B.	Ko pu	HE	W. Méd
	Lygeum spartum L.	Ly sp	GE	W.Méd.
	Phalaris bulbosa L.	Ph bu	TH	Macar-Méd
	Poa bulbosa L.	Po bu	TH	Paléo -Temp
	Puccinellia maritima (Huds.) Parl.	Pu m	HE	Euras
	Schismus barbatus (L.) TheIl.	Sc bar	TH	Macar-Méd
	Stipa tenacissima L.	St te	GE	Ibero-Maur
	Vulpia ciliata Link.	Vu ci	CH	Méd-Irano-Tour
Chenopodiaceae	*Arthrophytum scoparium* (Pomel) Iljin	Ar sc	CH	Sah -Med
	Atriplex dimorphostegia Kar. et Kir.	At di	CH	Sah-Sind.
	Atriplex halimus L.	At ha	CH	Cosmop
	Beta macrocarpa Guss.	Be ma	GE	Méd
	Chenopodium album L.	Ch al	TH	Cosmop
	Halogeton sativus (L.) Moq.	Ha sa	TH	W.Méd.
	Noaea mucronata (Forsk) Asch et Schw.	No mu	CH	Méd-Iran-Tour
	Salsola foetida Del.	Sa fo	TH	Sah-Sind
	Salsola vermiculata L.	Sa ver	CH	Sah-Méd

Table 3. *continued*

Families	Species according to Quezel and Santa (1962 – 1963)	Code	Biological type	Biogeographical type
Chenopodiaceae	*Suaeda fruticosa* L.	Su fr	CH	Cosm
Lamiaceae	*Ballota hirsuta* Pomel	Ba hi	TH	Ibéro-Maur
	Lavandula dentata L.	La de	CH	W.Méd
	Lavandula multifida L.	La mu	CH	Méd
	Salvia verbenaca (L.) Briq.	Sa ver	HE	Méd-Atl
	Marrubium vulgare L.	Mar vu	HE	Cosmop
	Teucrium polium subsp. *capitatum* L.	Te po	CH	Eur-Med
	Teucrium pseudochamaepitys L.	Te ps	TH	W - Méd
	Thymus ciliatus subsp *coloratus* Desf.	Th ci	CH	End. N.A
Brassicaceae	*Alyssum campestre* L.	Al ca	TH	Méd
	Erucaria uncata (Boiss.) Asch. et Sch w.	Er un	TH	Sah-Sind.
	Eruca vesicaria (L.) Car.	Er ve	HE	Méd
	Lobularia maritima (L.) Desv.	Lo ma	TH	Méd
	Matthiola longipetala (Vent.) OC.	Ma lo	CH	Méd.-Sah.-Sind
	Muricaria prostrata (Desf.) Desv.	Mu pr	TH	End. N.A
	Raphanus raphanistum L.	Ra ra	TH	Méd
	Sinapis arvensis L.	Si ar	TH	Paléo-temp
	Sisymbrium runcinatum Lag.	Si ru	TH	Méd.-Iran-Tour
Fabaceae	*Astragalus epiglottis* L.	As ep	TH	Méd
	Calycotome spinosa (L.) Lamk	Ca sp	CH	W.Méd
	Medicago arborea L.	Me ar	CH	Méd
	Medicago minima Grufb.	Me mi	TH	Eur.-Méd
	Medicago rugosa Desr.	Me ru	TH	Cosmp
	Medicago truncatula Gaertn.	Me trun	TH	Méd
	Trifolium angustifolium L.	Tr an	TH	Méd
	Trifolium stellatum L.	Tr st	TH	Méd
	Trigonella polycerata L.	Tr po	TH	Ibéro-Maur
Liliaceae	*Asparagus acutifolius* L.	As ac	GE	Méd
	Asparagus albus L.	As al	GE	W.Méd
	Asparagus stipularis Forsk.	As st	GE	Macar-Méd
	Asphodelus microcarpus Salzm. et Viv.	As mi	GE	Canar-Méd
	Urginea maritima (L.) Baker	Ur ma	GE	Canar.Méd.
Cistaceae	*Cistus albidus* L.	Ci al	TH	Cosmop
	Cistus villosus L.	Ci vi	CH	Méd
	Helianthemum apertum Pomel	He ap	TH	End. N.A
	Helianthemum cinereum subsp. *rubellum* (Presl.) M.	He ci	HE	Eur. Mérid (sauf france). N.A
	Helianthemum hirtum Mill.	He hi	CH	N.A
Apiaceae	*Bupleurum semicompositum* L.	Bu se	TH	Méd
	Daucus carota L. (*sensu lato*)	Da ca	TH	Méd
	Eryngium triscuspidatum L.	Er tr	TH	W.Méd
	Thapsia garganica L	Th ga	CH	Méd
Plantaginaceae	*Plantago albicans* L.	Pl al	TH	Méd
	Plantago lagopus L.	Pl la	HE	Méd
	Plantago ovata Forssk.	Pl ov	TH	Méd
Zygophyllaceae	*Fagonia arabica* L.	Fa ar	TH	Sah-Sind
	Fagonia cretica L.	Fa cr	TH	Méd
	Peganum harmala L.	Pe ha	CH	Méd
Tamaricaceae	*Tamarix boveana* Bunge	Ta bo	PH	Sah
	Tamarix gallica L.	Ta ga	PH	N.Trop
Boraginaceae	*Echium pycnanthum* subsp. *humile* (Desf.) Jah. et M.	Ec py	TH	Méd. Sah
	Echium vulgare L.	Ec vu	HE	Méd

Table 3. *continued*

Families	Species according to Quezel and Santa (1962 – 1963)	Code	Biological type	Biogeographical type
Malvaceae	*Malva aegyptiaca* L.	Ma ae	CH	Sah-sub-Med
	Malva sylvestris L.	Ma sy	TH	Euras
Euphorbiaceae	*Euphorbia exigua* L.	Eu ex	TH	Méd. Eur
	Euphorbia falcata L.	Eu fa	TH	Méd. As
Caryophyllaceae	*Herniaria hirsuta* L.	He hi	TH	Paleo -Temp
	Paronychia argentea (Pourr.) Lamk.	Pa ar	CH	Méd
Oxalidaceae	*Oxalis corniculata* L.	Ox co	TH	Cosmp
	Oxalis pes-caprae L.	Ox pe	TH	Méd
Ranunculaceae	*Adonis dentata* Del.	Ad de	TH	Méd
	Ceratocephalus falcatus (L.) Pers.	Ce fa	TH	Méd-Iran-Tour
Anacardiaceae	*Pistacia lentiscus* L.	Pi le	PH	Méd
Géraniaceae	*Erodium moschatum* (Burm.) L'Her.	Er mo	TH	Méd
Pinaceae	*Pinus halepensis* L.	Pi ha	PH	Méd
Convolvulaceae	*Convolvulus althaeoïdes* L.	Co al	TH	Macar-Méd
Primulaceae	*Anagallis arvensis* L.	An ar	TH	Sub-Cosmop
Resedaceae	*Reseda alba* L.	Re al	TH	Euras
Rhamnaceae	*Ziziphus lotus* (L.) Desf.	Zi lo	PH	Méd
Thymeleaceae	*Daphne gnidium* L.	Da gn	CH	Méd
Rosaceae	*Sanguisorba minor* Scop.	Sa mi	TH	Euras
Globulariaceae	*Globularia alypum* L.	Gl al	CH	Méd
Papaveraceae	*Papaver rhoeas* L.	Pa rh	TH	Paléo-Temps
Apocynaceae	*Nerium oleander* L.	Ne ol	CH	Méd
Oleaceae	*Olea europea* L.	Ol eu	PH	Méd
Rutaceae	*Ruta chalepensis* L.	Ru ch	CH	Méd
Urticaceae	*Urtica membranacea* Poiret	Ur me	TH	Méd
Solanaceae	*Withania frutescens* Pauquy	Wi fr	CH	Ibéro-Maur
Myrtaceae	*Eucalyptus globulus* Labill.	Eu gl	PH	Aust-Méd
Crassulaceae	*Scabiosa stellata* L.	Sc st	TH	W.Méd
Araliaceae	*Hedera helix* L.	He he	TH	Eur-Méd
Mimosaceae	*Acacia albida* Del.	Ac al	PH	Af.Trop
Palmaceae	*Chamaerops humilis* L.	Ch hu	CH	Méd
Amaryllidaceae	*Agave americana* L.	Ag am	GE	Méd-Amér
Fagaceae	*Quercus ilex* L.	Qu il	PH	Méd

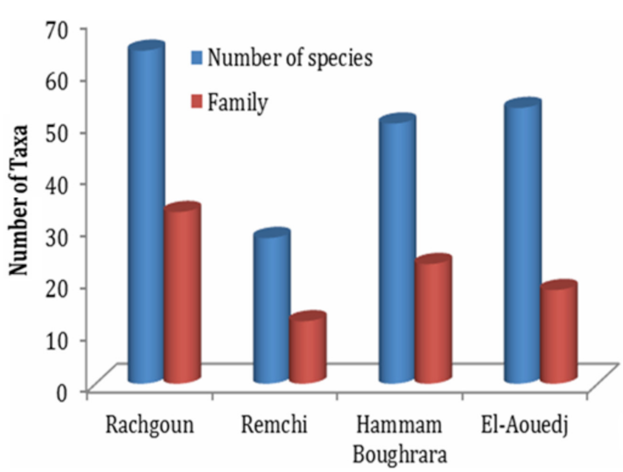

Fig. 2. Number of species and families in the different sites of the study area.

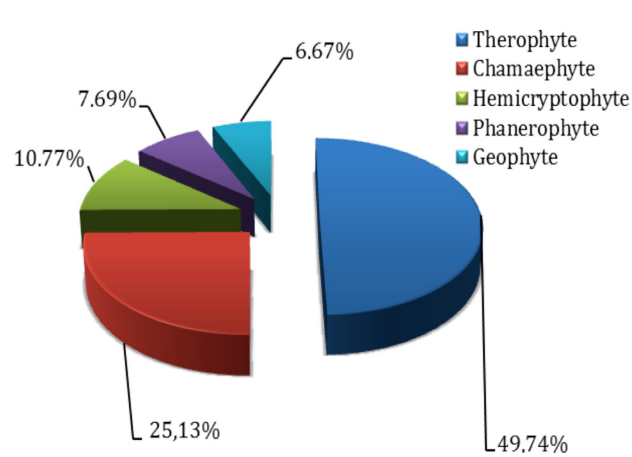

Fig. 3. Distribution of biological types in the study area.

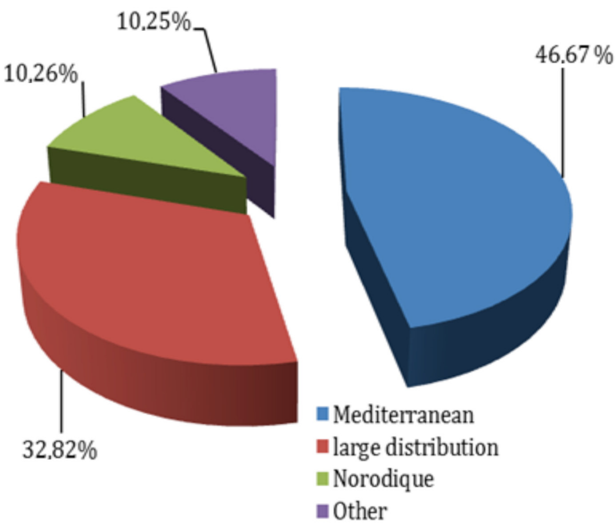

Fig. 4. Distribution of phytochoric elements in the study area.

a short life cycle and which are more or less demanding in terms of water and trophic needs (Ghezlaoui, Benabbadji 2018).

Chorological types

The analysis of the chorological spectrum of the region (Fig. 4) is generally marked by the predominance of the Mediterranean element (91 species, 46.67%). This reflects the global and logical affinity of our flora to the Mediterranean region and its climatic conditions (Quezel 1983; Le Houerou 1995). Taxa with a large distribution were second most numerous with 64 taxa (32.82%). The abundance of these species is generally related to therophytization of the Mediterranean flora caused by several ecological and anthropogenic factors (Miara et al. 2016). The Nordic taxa occupied the third position with a total number of 20 taxa (10.26%). This low number can be explained by the remote geographical location of northern Europe (Habib et al. 2020). The other elements are poorly represented but contribute to the diversity of the plant genetic potential in the study area.

The perturbation index in the four sites of study was 75.54%. This confirms the presence of therophytization in these regions by the dominance of therophytes and chamaephytes. Strong land degradation caused by man is clearly visible (clearing, grazing). Anthropogenic disturbances are largely responsible for the current vegetation structure in the Maghreb (Quezel, Barbero 1990). There have been many reports on disturbances caused by man and grazing, ranging from matorralisation through steppisation up to desertification (Berbero et al. 1990; Quezel 2000).

Correspondence analysis

Species ordinations (correspondence analysis) for the four sites are presented in Figs. 5 to 8, which show groups of species with similar ecological affinities (Aboura et al. 2006) to environmental factors (edaphic, nitrates, humidity) and form ecological gradients (Ghezlaoui et al. 2013). The first two axes explained most of the variation. For each ordination, the proportion of inertia (percentage variation explained) was calculated (Azzaoui et al. 2017).

Analysis of data for Rachgoun site is shown in Fig. 5 and Table 4 (value 2.30, inertia 22.61%). Species at the top of the ordination included the post-cultural species (*Sinapis arvensis*) and halophyte (*Tamarix gallica, Atriplex halimus*). The presence of monospecific stands of *Atriplex halimus*

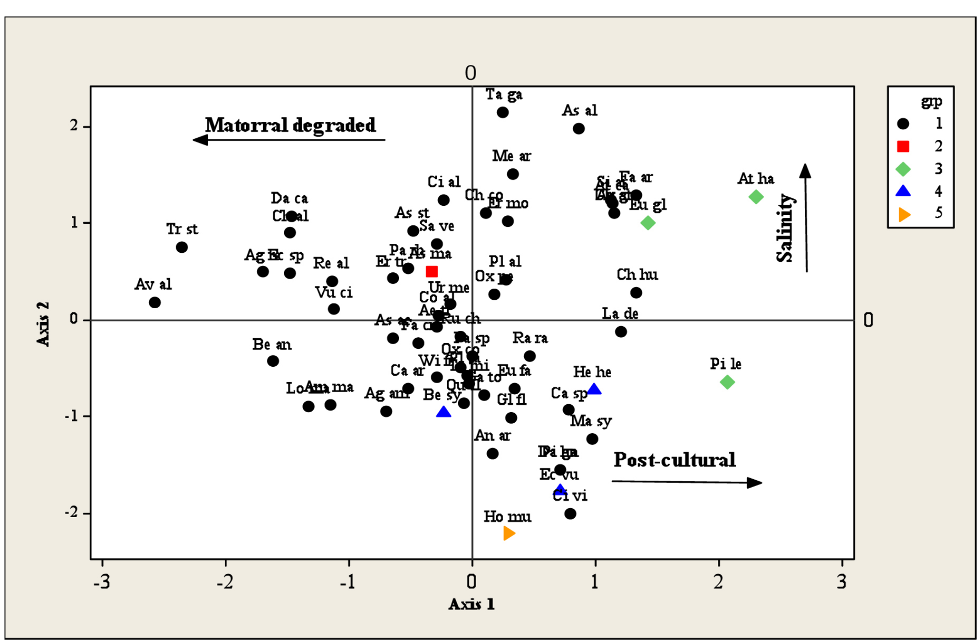

Fig. 5. Factorial plane of species Axis 1 – Axis 2 (Rachgoun site).

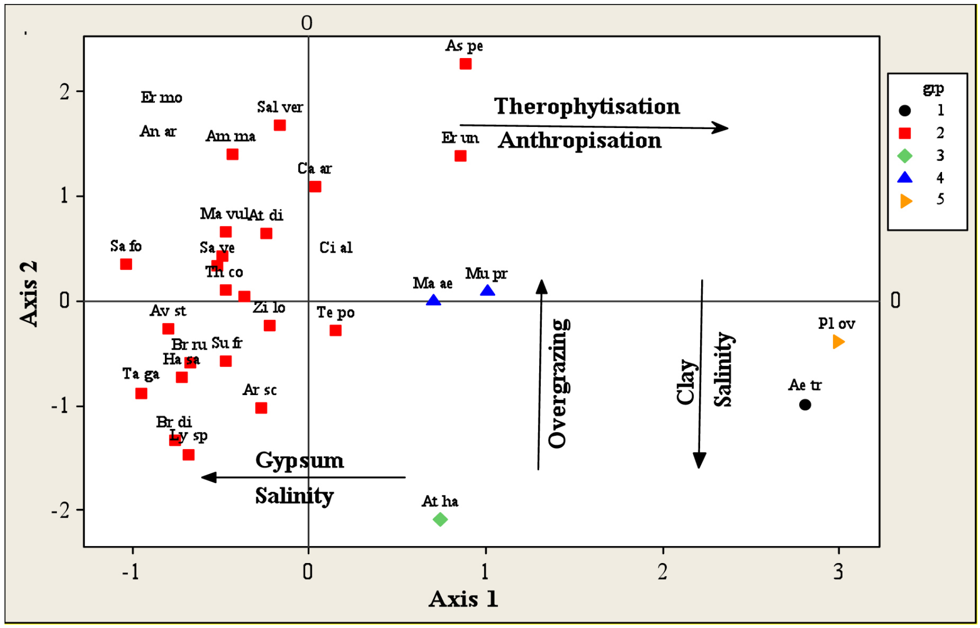

Fig. 6. Factorial plane of species Axis 1 – Axis 2 (Remchi site).

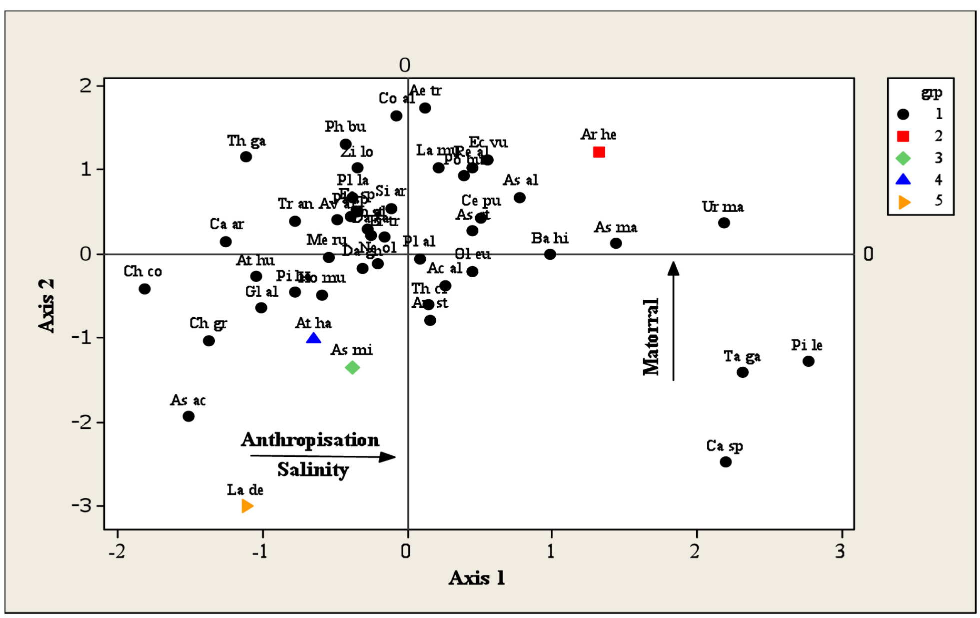

Fig. 7. Factorial plane of species Axis 1 – Axis 2 (Hammam Boughrara site).

or Tamarix gallica suggest higher salinity (Sari et al. 2012). Tamarix gallica is a very abundant plant, especially on the Mediterranean coast in beds of the river due to suitable moisture and salinity conditions (Ben-daânoun 1981). The presence of xerophyte species like *Asparagus albus* indicates anthropogenic action.

Pre-forest species such as *Lobularia maritima* were grouped on the bottom or left side of the ordination. Moreover, an increasing gradient of humidity from the top to bottom of the ordination was suggested by the presence of pre-forest species like *Malva sylvestris* at the bottom of the ordination.

Analysis of data for Remchi site is shown in Fig. 6 and Table 4 (value: 7.33, inertia 36.7%). This axis appeared to be characterized by a gradient of gypsum going from the right to left side of the ordination, and therophytisation the opposite direction.Terophytization can be explained by the ultimate stage of ecosystem degradation with sub-nitrophilic species associated with overgrazing and fertilizer residue (Barbero et al. 1981). Indeed, annual species (such as *Plantago ovata, Astragalus* sp., *Pentaglottis* sp.) represent the classes of *Thero-Brachypodietea* (Braun-Blanquet 1947) and *Stellarietea mediae* (Braun-Blanquet 1931).

Teucrium polium occurs in the centre of the ordination

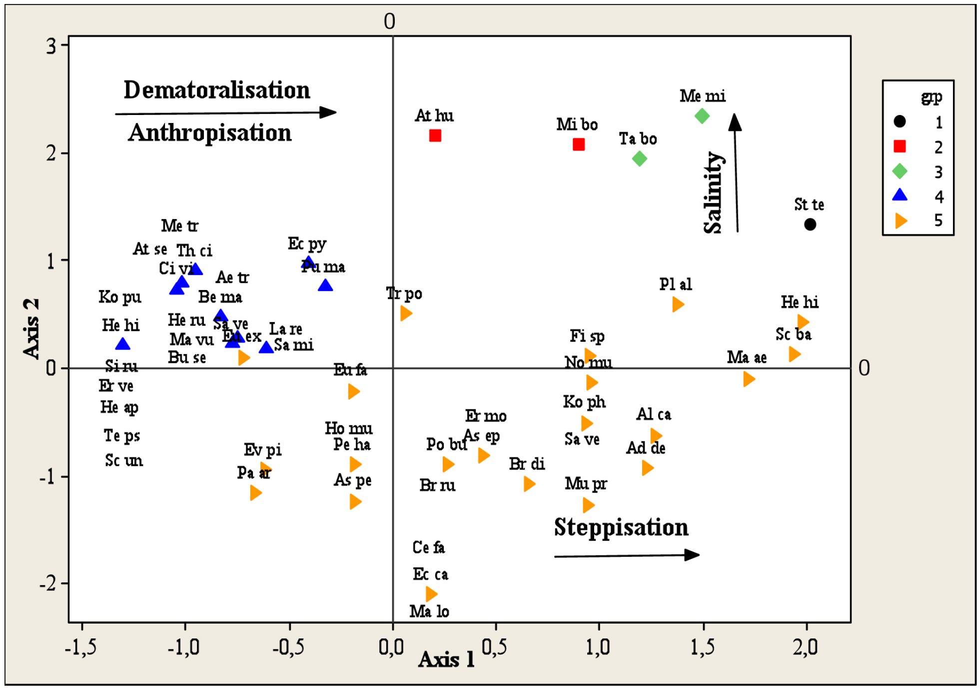

Fig. 8. Factorial plane of species Axis 1 – Axis 2 (El-Aouedj site).

and shows absolutely no affinity to any gradient. Halophyte species (such as *Suaeda fruticosa, Salsola foetida*) were grouped on the left side of the ordination and indicated an increasing salinity gradient to the left. These species are characteristic of *Atriplico halimi-Suaedetum fruticosae* ass. nov. (Aimé 1991) and *Salsolo-Peganion* alliance, which include mostly annual therophytes said nitratophiles (Sari-Ali et al. 2012).

Analysis of data for Hammam Boughrara site is shown in Fig. 7 and Table 4 (value 2.55, inertia 22.60%). The species *Lavandula dentate* and *Asphodelus microcarpus* were located at the bottom left of the ordination. These species are associated with low level of anthropization of the environment. Human action is also indicated

Table 4. High contribution taxa for the Axis 1 and Axis 2 of the factorial analysis of correspondence

Site	Positive pole	Negative pole
Rachgoun	*Atriplex halimus* (2.29)	*Avena alba* (–2.58)
	Sinapis arvensis (1.12)	*Trifolium stellatum* (–2.35)
	Malva sylvestris (0.96)	*Agave americana* (–0.69)
	Asparagus albus (0.86)	*Aegilops triuncialis* (–0.29)
	Tamarix gallica (0.24)	*Ampelodesma mauritanicum* (–0.15)
Remchi	*Plantago ovata* (2.99)	*Salsola foetida* (–1.03)
	Aegilops triuncialis (2.81)	*Tamarix gallica* (–0.94)
	Astragalus pentaglottis (0.88)	*Lygeum spartum* (–0.67)
	Atriplex halimus (0.74)	*Suaeda fruticosa* (–0.46)
	Teucrium polium (0.15)	*Atriplex dimorphostegia* (–0.24)
Hammam Boughrara	*Urginea maritima* (2.18)	*Thapsia garganica* (–1.10)
	Asteriscus maritimus (1.44)	*Lavandula dentate* (–1.10)
	Artemisia herba-alba (1.33)	*Atractylis humilis* (–1.04)
	Asparagus albus (0.78)	*Asphodelus microcarpus* (–0.38)
	Aegilops triuncialis (0.12)	*Atriplex halimus* (–0.33)
El–Aouedj	*Schismus barbatus* (1.93)	*Teucrium pseudo-chamaepitys* (–1.30)
	Malva aegyptiaca (1.71)	*Koeleria pubescens* (–1.30)
	Tamarix boveana (1.19)	*Cistus villosus* (–1.04)
	Noaea mucronata (0.95)	*Thymus ciliatus* (–0.95)
	Poa bulbosa (0.26)	*Astragalus pentaglottis* (–0.18)

by the presence of thorny and/or toxic species that are nonpalatable to cattle. The anthropization gradient from left to right was indicated by the presence of *Asphodelus microcarpus*, a non-palatable species on the left side of the ordination. The presence of *Urginea maritima*, an anthropozoic species, on the right side of the ordination indicated a particularly disturbed environment. This species is associated with ruderal communities that develop after prolonged overgrazing (Le Houerou (1995). *Atriplex halimus*, a perennial species with deep roots, has a great adaptation potential to develop in salt soils environments of very varied texture (Pouget 1980).

At the extreme left and below appear the species Scorzonera undulalta and lower still *Teucrium chamaepitys* species which occupies the stony slopes of the arid steppic or pre-steppic formations, indicates stable climax on substrates that are always highly saline and more often anthropogenic by intense grazing (Aimé 1991). They represent the ultimate state of dematoralization, which is trigger of steppization. Steppization causes a shift of vegetation from a forest to steppe type (Le Houerou 1995).

Analysis of data for the El-Aouedj site is shown in Fig. 8 and Table 4 (value 4.74, inertia 47.4%). On the right side of the orination indicated salinity (*Tamarix boveana*) and overgrazing (*Noaea mucronata*) gradients. The species *Noaea mucronata* characterizes the steppe and pre-steppe vegetation and a state of advanced degradation. These communities are stable climaxes on substrates that are always quite saline and most often anthropized by intensive grazing (Aime 1991). *Tamarix* appears to be an exogenous species in the area (introduced by reforestation in the 1970s), as Simonneau (1952) notes that "the phanerophytes or trees are mostly planted. Some, however, are subspontaneous". *Tamarix boveana* communities have been undergoing significant regression under the combined effect of climate and anthropogenic pressure. Currently, the *Tamarix* vegetation occurs around the Daya (Ghezlaoui et al. 2013).

On the left side of the ordination, there are steppe species of Mediterranean dry meadows (*Thymus ciliatus, Koeleria pubescens*). The gradients indicate anthropization related to cultivated plants (as *Hordeum murinum*) and therophitisation (as *Astragalus pentaglottis, Marrubium vulgare*). *Thymus ciliatus* subsp. *coloratus* is found on degraded soil with fine soil or limestone (Bouazza et al. 2001).

Conclusions

The application of the new global bioclimatic classification (Rivas-Martinez et al. 1993) in the study region made it possible to identify four thermotypic horizons and three ombrotypic horizons. The Mediterranean macrobioclimate was the dominant pattern, including a wide range of bioclimates such as the Mediterranean pluviseasonal-oceanic, Mediterranean xeric-oceanic and Mediterranean xeric continental (Ghezlaoui, Benabadji 2018).

Tamaricaceae plant communities in western Algeria contained 195 species, dominated by the Asteraceae and Poaceae. The study area was characterized by important plant diversity and there was significant variation in specific richness along the North-South ecological gradients. The study area is threatened by climate change and human activity, which have caused degradation. The study of plant communities with the genus *Tamarix* in western Algeria, which was based on correspondence analysis, made it possible to characterize three ecological gradients responsible for the distribution of these taxa at the level of the four sites. These gradients correspond to the following ecological factors: salinity, moisture, anthropization and therophytization. It is important to take into account these gradients in order to succeed in conservative management in these ecosystems (Chemouri et al. 2015).

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References

Aboura R. 2006. Phytoecological comparaison of Atriplexaie located in North and South of Tlemcen. Master Thesis. Tlemcen University, Algeria.

Aboura R., Benmansour D., Benabadji N. 2006. Phytoecological comparaison of Atriplexaie in en Oranie (Algeria). *Ecol. Mediter.* 32: 73–84.

Aime S. 1991. Ecological study of the transition between the sub-humid, semi-arid and arid populations in the thermo Mediterranean floor of the Oranian Tell (North-western Algeria). Ph.D. Thesis, Aix-Marseille III University, Marseille, France.

Azzaoui M.E., Maatoug M., Berrayah M. 2017. Phytoecological study of *Tetraclinis articulata* (Vahl) Mast.in the woodland of Beni Affene, Sdamas chergui (Tiaret, Algeria). J. *Fund. Appl. Sci.* 9: 971–987.

Barbero M., Quezel P., Rivas-Martinez S. 1981. Contribution to the study of forest and pre-forest groups in Morocco. *Phytocoenologia* 9: 311–412.

Babero M., Quezel P., Loisel R. 1990. Contributions of phytoecology in the interpretation of human induced changes and distibuances on Mediterranean ecosystems. *Mediter. Forest* 12: 194–216.

Baum B.R. 1978. *The Genus* Tamarix. Jerusalem Academic Press, Israel. 213 p.

Belkhoudja A. 2014. Diachronic study of formation at Tamaricaceae in the north of Tlemcen. Master Thesis. Tlemcen University, Algeria.

Benabadji N., Bouazza M. 2000. Contribution to a bioclimatic study of the steppe to *Artemisia herba-alda* Asso. in Oranie (Western Algeria). *Dry Rev.* 11: 117–123.

Benabadji N., Bouazza M., Metge G., Loisel R. 2004. The soils of the steppe at *Artemisia herba-alba* Asso. in south of Sebdou (Oranie, Algeria). *Synthesis* 13: 20–28.

Ben-daânoun M. 1981. Synecological and syndynamic study of the halophilic and hyrohalophilic vegetation of Bou-Regreg (Atlantic coast of Morocco). Application and development prospects. Ph.D. Thesis, Aix-Marseille III University, Marseille.

Bemmoussat F.Z. 2004. Bioclimatic and physionomic relationship of halophyte stands. Master Thesis. Tlemcen University, Algeria.

Bestaoui K. 2001. Contribution to a taxonomic and ecological study of matorrals in the region of Tlemcen. Magister Thesis. Tlemcen University, Algeria.

Bouazza M., Benabadji N., Loisel R. 2001. Assessment of the flora of Tlemcen region (Oranie - Algeria). *Mediter. Forest* 22: 130–136.

Braun-Blanquet J. 1931. Overview of the lower Langue-doc vegetation. *Sigma Communication* 9: 35–40.

Braun-Blanquet J. 1947. The vegetation cover in the Montpellier region and its relationship with soil. *Sigma Communication* N° 94.

Braun-Blanquet J. 1952. Applied Phytosociology. *Sigma Communication* N° 116.

Chemouri F.Z., Ghezlaoui-Bendi-Djelloul B., Benabadji N. 2015. Phyto-diversity of the vegetation of the Tlemcen Mountains (Western Algeria). *Rev. Ecol. Balkan.* 7: 1–11.

Daget PH. 1980. On botanical biological types as an adaptative strategy (case of therophytes). In: Barbault R., Blandin P., Meyer J. (eds) *Theoretical Ecology Research: Adaptative Strategies*. 110 p.

Djebaïli S. 1984. Phytosociological and phytoecological research on the vegetation of the high steppe plains and the Algerian Saharan Atlas. University Publications Office, Algiers. 177 p.

Floret C.H., Galan M.J., Le Floch H., Orshan G., Romane F. 1990. Growth forms and phenomorphology traits along an environmental gradient: tools for studying vegetation. *J. Veget. Sci.* 1: 71–80.

Ghezlaoui S.B.E. 2011. Biomorphology and polymorphism aerial devices of some halophytes in Oranie, case of *Atriplex halimus* L. and *Tamarix gallica* L.. Ph.D. Thesis, University of Tlemcen, Algeria.

Ghezlaoui S.B.E., Benabadji N., Benabadji N. 2013. Phytoecological and phytoedaphological characterization of steppe plant communities in the south of Tlemcen (Western Algeria). *Open J. Ecol.* 3: 495–504.

Ghezlaoui S.B.E., Benabadji N. 2018. The vegetation of the Tlemcen mountains (Algeria). Phytoecological aspect. *Bot. Complut.* 42 : 101–124.

Guinochet M. 1973. *Phytosociology*. Ecology collection, Masson Ed., Paris. 227 p.

Habib N., Regagba Z., Miara M.D., Ait Hammou M., Snorek J. 2020. Floristic diversity of steppe vegetation in the region of Djelfa, North-West Algeria. *Acta Bot. Malac.* 45: http://dx.doi.org/10.24310/abm.v45i0.7987

Hadj Allal F. 2013. Contribution to the study of the genus Tamarix: Botanical and phytoecological aspects in the region of Tlemcen. Magister Thesis. Tlemcen University, Algeria.

Hasnaoui O. 2008. Contribution to the study of the Chamaeropie in the region of Tlemcen. Ecological and mapping. Ph.D. Thesis, University of Tlemcen, Algeria.

Heywood V.H., Brummitt R.K., Culham A., Seberg O. 2007. *Flowering Plant Families of the World.* Kew Publishing, London. 424 p.

Khatibi R., Soltani S., Khodagholi M. 2016. Bioclimatic classification of central Iran using multivariate statistical methods. *Appl. Ecol. Environ. Res.* 14: 191–231.

Le Houerou H.N. 1979. Woody forage in North Africa: current state of knowledge. In: Le Houerou H.N. (ed) International Centre for Livestock in Africa Addis Abeba, pp. 57–67.

Le Houerou H.N.1995. Bioclimatology and Biogeography of the Arid Steppes of Northern Africa. Biological Diversity, Sustainable Development and Desertification. Mediter. Opt. Ser. B Res. Stud. 369 p.

Loisel R., Gamila H. 1993. Translation of the effects of brushwood on forest and pre-forest ecosystems by disturbances index. *Annals of the Society of Natural Sciences and Archaeology of Toulon and the Var* 45: 123–132.

Madon O., Médail F. 1997. The ecological significance of annuals on Mediterranean grassland (Mt Ventoux, France). *Plant Ecol.* 129: 189–199.

Mankolli H., Cekani M., Abazi U., Kopali A. 2009. Bioclimatic classifications in the ecosystem of Dajt-Tirana, Albania. *J. Int. Environ. Appl. Sci.* 4:119–124.

Merzouk A. 2010. Contribution to the phytoecological and biomorphological study of halophilic plant populations in the Oran region (Algeria). Ph.D. Thesis, University of Tlemcen, Algeria.

Miara M.D., Ait Hammou M., Hadjadj Aoul S., Dahmani W., Negadi M., Rebbas K., Bounar R., Smaili T. 2016. Note on therophytes in the mountains of Tiaret (massive of Guezoul-Western Algeria). *Environ. Ecol.* 12: 17–24.

Pouget M. 1980. Soil-vegetation relations in the Southern-Algiers region steppes. Ph.D. Thesis, Aix-Marseille III University.

Ozenda P. 1983. *Sahara Flora*. CNRS, Paris. 622 p.

Quezel P., Santa S. 1962-1963. *New Fflora of Algeria and Southern Desert Regions*. C.N.R.S., Paris. 1170 p.

Quezel P.J., Gamisans J., Gruber M. 1980. Biogeography and etablishment of Mediterranean flora. Naturalia Monspelientsia, Montpellier. Pp. 41–51.

Quezel P. 1983. Flora and current vegetation of North Africa, their significance according tothe origin of the evolution and migrations of flora and past vegetation structures. *Bothalia* 14: 411–416.

Quezel P., Barbero M. 1990. Mediterranean forests, problems posed by their ecological significance and conservation. *Acta Bot. Malac.* 15: 145–178.

Quezel P. 2000. *Reflection on the Evolution of Flora and Vegetation in Mediterranean Maghreb*. Ibis Press, Paris. 118 p.

Raunkiaer C. 1934. *The Life Form of Plants and Statistical Plant Geography*. Clarendon Press, London. 632 p.

Rivas-Martinez S. 1993. Bases for a new bioclimatic classification of the earth. *Folia Bot. Madriet.* 10: 1–23.

Rivas-Martínez S. 2004. Global bioclimatics (bioclimatic classification of the earth). Retrieved from http://www.globalbioclimatics.org/book/bi oc/global-Bioclimatics-0.htm.

Rivas-Martínez S. 2008. Global bioclimatics (bioclimatic classification of the earth). http://www.globalbioclimatics.org/book/bioc/global-bioclimatics2008-00.htm.

Rivas-Martinez S., Penas A., Diaz T.E. 2004a. Bioclimatic map of Europe-Bioclimates. Retrieved from http://www.globalbioclimatics.org/form/bi-med.htm.

Rivas-Martinez S., Penas A., Diaz T.E. 2004b. Bioclimatic map of Europe-Thermotypes. Retrieved from http://www.globalbioclimatics.org/form/tb-med.htm.

Rivas-Martínez S., Sáenz S.R., Penas A. 2011. Worldwide

bioclimatic classification system.*Global Geobot.* 1: 1–634.
Rivas-Martínez S., Penas A., Del Rio S., Rivas Sáenz S., García-Sancho L. 2015. New bioclimatic Antarctic data variants and thermotypes. *Int. J. Geobot. Res.* 5: 61–63.
Sari Ali A., Benabadji N., Ghezlaoui B.E., Bouazza M. 2011. Physignomic aspects of the halo-resistant and halophilic vegetation in Northern and Southern Western Algeria. *Mediter. Ser. Estud. Biol.* 22: 213–250.
Sari Ali A., Benabadji N., Bouazza A. 2012. Floristic composition of the halophilic and salt-resistant plant population in Hammam-Boughrara (Oran-Algeria). *Open J. Ecol.* 2: 96–108.
Villar J.L., Alonso M.Á., Juan A., Crespo M.B. 2014. The genus *Tamarix* (Tamaricaceae) in Crete (Greece). *Willdenowia* 44: 321–326.

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