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Floristic and phytogeographic study of the vegetation of Djebel Médjounes (Setifian High Plains, Algeria)

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ABSTRACT The floristic and phytogeographical study of the pre-forest vegetation of Djebel Médjounes allowed for the evaluation of the floristic dynamics under anthropogenic and natural pressures due to climate change. Of the 237 phytosociological surveys, 420 taxa belonging to 53 families and 226 genera were recorded. The floristic composition reveals 186 Therophytes (45.03%), 133 Hemicryptophytes (32.20%), 33 Geophytes (8%), 40 Chameophytes (9.68%), 19 Nanophanerophytes (4.84%), and 2 Microphanerophytes, or 0.24%of the floristic cohort. The best represented families in terms of genera and species are Asteraceae (73 species, 17.33%) and Poaceae (55 species, 13.06%). The rest of the families have less than 50 species: Fabaceae (26 species, 11.16%), Brassicaceae (25 species, 5.93%), Lamiaceae (24 species, 5.7%), Caryophyllaceae (18 species, 4.27%), Boraginaceae (17 species, 4.03%), Apiaceae (13 species, 3.08%), Cistaceae and Crassulaceae (12 species, 2.85%), Ranunculaceae (10 species, 2.37%). From a phytogeographical perspective, the Mediterranean element is relatively predominant with 244 species (85.37%), of which 37 endemic species were inventoried. The identified floristic diversity component is induced by strong anthropogenic pressure (overgrazing, fires, exploitation) in addition to a regression of precipitation.

KEY WORDS Phytogeographical diversity; phytodiversity; anthropization; Djebel Medjounes; Algeria.

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INTRODUCTION

Flora and vegetation are key elements for the study of biodiversity, their analysis allows for the evaluation of the state of ecosystems and helps in the development and implementation of conservation and protection strategies. The Mediterranean zone's forest heritage has been subjected to sustained decline for decades. Climate actions (summer drought, irregular rain), anthropogenic (deforestation, overgrazing) and fires are the main causes of the extension of shrublands and the emergence of pre-forest vegetation groups. Such evolution has caused the substitution of mesophytic vegetation with xerophytic vegetation to varying degrees (Quezel & Barbero, 1990). Some environments such as rocky environments (as cliffs and rocks) play a major role in the conservation of certain plants populations (Quezel, 1957; Vogel et al., 1999).

Although much work has been done on Algerian flora and vegetation (Dahmani, 1984, 1997; Madoui, 1987, 1995, 2017, 2019; Merikhi, 1987, 1995; Gharzouli et al., 1989, 2000, 2002, 2005a, 2005b, 2007; Djebaili et al., 1989; Laouar, 1995; Khaloufi, 1995; Chermat, 1998; Quezel, 1999a, b; Boulaacheb et al., 2000, 2004, 2005, 2006a, 2006b, 2009, 2007, 2011; Bounar et al., 2001, 2003, 2008, 2011, 2012; Sarri et al., 2000, 2002; Vela et al., 2007; Rebbas et al., 2012; Yahi et al., 2012, Chermat et al., 2013, Gherzouli, 2013; Rebbas, 2014, etc.), the vegetation of Djebel Medjounes (High Plateaus of Sétif), located in the north, remains little known. Like the rest of the country, this region is subjected to a Mediterranean climate which influences the vegetation formations in general and the shrub formations in particular. Rainfall is centered on the cold seasons, and a long or very long summer drought, lasting 2 to 7 or 8 months per year Quezel (2000).

The High Plateaus of Sétif (Algeria) due to their great climatic, geological and geographical diversity are a refuge for many endemic and northern species. The floristic studies of these localities are an important source of information and their knowledge allows for the development of a program for local, regional and national sustainable development and valorization that can be integrated into plans for the management and management of natural resources.

MATERIAL AND METHODS

Study area

The Djebel Medjounes (High Plateaus of Sétif) reaches an altitude of 1461 m and covers an area of 6,000 ha. It is located between the geographical coordinates 36°18’15” N Latitude and 5°31’17” E Longitude in DMS (degrees, minutes, seconds) or 36.3042° and 5.5214° (in decimal degrees) (Fig. 1).

The Djebel Medjounes is surrounded by a set of massifs, to the northeast the Djebels Moul el Djediane (1225 m) and Tamtarte (1008 m), to the northwest Djebel Chenatour (1370 m) and Djebel Senatour (1076 m); from East to West it is the Djebels Zerib (1317 m) and Zkarma (1361 m) and to the south the Djebels Mnaguer (1416 m) and Oulad Gues (1121 m).

The forest area is based on a mosaic of sedimentary formations from the Triassic, Cretaceous, Ter-

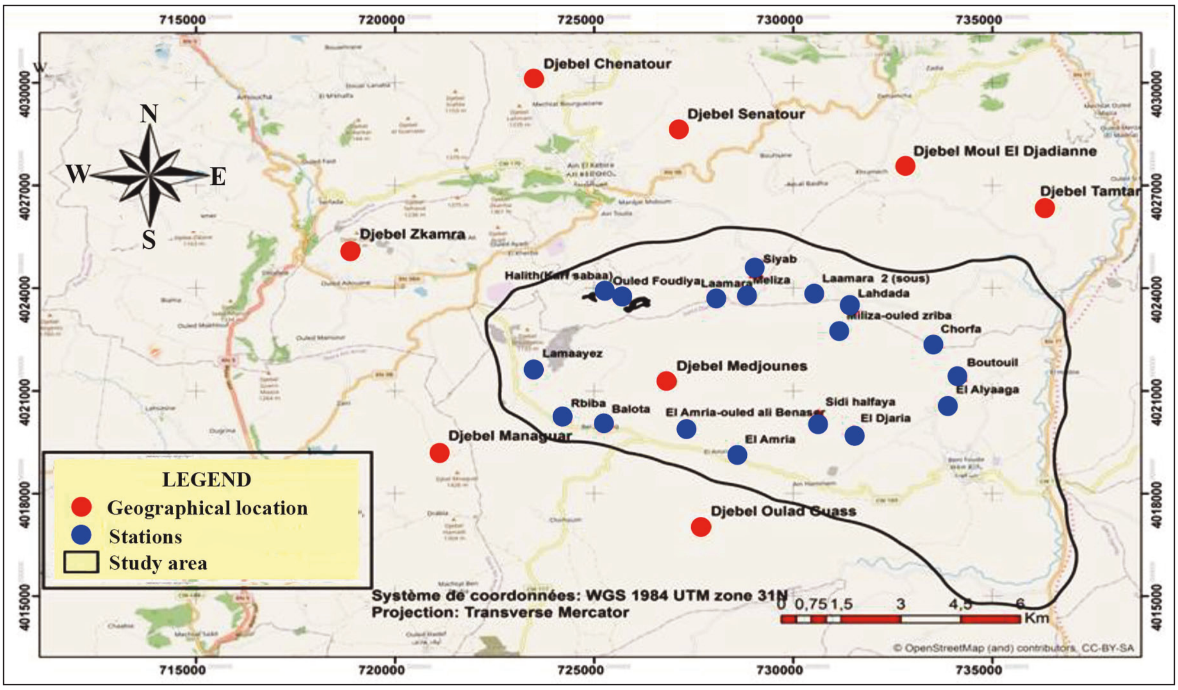

Figure 1. The study area's position in geographic terms (carried out by Gourari, 2020).

tiary, and Quaternary and are made up of an alternation of marls and calcareous marls (Vila, 1977, 1980). It is crisscrossed by numerous small alluvial and colluvial valleys. The hydrographic network consists of oueds such as oued Zatine, oued Dahab, oued Dahamcha, traversed by violent and frequent floods during the rainy season, are dry in summer.

The soils are calcimagnesic (rendzines, calcareous brown soils), raw and with little evolved minerals from erosion and input (M`Zoughem & Chenafa, 2006; Tedjar, 2011).

The study area receives 410 mm per year, the average calculated over a period of 32 years (1982–2020). The average monthly temperature is 15.48 °C, the coldest month is January with 2.03 °C, July is the hottest month with 33.67 °C. The dry season extends from May to September. According to the continentality index of Rivas-Martinez (1982, 2002), the climate is of the continental type (M-m = 31.64 °C), temperate-cool. Emberger's quotient (Q2) is equal to 51.48, with a semi-arid bioclimatic level with cold winters characterized by the concomitance of forest and steppe species (Le Houerou, 1995).

The study area is part of the mountain regions of the Tellian Atlas, the North African Mediterranean domain (Quezel, 1978) also called "Mauritanian Mediterranean" according to LAPIE (1909–1914) and Maire (1926) or "Maghrebian Mediterranean" according to Barry et al. (1976). According Meddour (2010) the study area belongs to the Maghrebo-Tellian domain, the Tello-Constantinian sector, and the Bibano Guelmois district.

Data collection and floristic inventory

The floristic inventory was carried out based on 237 phytosociological surveys according to the sigmatist method of Braun-Blanquet (1932) and according to a subjective sampling taking into account the vegetation structure (matorrals, garrigues, grasslands, steppes, cliffs) and ecological factors (altitude, exposure, and slope).

The surveys were carried out in 14 stations, 7 on the north slope (Laamaera, Ouled Foudiya, Chorfa, Meliza, Siyab, Lahdada, and Boutouil) and 7 on the south slope (Lamaaz, Ballota, Rbiba, Ouled Ali Benacer, El Amria, Dajaria, and Sidi Halfaya) (Fig. 2).

During the years 2016–2018, plant samples were collected from 14 stations located on the north and south slopes of the Djebel Medjounes mountain. The surface area of the surveys ranged from

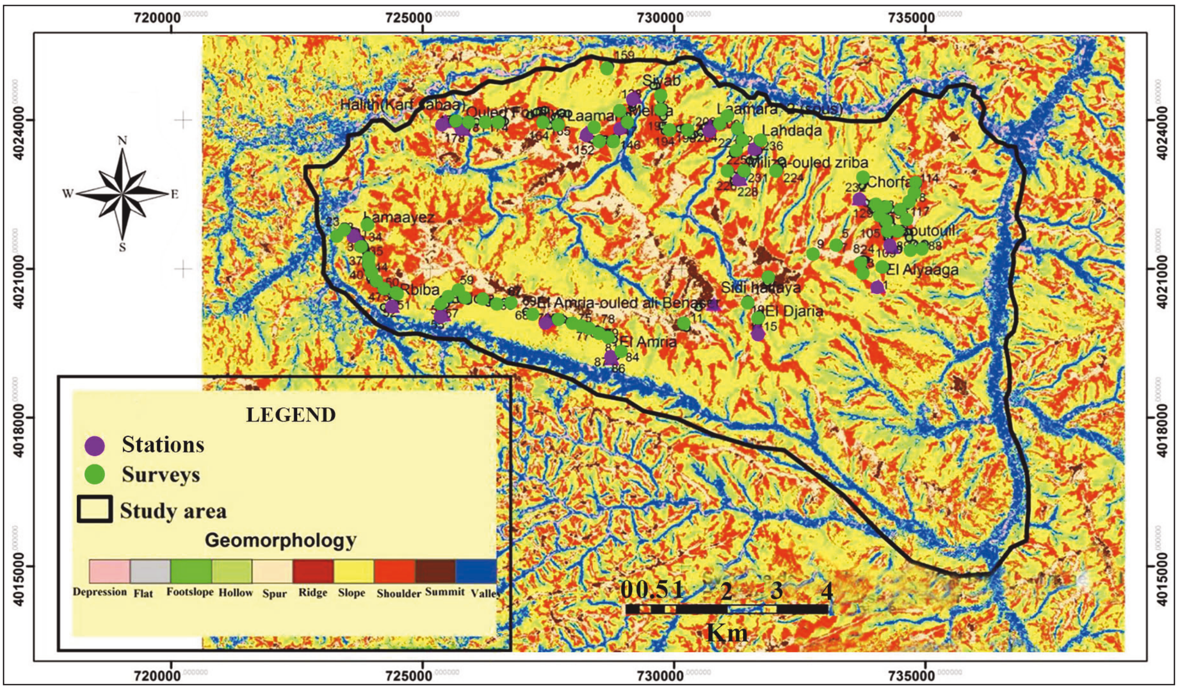

Figure 2. Location of the phytosociological surveys in Djebel Medjounes (Gourari & François, 2020).

10 m² for cliffs, 10–100 m² for rocky and barren grasslands, steppes, and 50–100 m² for shrublands. The plant samples were collected during all four seasons and the coordinates of the stations were recorded using GPS. The species samples were identified using the floras of Quezel & Santa (1962-1963) and Ozenda (1977) and the nomenclature used was based following Dobignard & Chatelain (2010–2013), Maire (1952–1987), and Chatelain et al. (2018). The classification of phytogeographic spectra was based on the work of Quezel & Santa (1962-1963), Le Floch et al. (1989), Le Houerou (1995), and Maire (1952–1987) and the biological types were defined according to the classification of Raunkiaer (1934). The rarity of species was based on the reference flora for Algeria (Quezel & Santa, 1962–1963).

RESULTS AND DISCUSSIONS

Floristic analysis

The inventory carried out using 237 surveys that listed 420 species belonging to 226 genera and 53 botanical families. The best represented families in terms of genera and species are Asteraceae (73 species and 47 genera, 17.33%) and Poaceae (55 species and 35 genera = 13.06%), followed by Fabaceae (26 species and 17 genera = 11.16%); Brassicaceae (25 species and 16 genera = 5.93%); Lamiaceae (24 species and 12 genera = 5.7%); Caryophyllaceae (18 species and 7 genera = 4.27%); Boraginaceae (17 species and 7 genera = 4.03%), Apiaceae (13 species and 8 genera = 3.08%); Cistaceae and Crassulaceae (12 species and 5 genera = 2.85%). The rest of the families have fewer than 10 species (Fig. 3). Asteraceae and Poaceae play a leading role on a global scale (Craven, 2009) and predominate in the Algerian flora (Quezel & Santa, 1962-1963). These results, whether for genera or species, are similar to those obtained by Gharzouli & Djellouli (2005), Bounar (2001), Boulaacheb et al. (2005), Gharzouli (2007) and Chermat et al. (2013).

The report states that the ratio of number of families to number of species is 13%. The generic coefficient, or the ratio of number of genera to number of species, is 54%. Analysis of the biological spectrum (Fig. 4) shows the dominance of therophytes (186 taxa = 45.03%). This richness in therophytes (*Guenthera amplexicaulis*, *Echinaria capitata*,*Calendula arvensis*, *Micropus supinus*, *Erodium cicutarium*, *Filago germanica*, *Bombycilaena erecta*, etc.) is a characteristic of arid Mediterranean areas where there is a high level of water stress (Daget, 1980; Madon & Medail, 1996). Hemicryptophytes represent 133 taxa, or 32.20%. Dahmani (1997), Barbero et al. (1988–2001), and Gharzouli (2007) report that their abundance in Maghreb countries is due to the richness of the soil in organic matter, altitude, and humidity (*Eryngium campestre*, *Thapsia garganica*, *Bupleurum spinosum*, *Eryngium triquetrum*, *Carduncellus pinnatus*, *Plantago lagopus*, *Teucrium polium* subsp. *capitatum*, etc.). Chamophytes are also wellrepresented (40 species = 9.68%). According to Orshan et al. (1984) and Floret et al. (1990), chamophytes are fairly resistant to ecological and anthropogenic constraints and are able to adapt to drought (*Artemisia herba-alba*, *Launaea acanthoclada*, *Carlina gummifera*, *Helianthemum cinereum* subsp. *rotundifolium*, *Fumana thymifolia*, *Cistus creticus*, *Sedum album*, *Thymus munbyanus* subsp. *munbyanus*, *Teucrium pseudochamaepitys*, etc.).

The number of chamophytes may indicate a steppe influence, which could lead to a regression in regional preforest formations. Geophytes (33 taxa = 8%) are represented by Asphodelaceae (*Asphodelus ramosus*, *Asphodelus tenuifolius*), Poaceae(*Ampelodesmos mauritanicus*, *Echinaria capitata*, *Hordeum bulbosum*), and Orchidaceae (*Ophrys speculum*, *Ophrys lutea*). Nanophanerophytes are more or less represented, constituting 20 taxa (= 4.84%): *Crataegus monogyna*, *C. azarolus*, *Prunus dulcis*, *Quercus ilex* subsp. *ballota*, *Asparagus acutifolius*, *Pistacia terebinthus*, *P. lentiscus*, *Ziziphus lotus*, *Clematis flammula*, *Thymelaea hirsuta*, *Calicotome spinosa*, *Retama raetam*, *Genista tricuspidate*, *Daphne gnidium*, *Rhamnus lycioides* subsp. *oleoides*, *Globularia alypum*, *Rosmarinus eriocalyx*, *Prunus spinosa*).

Despite their low specific diversity, nanophanerophytes sometimes play a determining role in the establishment of a specific flora due to their coverage (Le Compte Barbet, 1975).

Microphanerophytes only have one taxon (*Cupressus sempervirens*), or 0.24% of the flora, this biological type, reforested in the region, seems to be better adapted to desertification.

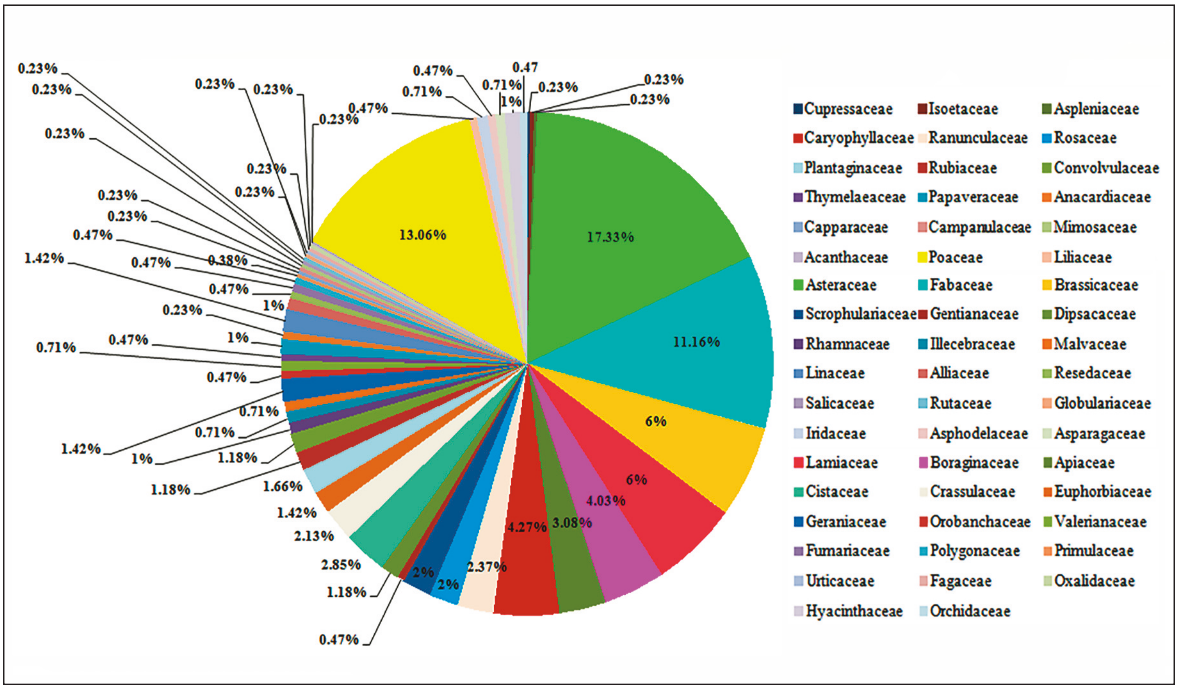

Figure 3. Percentages of plant families identified in Djebel Medjounes.

The floristic composition is of the type: Thero>Hemicrypt>Cham>Geo>Nanophan> Megaphan, which highlights strong human pressure (grazing,urbanization, fire) (Fig. 4). Barbero et al. (1990) and Quezel (2000) note that therophytization is considered to be a final phase of degradation of Maghreb forest and pre-forest ecosystems with sub-nitrophilic species related to overgrazing.

Phytogeographic analysis

Each phytogeographic region corresponds to a defined element (Ellenberg et al., 1967). The 420 recorded species are distributed in 7 chorological sets and 12 phytogeographic elements.

The Mediterranean chorotype is the most important in this flora with 183 species (44.96%); of these, 114 species are Mediterranean species sensu stricto (28% of the total number of species) and 26 species (6.14%) are distributed in Western Mediterranean area: *Linum suffruticosum*, *Catananche caerulea*, *Lygeum spartum*, *Cirsium echinatum*, etc. The circummediterranean elements include 9 species (2.21%): *Romulea bulbocodium*, *Ophrys speculum*, *Alkanna tinctoria*, *Stipa tortilis*, *Triticum turgidum*, etc. The Ibero-Mauritanian element, which encompasses the Mediterranean part of the Iberian Peninsula and the north of Morocco, Algeria and Tunisia, is present with 11 species (2.70%): *Onopordum acanthium*, *Santolina rosmarinifolia*, *Diplotaxis virgata*, *Bupleurum spinosum*, etc. The European chorotype has 26 species (6.38%). This element shows a disproportionate number of biological types with the complete absence of megaphanerophytes, which is probably due to degradation phenomena related to climate change and very ancient human impacts. The paleotemperate elements, which covers vast regions of the globe, represent 3.93% of the total flora (16 species): *Cerastium brachypetalum*, *Ranunculus arvensis*, *Papaver rhoeas*, *Papaver argemone*, *Campanula erinus*, etc.

The circumboreal elements have only 6 species (1.47%): *Myosotis debilis*, *Phleum pratense*, *Lolium perenne*, *Dactylis glomerata*. They are introduced to North Africa through two migration routes, one Iberian (Andalusian-Rifian bridge) and one Italian (Sicilian-Tunisian bridge), during the wetter periods earlier than the Quaternary (Maire, 1928). The rate of the European chorotype is relatively low (4 species = 0.98%); it is represented by the following species: *Echium vulgare*, *Euphorbia amygdaloides*, *Crepis sancta*, *Mentha piperita*.

The floristic composition is characterized by a high contribution (158 species = 38.82%) from the large distribution ensemble, which is a testament to the impact of human activityand the therophytisation of the flora (*Trifolium scabrum*, *Echinaria capitata*, *Geranium robertianum*, *Hippocrepis ciliata*, *Lathyrus sativus*, *Medicago minima*, *Vicia sativa*).

The cosmopolitan ensemble is well represented by 16 species (3.93%) and subcosmopolitan species count 2 species (0.49%). The species in this element have a very wide range of tolerance and are able to adapt to a wide range of ecological factors (*Avena sativa*, *Poa annua* subsp. *exilis*, *Sonchus arvensis*, *Sonchus oleraceus*, *Capsella bursa-pastoris*). They are mainly associated with moist environments, pastures, fields, and crops.

The transition ensemble consists of Mediterranean ensembles and neighboring ensembles. The largest group corresponds to Euro-Mediterranean species (48 species = 11.79%), including *Crataegus monogyna*, *Pallenis spinosa*, *Eryngium campestre*, *Fumana laevipes*, *Anisantha madritensis*, *Teucrium polium* subsp. *capitatum*, *Thapsia garganica*, etc. It is followed by the Eurasian element, which constitutes the major flora of temperate regions and plays an important role in the north of the Mediterranean. There are 30 species (7.37%) (*Torilis nodosa*, *Convolvulus arvensis*, *Geranium molle*, *Sedum album*, *Arenaria serpyllifolia*, etc.). The Mediterranean-Atlantic are 11 species 11 (2.70%) (*Salvia lanigera*, *Ornithogalum umbellatum*, *Echinaria capitata*, *Centaurea aspera*, *Matthiola sinuata*, etc.).

The Mediterranean and Irano-Turanian group includes 8 species (1.96%), the rate of which is explained by a steppic influence, especially on the south slope (*Eremopyrum orientale*, *Aegilops geniculata* subsp. *geniculata*, *Hordeum bulbosum*, *Vulpia ciliata*, *Diplotaxis harra* subsp. *harra*, *Sisymbrium runcinatum*, *S. irio*). The presence of the Saharo-Sindian-Mediterranean (7 species = 1.71%) and Saharo-Mediterranean (3 species = 0.73%%), *Micropus supinus*, *Erodium guttatum*, *Astragalus crenatus*, indicates the Saharan influence on this region. Their presence indicates the impact of climate change on the initial flora by favoring their installation.

The Euro-Siberian group is very poorly represented, with 4 species (0.98%): *Cichorium intybus*, *Carduus nutans*, *C. macrocephalus*, *Silene dioica*. Other categories are poorly represented with fewer than four species. The tropical ensemble is represented by 4 paleo-subtropical species (*Brachypodium distachyon*, *Gynandriris sisyrinchium*, *Anisantha rubens*, *Lolium rigidum*) and 2 subtropical species (*Muricaria prostrata* and *Matthiola lunata*). The endemic ensemble is present with 40 species, representing 9.50% of the total flora (Table 1): 28 North African endemics (6.65%), 3 Moroccan endemics (0.71%), 3 Algerian-Tunisian endemics (0.71%), 4 Algerian-Moroccan endemics (0.95%), and 2 Algerian endemics (0.47%).

There are 40 rare species, of which 21 (2.47%) are very rare (R), 10 (6.5%) are rare (AR), and 9 (3.1%) are fairly rare (RR) (Fig. 5). Of the 40 species, 8 are on the list of non-cultivated plant

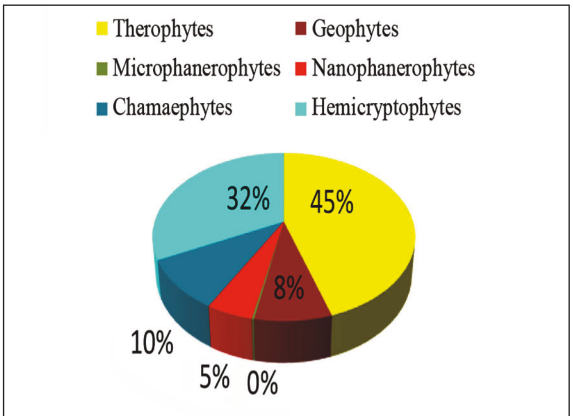

Figure 4. Rates of biological types identified in Djebel Medjounes.

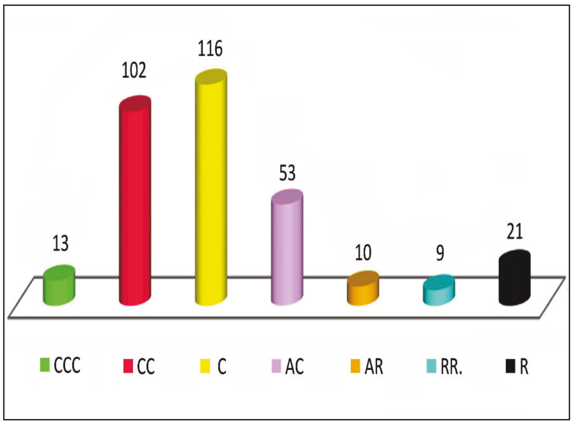

Figure 5. Attendance rate of species identified in Djebel Medjounes.

species protected by the Algerian law of January 4, 2012 (*Tragopogon porrifolius* subsp. *macrocephalus*, *Silene colorata* subsp. *amphorina*, *Lomelosia stellata*, *Thymus guyonii*, *Ononis natrix* subsp. *angustissima*, *Linum grandiflorum*, *Salix triandra*, *Linaria pelisseriana*).

Boulaacheb (2009) notes that ruderal, nitrophilic, and unpalatable species are indicators of disturbed and open habitats, signs of strong human activity. These include: *Ornithogalum umbellatum*, *Asphodelus ramosus*, *Asphodelus tenuifolius*, *Leontodon hispidus*, *Eryngium campestre*, *Eryngium bourgatii*, *Eryngium triquetrum*, *Sixalix atropurpurea*, *Galium odoratum*, *Galium fruticosum*, *Salvia lanigera*, *Salviaverbenaca*, *Plantago serraria*, *Plantago lanceolata*, *Plantago coronopus*, *Hypochaeris achyrophorus*, *Helianthemum nummularium*, *Helianthemum cinereum*, *Rumex crispus*, *Rumex bucephalophorus* subsp. *gallicus* f., *Trifolium stellatum*, *Trifolium glomeratum*, *Centaurea oranensis*, *Centaurea sphaerocephala*, *Minuartia montana*, *Centaurium pulchellum*, *Centaurium erythraea*.

On the south flank of the Djebel Medjounes mountain, we also observed the infiltration of steppe and Saharan plants, indicating the impact of

Species	Chorology	Species	Chorology
Astragalus froedinii Murb.	End. du Maroc	*Silene patula* subsp. *amurensis* (Pomel) Jeanmonod	End. N. A.
Bunium fontanesii (Pers.) Maire	End. N. A.	*Carduncellus pinnatus* (Desf.) DC.	End. N. A.
Sedum pubescens Vahl	End. N. A	*Thymus guyonii* de Noé	End. Alg.
Silene atlantica Coss. & Durieu	End. N. A.	*Cirsium palustre* (L.) Scop.	End. N. A.
Helianthemum ruficomum (Viv.) Spreng.	End. N. A.	*Atractylis caespitosa* Desf.	End. N. A.
Herniaria hirsuta L.	End. N. A.	*Leontodon hispidus* L.	End. N. A.
Echium horridum Batt.	End. N. A.	*Echium parviflorum* Moench	End. N.A.
Echium humile Desf.	End. N. A.	*Echium humile* subsp. *pycnanthum* (Pomel) Greuter & Burdet	End. N.A.
Paronychia arabica (L.) DC.	End. N. A.	*Origanum vulgare* subsp. *glandulosum* (Desf.) Ietsw.	End. N. A.
Galium tricornutum Dandy	End. N.A.	*Iberis odorata* L.	End. Alg. Mar.
Diplotaxis simplex (Viv.) Spreng.	End. N. A.	*Rhaponticum acaule* (L.) DC.	End. N. A
Hertia cheirifolia (L.) Kuntze	End. N. A.	*Delphinium pentagynum* Lam.	End. Alg. Tun
Hedysarum boveanum Bunge ex Basiner	End. N. A.	*Rosmarinus eriocalyx* Jord. & Fourr.	End. N. A.
Astragalus armatus Willd. subsp. *armatus*	End. N. A.	*Genista tricuspidata* Desf.	End. N. A.
Thymus munbyanus Boiss. & Reut. subsp. *munbyanus*	End. N. A.	*Gagea granatellii* (Parl.) Parl.	End. Alg.
Thymus broussonetii Boiss. subsp. *broussonetii*	End. du Maroc	*Hedysarum pallidum* Desf.	End. N.A.
Thymus munbyanus subsp. *ciliatus* (Desf.) Greuter & Burdet	End. N. A.	*Linum usitatissimum* L.	End. Alg. Mar.
Hippocrepis atlantica Ball	End. N. A.	*Linum bienne* Mill.	End. Alg. Mar.
Sinapis pubescens L.	End. Alg. Tun	*Vulpia alopecuros* (Schousboe) Dumort.	End. du Maroc
Tragopogon porrifolius L. subsp. *macrocephalus* Batt.	End. Alg. Mar.	*Linaria reflexa* (L.) Chaz. subsp. *brevicalcarata* D.A.Sutton	End. Alg. Tun.

Table 1. List of endemic species (End.) of North Africa, or limited to some of its regions, found in Jebel Medjounes.

climate change on one hand and over exploitation on the other hand: *Artemisia herba alba*, *Ajuga iva*, *Thymelaea hirsuta*, *Ziziphus lotus*, *Retama raetam*, *Stipa parviflora*, *Macrochloa tenacissima* , *Lygeum spartum*, *Anisantha rubens*, *Atractylis serratuloides*, *Lobularia canariensis* subsp. *rosula-venti*, *Erodium guttatum*, *Helianthemum ruficomum*, *Reseda arabica*, etc.

On the south slope, with a very high population density, the vegetation is characterized by herbaceous grasslands and rocky areas that provide information about the type of activity (pastoralism) and the degree of openness of the environment (Fig. 6).

On the contrary, the north flank with very low population density is more or less preserved. It is marked by the presence of woody plants and is characterized by matorrals with *Rhamnus alaternus* and matorrals with holm oak (Figs. 7, 8). Both slopes are characterized by the presence of Diss (*Ampelodesmos mauritanicus*) and *Calicotome spinosa*. These species result from the degradation of wooded matorrals with green oaks (Boulaacheb, 2005).

Mining in the north slope (Boutouil, Lahdada) is known by ecologists as a form of nature aggression in all its forms (Fig. 9).

Figure 6. Clear shrublands. South slope of ouled Ali Benaser.

Figure 7. Matorrals with gaps. North slope of Mliza.

CONCLUSIONS

The pre-forest vegetation of Djebel Médjounes is characterized by a very diverse flora with 420 species of which 40 endemic taxa. A significant number of species with medicinal value (63 species) could improve the income of local populations while ensuring the conservation of floral diversity. The biological spectrum generally corresponds to a characteristic pattern of Mediterranean pre-forest formations with the dominance of therophytes related to a increasing gradient of aridity in the northeastern Algerian High Plateaus.

The vegetation cover of this massif shows a strong contrast between the north slope where shrublands and garrigues dominate and degraded forms of shrublands and the south slope where stripped lawns formed of Saharan and steppe species dominate. Climate change and human pressure (overgrazing, harvesting) are the main causes of degradation of the Djebel Medjounes, causing a decline in species and a reduction in plant diversity.

This work on the plant diversity of the Djebel Medjounes provides a scientific basis for planning sustainable development linked to the preservation of this ecosystem and its heritage.

Figure 8. Matorrals. North slope of Laamara.

Figure 9. Mining operation in the north slope (Boutouil).

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