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Biodiversity of bulbous and tuberous geophytes from the El Kala National Park (North-Eastern Algeria): checklist, vulnerability and conservation

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Resumen

Biodiversidad de geófitos bulbosos y tuberosos del parque nacional El Kala (noreste de Argelia): lista de especies, vulnerabilidad y conservación

Treinta estaciones en el Parque Nacional El Kala (Noreste de Argelia) fueron objeto de un inventario florístico que se centró en el estudio de la ecología de geófitos bulbosos y tuberosos. La flora se caracteriza por una alta proporción de taxones raros y/o endémicos, entre ellos, 6 especies son endemismos algero-tunecinos pertenecientes a la familia Orchidaceae. En este trabajo, se da a conocer la presencia de una nueva especie para la flora argelina, *Ophrys fusca* subsp. *lupercalis*. Los análisis multivariantes revelaron, ciertas variables ambientales que determinan la distribución de los geófitos. Los lugares de interés son particularmente sensibles a las amenazas, particularmente las de origen antrópico.

Palabras clave: Especies raras; Endemismo; Flora.

Abstract

Thirty stations at the El Kala National Park (North Eastern Algeria) were the subject of a floristic focused on the study of the ecology of bulbous and tuberous geophytes. The floristic analysis was used to draw up a checklist of 67 species belonging to 36 genera and 14 families, among of which 19 species a high proportion of rare and /or endemic taxa; among them six signed taxa are endemic to algerian-tunisian mainly represented by family of Orchidaceae. In this work, we recorded the presence of a new species for the Algerian flora which is *Ophrys fusca* subsp. *lupercalis*. Multivariate analyses revealed certain environmental variables determining the distribution of geophytes. The visited sites show an alarming vulnerability and subject to threats, particularly anthropogenic ones.

Key words: Rare species; Endemism; Flora.

Introduction

The Mediterranean plant biodiversity is commonly known in the world, as one of the most three remarkable ecosystems, regarding species richness, and endemism (Myers *et al.* 2000). The geographic analysis of the high plant diversity (Barthlott *et al.* 1999) and the areas of high endemism rate (Verlaque *et al.* 1997) have shown an important complimentary tool for, classifying the whole Mediterranean basin as a "*hot-spot*" through the world (Médail & Quézel 1997).

Although, the flora of the southern- Mediterranean basin remains unknown, in particular the Algerian-Tunisian coastal mountainous, historically named "Kabylies–Numidia–Kroumirie", a phytogeographical name basically used by Quézel & Santa (1962-1963), and having a great floristic richness and a very high endemism rate (Véla & Benhouhou 2007).

The coastal of Numidia, "K3" in term biogeographical divisions as proposed by Quézel & Santa (1962) makes at the east a precise biogeographic unit and an Important Plants Areas (IPA) (Yahi & Benhouhou 2010) around the El Kala National Park (Marre 1992). In an ecological view point, this region is considered as highly important, considering its geographical location, climate, and its lakes and forests (de Bélair 1990). The yearly rainfalls are moderated in the coast, however they become abundant with the altitude (614 mm from El Kala city, 1.213 mm to the top of El Ghora soil) (Seltzer 1946), the ideal conditions for the development of bulbous and tuberous geophytes, tuber and rhizome (Danin & Orshan 1990). The perennial subterranean organs promote the plant survivals in periods of serious climatic conditions (Procheş *et al.* 2015). This form of life is more common in Monocots, including families of Orchidaceae, Asparagaceae, Amaryllidaceae and Liliaceae, as well as some Eudicots taxa (Vesely *et al.* 2012).

In Algeria, very recent limited data are available on the bulbous geophytes, meanwhile some other studies have been carried out on Orchidaceeae (de Bélair 2000, de Bélair & Boussouak 2002, de Bélair *et al.* 2005, Hadji & Rebbas 2013, Babali *et al.* 2013, Kreutz *et al.* 2013, 2014, Bougaham *et al.* 2015, Beghami *et al.* 2015; Hamel & Meddad-Hamza 2016, Hamel *et al.* 2017, Madoui *et al.* 2017, Boukehili *et al.* 2018) and Asparagaceae (Véla *et al.* 2016, Boubetra *et al.* 2017).

On top of that, the knowledge of the bulbous plants in Algeria and their distribution is mainly based on historical observations (Maire 1959-1987, Quézel & Santa 1962), and consequently several new species of Algeria (not found in the historic references) and some taxa "synonyms" established in the distinct species have been discovered in the last few years (Rebbas & Véla 2008, 2013, de Bélair *et al.* 2013).

- Geophytes are a group of flora whose ecology is not very well known. To this end, this article aims:
- To establish the inventory of geophytes at the El Kala National Park (North Eastern Algeria) and proceed to their identification and classification in order to draw up a floristic Checklist.
- To study the environmental factors influencing the ecological distribution of inventoried species.
- To enrich our database of authoctonous plants in the region in order to understand the phenomena encountered in the southern shore of the Mediterranean.
- To draw attention to the importance of protecting the flora of the region with a view to preserving it by putting in place conservation measures in order to develop a flora that is very important for biodiversity and the dynamics of forest ecosystems.

Materials and methods

Study region

The present study was conducted at El Kala National Park (EKNP), with a total surface area of 78438 ha (Fig. 1). Stands as one of the best landscape diversities, its biological heritage was found as one of the most diversified western Mediterranean basin (Stevenson *et al.* 1988, Benyacoub & Chabi 2000, Brahmia *et al.* 2002). This site is located in the extreme North-Eastern Algeria, and boarded to the north by the Mediterranean Sea, to the east by the Algerian-Tunisian borders, to the west by the city of El Tarf and vast marshes of Mekhada, and to the south by the mountain of Medjerda (Benyacoub & Chabi 2000).

According to the Emberger climagram (1955), the El Kala region is located within the bioclimatic sub-humid level of hot winter, to the limit

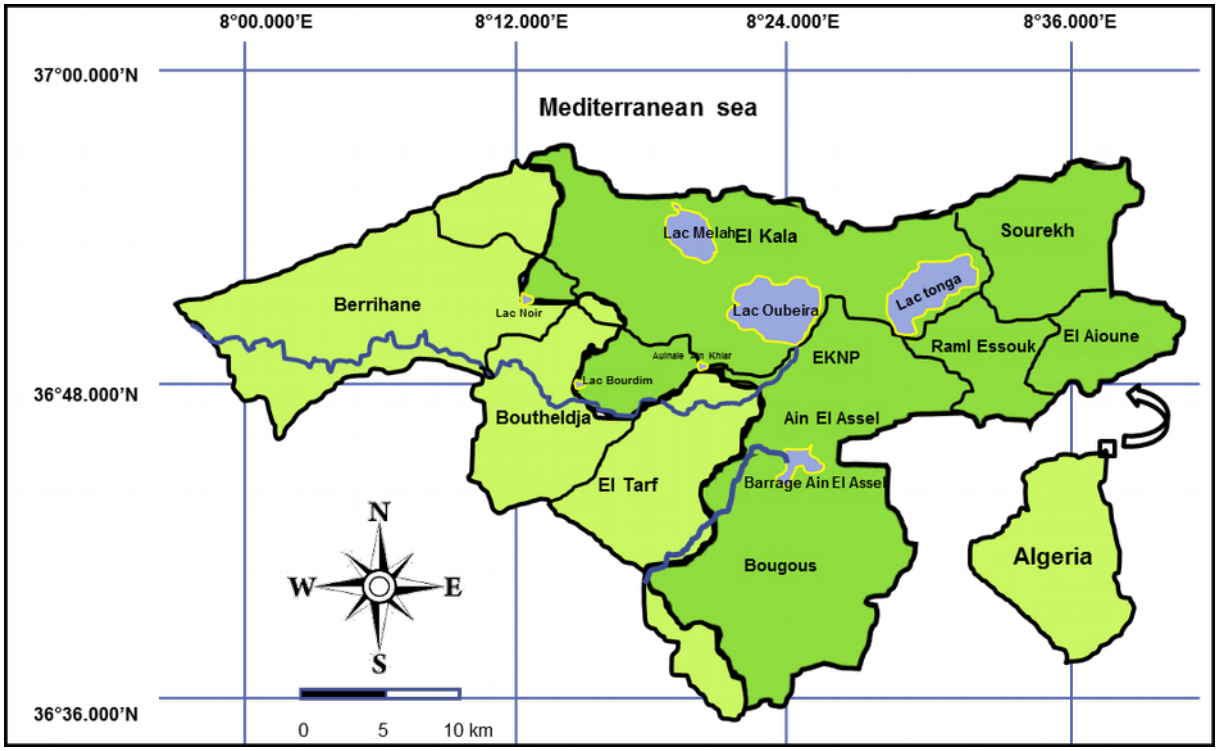


Figura 1. Ubicación del sitio de estudio EKNP.
Figure 1. Location of the study site EKNP.

of the humid level. The geological study showed that the study region mainly belongs to the Tertiary sector (Marre 1987), and it is represented by Numidian clays and sandstones, as well as deposits of sands, conglomerates, and banks of red or grey Pontian clay (Marre 1992).

Sampling of plants

Floristic Study

This study was carried out on 30 sites for the phytoecological monitoring, in which vegetation was studied for four years (2015-2018) with two seasons (Spring and Autumn) per year. The taxa have been identified accordingly to the new flora of Algeria and southern desert regions (Quézel and Santa 1962-1963), Flora of North Africa (Maire 1952-1987) and Italian Flora (Pignatti 1982).

The new nomenclature of the inventoried species were updated, taking into account recent works collected in the synonymic index, the bibliography of the North-Africa flora (Dobignard & Chatelain 2010, 2013), and the Electronic African plant database, accessible at [http://www.ville-ge.ch/musinfo/bd/cjb/africa/recherche.php].

In addition, the listed species were documented and indicated following their biogeographical type, as described by Pignatti (1982), Blanca *et al.* (2009), Dobignard & Chatelain (2010-2013) and Euro+Med Plant Base (http://ww2.bgbm.org/EuroPlusMed/).

Numerical analysis of the floristic data

All the floristic reports were subjected to two analyses: Canonical analysis of correspondences (CAC), and Linear Discriminant Analysis (LDA). The linkage between the flora data and the environmental variables was obtained by the CAC. The patch resulting in CAC leads to visualize the explanatory percentage of a variable on another (Ter Braak 1995). Moreover, the data of site table were subjected to the LDA (Legendre and Legendre 2012) to obtain a segregation of the main groups of the studied sites. Both of these analysis tests were performed using R software (Core Team 2013) for basic statistical analysis (package ade4, version 3.0.2) (Dray *et al.* 2018).

Results

Floristic composition

The floristic sampling allowed us to list 67 species belonging to 36 genera and 14 botanical families. The distribution of families by number of species is presented in (Table 1).

According to table 1, the family Orchidaceae dominates with 21 species (31.3%), second are the

Amaryllidaceae and Asparagaceae with respectively 28.35% and 18% of the total number of taxa recorded, followed by Iridaceae with 6 species as 9%. Whereas, Araceae and Liliaceae were found with 3 species (4.4%), and thus the Colchicaceae family presented by a rate of 3% with two species. The Apiaceae, Aristolochiaceae, Crassulaceae, Oxalidaceae, Primulaceae, Ranunculaceae and Xanthorrhoeaceae participate in it by a low rate of 1.5% with only one species for each family.

The majority of species found in the study area are greatly presented in two places, namely Oued Djenan (28 species) and Brabtia (17 species), while the site Point of Chacal is the poorest site, containing just two species. Some species are widely distributed through the observation site and within the same site; this is the case of Drimia numidica (Fig. 4e) found in 24 sites with a frequency higher than 50 individuals per site, meanwhile others exist only in one site, case Moraea sisyrinchium (Djebel El Korsi), with a very low frequency (5 individuals). According to the global list of determined species, the composition of the global biological spectre (Table 1) showed that bulbous geophytes along with their 38 taxa (56.7%) were found to be predominant on the tuberous geophytes (29 taxa presenting 43.3%).

Phytogeographical diversity

The determined species belong to several chorological groups (Table 1):

Mediterranean set: this group dominates with 49 species, presenting 73.13% of the classified flora, including 26 species for the Mediterranean link element (*sensu stricto*), 11 species for the Circum-Mediterranean link element, 9 species for the Steno-Mediterranean link element, 2 species for the Euro-Mediterranean link element and 1 species for the Atlantic Mediterranean link element. In this set, the richest families are those of the best ones represented in the studied flora. The families; Orchidaceae, Amaryllidaceae, Asparagaceae and Iridaceae, respectively show 17 taxa, 12 taxa, 7 taxa, and 5 taxa, since other families may present 2 or 1 taxa.

Eurosiberian set: This set represents 5.97% of the studied flora (4 taxa), and it is represented by two European taxa (*Colchicum autumnale* L. and *Gladiolus dubius* Guss.), and two Eurasian taxa (*Neotinea maculata* (Desf.) Stearn and *Gagea villosa* (Parl.) Parl.).

Allocthonous set: This set includes only one taxa of Oxalidaceae (*Oxalis pes-caprae* L.) family.

Endemic set: It is important set in the studied flora, and it includes 13 species (28.35%). Noteworthy, the great number of species was recorded in five sites; each one contains 3 species (Bougous, Chemin des Oiseaux, Djebel El Korsi, Feid El Allag and Oubeira). The Mellah site is considered as a poor site. It contains just one species. It has been observed that the Asparagaceae family is the richest in endemic species (five out of twelve taxa), followed by the Orchidaceae with 3 species, Amaryllidaceae, Apiaceae, Aristolochiaceae, Araceae and Primulaceae with respectively one taxa.

The genus *Hyacinthoides* Heist. ex Fabr. is represented by two taxa; while the rest of the genera are monospecific.

Rarity

The studied flora counted 19 rare species. This important number would due to the habitat diversity, especially the cork oak forests *Quercus suber* L., which include several rare and/or endemic species, like *Allium duriaeanum* J. Gay and *Romulea ligustica* Parl. subsp. *ligustica*. The species do not usually have the same heritage value; meanwhile some of them are endemic and rare, such as *Serapias stenopetala* Maire & T. Stephenson and *Aristolochia navicularis* E. Nardi. Additionally, all these species are in the IUCN Red List (2017) along with different status (CR for *S. stenopetala*, LC for *A. navicularis*) (Table 2). Rare species of the region could be found in other countries, like the species of the northern element (*Neotinea maculata*) and the Mediterranean element (*Allium commutatum* Guss., *Ophrys iricolor* Desf.). Nevertheless, three species of this flora are protected according to the Algerian legislation (Executive decree N°12/03, 2012) providing the list of protected non-cultivated plant species): *Anacamptis papilionacea* (L.) R. M.Bateman, Pridgeon & M. W. Chase, *Bunium crassifolium* (Batt.) Batt., *Cyclamen africanum* Boiss. & Reut.

Canonical Analysis of Correspondences (CAC)

This analysis joins the 67 plant species and environmental variables. The outline drawn by the first and second axes has an inertia rate of 68.70% (Fig. 2). It evidenced the distribution of the sites as a function to the variables of the environment

Code	Taxa	Family	Biogeographic type
X1	*Acis autumnalis* (L.) Sweet	Amaryllidaceae	Mediterranean
X2	*Allium ampeloprasum* L.	Amaryllidaceae	Mediterranean
X3	*Allium chamaemoly* L. subsp. *chamaemoly*	Amaryllidaceae	Mediterranean
X4	*Allium commutatum* Guss.	Amaryllidaceae	Steno-Mediterranean
X5	*Allium duriaeanum* J. Gay	Amaryllidaceae	Algerian-Tunisian endemic
X6	*Allium longispathum* Delaroche	Amaryllidaceae	Circum-Mediterranean
X7	*Allium nigrum* L.	Amaryllidaceae	Mediterranean
X8	*Allium roseum* L.	Amaryllidaceae	Mediterranean
X9	*Allium subvillosum* Salzm. ex Schult. & Schult. f.	Amaryllidaceae	Mediterranean
X10	*Allium triquetrum* L.	Amaryllidaceae	Mediterranean
X15	*Ambrosina bassii* L.	Araceae	Tyrrhenian subendemic
X43	*Anacamptis coriophora* subsp. *fragrans* (Pollini) R. M. Bateman, Pridgeon & M. W. Chase	Orchidaceae	Circum-Mediterranean
X44	*Anacamptis papilionacea* (L.) R. M. Bateman, Pridgeon & M. W. Chase	Orchidaceae	Circum-Mediterranean
X66	*Anemone palmata* L.	Ranunculaceae	Mediterranean
X16	*Arisarum vulgare* O. Targ. Tozz.	Araceae	Circum-Mediterranean
X18	*Aristolochia navicularis* E. Nardi	Aristolochiaceae	Tyrrhenian subendemic
X17	*Arum italicum* Mill.	Araceae	Euro-Mediterranean
X67	*Asphodelus ramosus* L.	Xanthorrhoeaceae	Steno-Mediterranean
X19	*Barnardia numidica* (Poir.) Speta	Asparagaceae	Algerian-Tunisian endemic, Boreal / Libya
X20	*Bellevalia mauritanica* Pomel	Asparagaceae	North African endemic
X14	*Bunium crassifolium* (Batt.) Batt.	Apiaceae	Algerian-Tunisian endemic
X31	*Colchicum autumnale* L.	Colchicaceae	European
X32	*Colchicum cupanii* Guss.	Colchicaceae	Steno-Mediterranean
X65	*Cyclamen africanum* Boiss. & Reut.	Primulaceae	North-East African endemic
X21	*Drimia fugax* (Moris) Stearn	Asparagaceae	Mediterranean
X22	*Drimia numidica* (Jord. & Fourr.) J. C. Manning & Goldblatt	Asparagaceae	Algerian-Tunisian/Spain endemic
X40	*Gagea granatellii* (Parl.) Parl.	Liliaceae	Mediterranean
X41	*Gagea villosa* (M. Bieb.) Sweet	Liliaceae	Eurasian
X34	*Gladiolus dubius* Guss.	Iridaceae	European
X23	*Hyacinthoides aristidis* (Coss.) Rothm.	Asparagaceae	Algerian-Tunisian endemic
X24	*Hyacinthoides lingulata* (Poir.) Rothm.	Asparagaceae	Maghreb endemic
X36	*Moraea sisyrinchium* (L.) Ker Gawl.	Iridaceae	Steno-Mediterranean
X25	*Muscari comosum* (L.) Mill.	Asparagaceae	Mediterranean
X11	*Narcissus elegans* (Haw.) Spach	Amaryllidaceae	Mediterranean
X12	*Narcissus tazetta* L.	Amaryllidaceae	Mediterranean
X45	*Neotinea maculata* (Desf.) Stearn	Orchidaceae	Eurasian
X26	*Oncostema peruviana* (L.) Speta	Asparagaceae	Mediterranean
X46	*Ophrys apifera* Huds.	Orchidaceae	Circum-Mediterranean
X47	*Ophrys bombyliflora* Link	Orchidaceae	Mediterranean
X48	*Ophrys fusca* subsp. *fusca*	Orchidaceae	Steno-Mediterranean
X50	*Ophrys fusca* subsp. *lupercalis* (Devillers & Devillers-Tersch.) Kreutz	Orchidaceae	Mediterranean
X49	*Ophrys iricolor* Desf.	Orchidaceae	Mediterranean
X51	*Ophrys lutea* Cav.	Orchidaceae	Steno-Mediterranean
X52	*Ophrys numida* J. Devillers-Terschuren et P. Devillers	Orchidaceae	Algerian-Tunisian endemic
X53	*Ophrys picta* Link	Orchidaceae	Mediterranean
X54	*Ophrys speculum* Link	Orchidaceae	Circum-Mediterranean
X55	*Ophrys tenthredinifera* subsp. *ficalhoana* (J.A. Guim.) M.R. Lowe et D. Tyteca	Orchidaceae	Mediterranean
X56	*Ophrys tenthredinifera* subsp. *tenthredinifera* Willd.	Orchidaceae	Mediterranean
X57	*Orchis lactea* Poir.	Orchidaceae	Steno-Mediterranean
X27	*Ornithogalum arabicum* L.	Asparagaceae	Mediterranean
X28	*Ornithogalum narbonense* L.	Asparagaceae	Circum-Mediterranean
X29	*Ornithogalum umbellatum* L.	Asparagaceae	Circum-Mediterranean
X64	*Oxalis pes-caprae* L.	Oxalidaceae	introduced
X13	*Pancratium maritimum* L.	Amaryllidaceae	Steno-Mediterranean
X58	*Platanthera bifolia* (L.) Rich.	Orchidaceae	Algerian-Tunisian endemic
X30	*Prospero autumnale* (L.) Speta	Asparagaceae	Circum-Mediterranean
X37	*Romulea bulbocodium* (L.) Sebast. & Mauri	Iridaceae	Mediterranean
X38	*Romulea ligustica* Parl. subsp. *ligustica*	Iridaceae	Mediterranean

Tabla 1 (*Continúa*). Lista de plantas bulbosas y tuberosas registradas en el área de estudio.

Table 1 (Continues). List of bulbous-tuberous plants recorded in the study area.

Code	Taxa	Family	Biogeographic type
X39	*Romulea ramiflora* Ten.	Iridaceae	Mediterranean
X59	*Serapias lingua* L.	Orchidaceae	Circum-Mediterranean
X60	*Serapias parviflora* Parl.	Orchidaceae	Mediterranean
X61	*Serapias stenopetala* Maire & T. Stephenson	Orchidaceae	Algerian-Tunisian endemic
X62	*Serapias strictiflora* Welw. ex Veiga	Orchidaceae	Circum-Mediterranean
X63	*Spiranthes spiralis* (L.) Chevall.	Orchidaceae	Euro-Mediterranean
X42	*Tulipa sylvestris* subsp. *australis* (Link) Pamp.	Liliaceae	Mediterranean
X33	*Umbilicus rupestris* (Salisb.) Dandy	Crassulaceae	Atlantic Mediterranean
X35	*Xiphion junceum* (Poir.) Parl.	Iridaceae	Steno-Mediterranean

Tabla 1 (*Continuada*). Lista de plantas bulbosas y tuberosas registradas en el área de estudio.
Table 1 (*Continued*). List of bulbous-tuberous plants recorded in the study area.

Taxa	Scarcity	JORA 2012	UICN 2017
Allium commutatum	HR*	-	-
Allium duriaeanum	HR*	-	-
Ambrosina bassii	C	-	LC
Anacamptis papilionacea	LR	P	-
Aristolochia navicularis	R	-	LC
Barnardia numidica	C	-	-
Bellevalia mauritanica	QC	-	-
Bunium crassifolium	HR	P	-
Cyclamen africanum	HC	P	-
Drimia numidica	C	-	-
Hyacinthoides aristidis	QC	-	-
Hyacinthoides lingulata	C	-	-
Neotinea maculata	R	-	-
Ophrys iricolor	R*	-	-
Ophrys numida	R*	-	-
Platanthera bifolia	R	-	-
Romulea ligustica subsp. ligustica	R	-	-
Serapias lingua	R*	-	-
Serapias stenopetala	HR*	-	CR

Tabla 2. Taxones endémicos y raros observados en el área de estudio (LR: menos raro; R: raro; HR: muy raro; QC: bastante común; C: común; HC: muy común; LC: menor preocupación, CR: en peligro crítico; P: Protegido). Datos históricos (Quézel & Santa 1962-1963) modificados*.

Table 2. Endemic and rare taxa observed in the study area (LR: less rare; R: rare; HR: highly rare; QC: quite common; C: common; HC: highly common; LC: minor concern, CR: in critical hazard; P: Protected). Nowadays, the historical data (Quézel & Santa 1962-1963), including several taxa, have been modified*.

and the physiognomy of vegetation.

The two sites of marine fringes (R20 and R23) appear relatively isolated on the positive side of the axis 2, and are characterized by their height position. The site R20 occupies a sandy substrate, and is distinguished by the species *Pancratium maritimum* L. (X13). Although, the site R23 is linked to the maritime cliff of the town of Vielle Calle and is distinguished by the species *Allium subvillosum* Salzm. ex Schult. & Schult. f. (X9).

Sites (R1, R10, R5, R9, R28, R29, R7, R4, R8, R3, R6 and R13) are associated with five dominant factors of the negative part of the Axis 2: herbaceous cover rate (Trhe), tree cover lignified rate (Trli), slope and bulb overlap area. The altitude (Alti) also mediates for the Bougous site (331 MASL) and El Ghora (445 MASL), and so these two sites limit the distribution of two endemic species; *Bellevalia mauritanica* Pomel (X20) and *Platanthera bifolia* L.) Rich. (X58). These fourteen sites were found to include a great number of listed species.

The three sites R18, R21 and R2, containing *Romulea bulbocodium* (L.) Sebast. & Mauri (X37), *Colchicum cupanii* Guss. (X32), *Arum italicum* Mill. (X17) and *Serapias stenopetala* (X61) were found isolated, in relation to the Numidian sandstone substrates.

The thirteen sites (R24, R14, R22, R25, R30, R26, R15, R12, R11, R17, R19, R27 and R16) were found grouped, in relation with the North-Eastern exposure. They include the species linked to overgrazing as *Asphodelus ramosus* L. (X67), *Ophrys bombyliflora* Link (X47) and *Ophrys tenthredinifera* subsp. *tenthredinifera* (J.A. Guim.) M.R. Lowe *et* D. Tyteca (X56).

Typology of sites

The Linear Discriminant Analysis performed on a total of 30 sites and 7 environmental variables has evidenced the existence of an altitude gradient in the direction of axis 1 (Fig. 3). The plan made through the first and the second axes summarize an inertia rate of 84.94%.

The group «G5» includes the two sites (R20 and R23), characterized by a variable substrate, and located in the maritime beach of the studied region.

The group «G4» includes the six sites (R8, R10, R11, R12, R18 and R22), organized around a high rate of herbaceous associated with a weak representation of the lignified plants.

The group «G1» contains two sites (R1 and R27), and it solely includes lignified species on calcareous substrata.

The group «G2» stretch throughout the negative

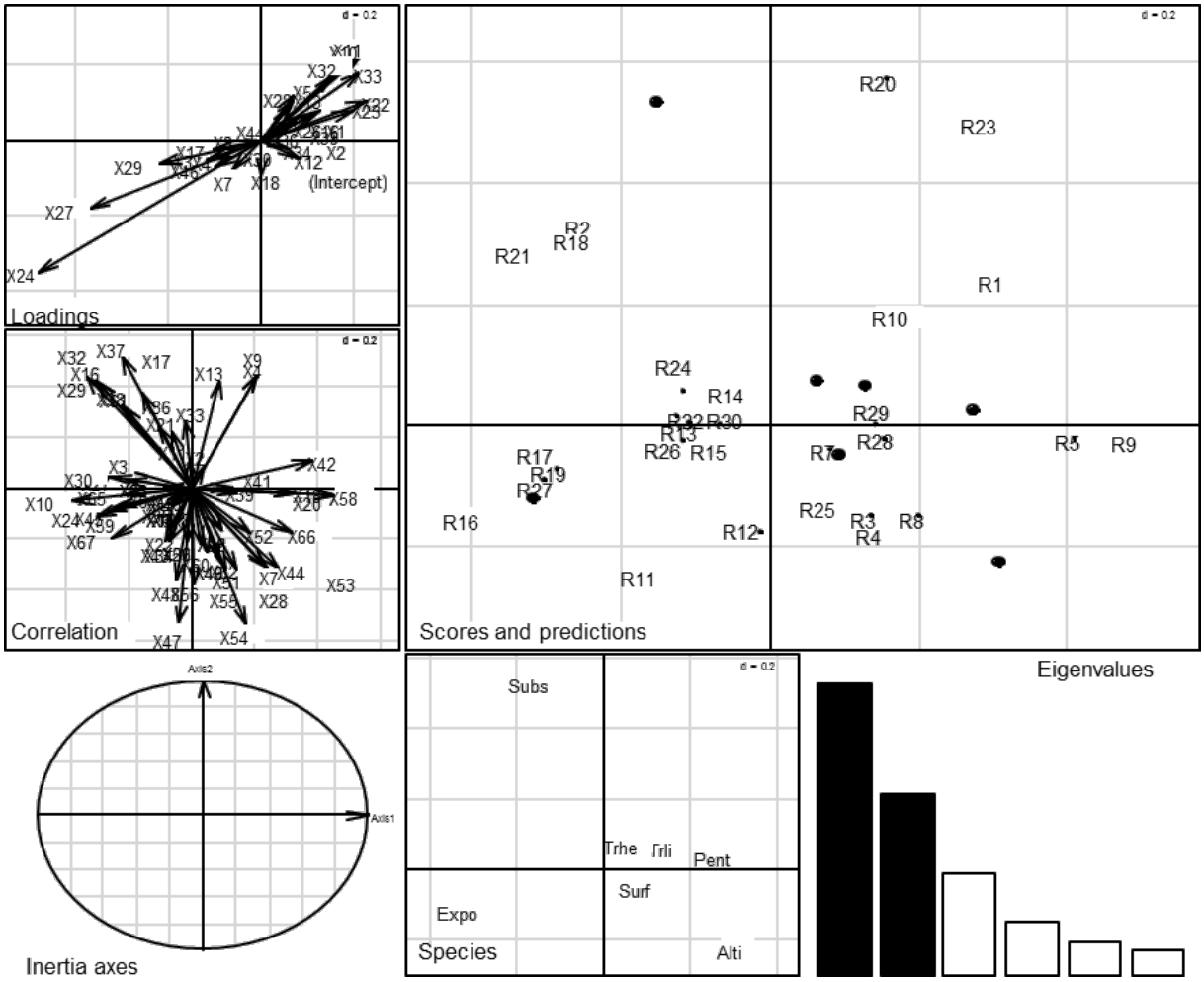


Figura 2. Mapa del análisis canónico de correspondencias (CAC); 30 sitios x 67 especies x 7 variables ambientales
Figure 2. Map of the canonical analysis of correspondences (CAC); 30 sites x 67 species x 7 environmental variables.

part of axis 2, and it is formed by two sites of medium and high altitude (R2, R3, R4, R5, R6, R13, R14, R15, R16, R17, R19, R21, R24, R25, R26, R28, R29 and R30). These sites are absolutely characterized by high rates of herbaceous and lignified, along with large areas of bulbous plants.

Lastly, the group «G3» is constituted by two sites R7 and R9, and it occupies a ridge at high altitude. These two sites are characterized by high rates of lignified, and mainly by strong slopes (45%).

Discussion

Floristic composition

The inventory of bulbous and tuberous species at the El Kala National Park evidenced the presence of 67 taxa with specific or sub specific ranks. Three families (Orchidaceae, Amaryllidaceae and Asparagaceae) are principally represented within the inventoried area, and they are highly dominant in the monocotyledon flora geophytes of the Mediterranean basin (Parsons & Hopper 2003).

Moreover, the orchid flora of the studied area could be considered as quite interesting when compared with that obtained in region of Souk Ahras by Boukehili *et al.* (2018), who have estimated 27 species, and that reported by Hamel & Meddad-Hamza (2016), showing 20 species in Edough peninsula site, as well as the previous results of Martin *et al.* (2015), regarding 50 species recorded in Tunisia.

This dominance of orchids in the determined flora would be strongly related to edaphic and climatic factors, as indicated by de Bélair *et al.* (2005), Kreutz *et al.* (2013, 2014) and Hamel *et al.* (2017).

The First-order diversity is high in the other remaining families; they do not only present large number of species, but also a high family numbers

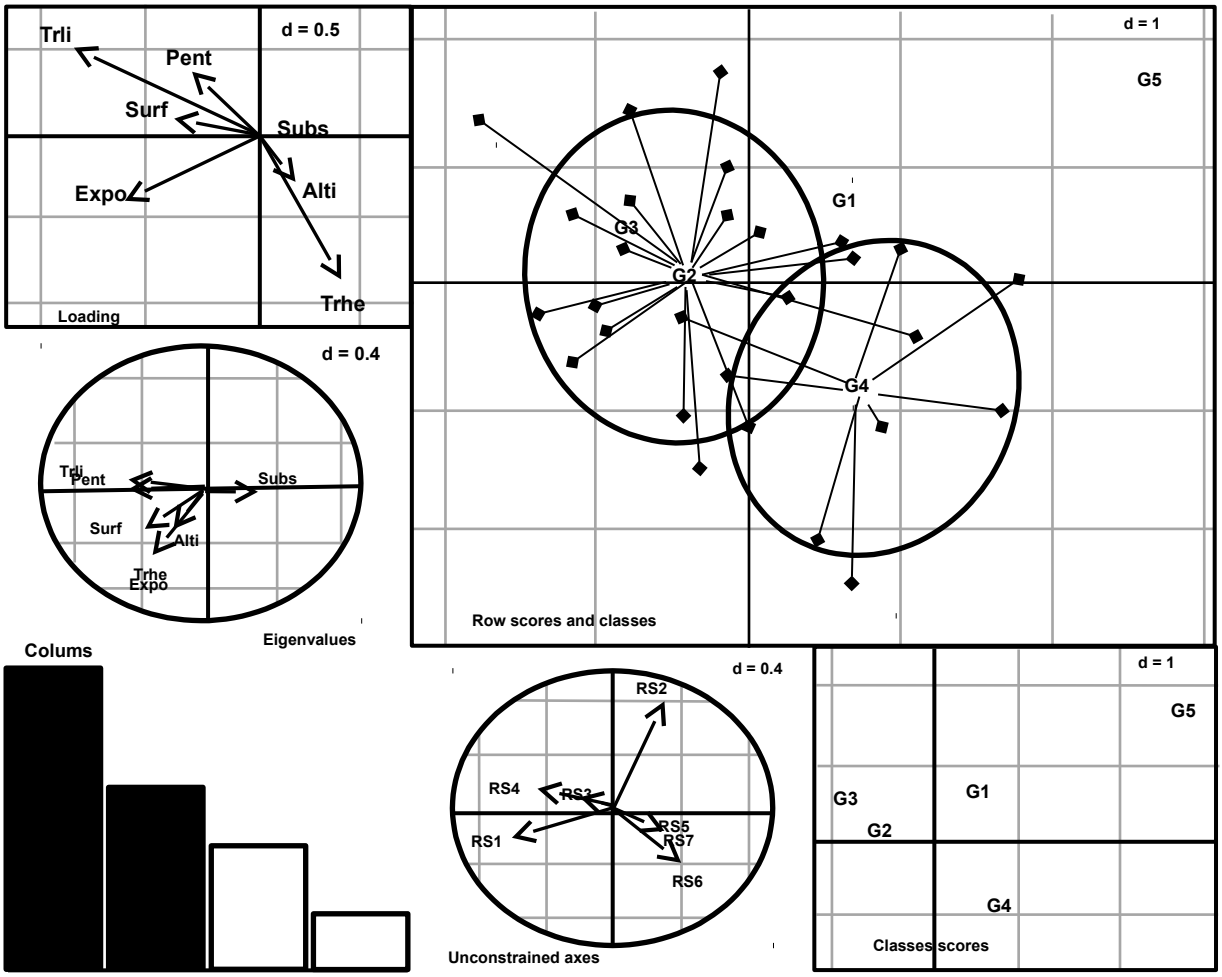


Figura 3. Mapa del análisis discriminante lineal (LDA) en 30 sitios x 7 variables ambientales.
Figure 3. Map of the Linear Discriminant Analysis (LDA) on 30 sites x 7 environmental variables.

(Daget & Gaston 2001). These results are concord with those obtained by the work carried out on the vascular flora of the Edough Peninsula by Hamel (2013), and the work of de Bélair (1990) on the vegetation of the lacustrine zones of El Kala National Park.

In this study, we have noticed the presence of a new species belonged to Algerian flora *Ophrys fusca* subsp. *lupercalis* (Fig.4a). Though, the species was indicated as widely distributed in the Mediterranean basin (Devillers & Devillers-Terschuren 1994), since the flora of Algeria (Quézel & Santa 1962-1963) and that of the North-Africa (Maire 1952- 1987) ignore its presence. This is alike to Tunisia flora (Le Floc'h *et al.* 2010). The recent literature works done on the North-Africa flora (Dobignard & Chatelain 2010) indicate probably the presence of the species in Tunisia.

Hence, El-Kala is believed to be a biogeographical crosslink for its fauna and flora (de Bélair 2005).

Additionally, the unexpected discovering of this species, too far from its classical sites of the western Mediterranean (Spain) (Blanca *et al.* 2009), auguring the existence of other populations, leading to searching within potential area of the populations.

The studied flora showed a set of heterogeneous biogeographical value, whose establishment in fact responds to the extreme palaeogeographical and paleoclimatic complexities of the Mediterranean region (Quézel & Médail 2003). Indeed, the Mediterranean element dominates with 73.13%, and this is in line with those reported by Quézel (1983), showing an increase in the Mediterranean species in the flora of North-Africa. Our study area includes 13 endemic species of rate 28.35%, as 17.1% of the regional endemic species of sector "K3" (Numidia) found in our study area. This percentage is higher than that given by Hamel *et al.* (2013) for the endemic geophytes of Edough Peninsula (3.8%).

Whilst, the Eurosiberian species exhibits a low percentage (5.97%), and it overall represents the remnants of a flora found in North Africa during the glacial periods, and it appears almost exclusively from the Iberian Peninsula (Quézel 1978).

Habitat diversity of the studied flora

The cork oak forest and lawns of the study area was found as rich in species, containing more than 40 species for each (Table 3), while the maritime cliffs and Zenaie oak include, respectively 12 and 11 species (poorest site), and that eucalyptuses occupy the intermediate position with 14 species.

These results confirm that the Numidia region (where indicate our site) and other areas, such as Kabylie and Kroumirie in Tunisia, presenting a high floristic richness, are classified as new hotspots, along with the ten other regional hotspots of Mediterranean biodiversity (Médail & Quézel 1997, Médail & Diadema 2006, Véla & Benhouhou 2007). As for endemism, it is the most common in the cork oak forests, with 9 taxa, followed along with Zenaie oak forests and lawns, respectively 5 and 3 species.

Eucalyptaie and sea cliffs are the poorest sites with 2 taxa for each, which explains that the floristic accompanying the cork oak forests possesses coping mechanisms throughout the summer dry season (nearly 4 months) that characterizes the Eastern Numidia (Bennadja *et al.* 2013).

In contrast, the distribution of the endemic species does not occur spontaneously. They were found in regions, whose flora has to do with the recent or previous geographical reasons (Boulos 1997, Verlaque *et al.* 1997). According to Barbéro *et al.* (2001), this richness of endemic herbaceous forests accounts for the variability of biogeographic,ecological states and the fragmentation of the continental areas in relation with anthropogenic actions.

Habitat	No. spp	Endemic taxa
Cork oak forest	56	*Allium duriaeanum*, *Ambrosina bassii*, *Aristolochia navicularis*, *Barnardia numidica*, *Bellevalia mauritanica*, *Bunium crassifolium*, *Cyclamen africanum*, *Drimia numidica*, *Hyacinthoides lingulata*
Lawns	41	*Drimia numidica*, *Ophrys numida*, *Serapias stenopetala*
Eucalyptaie	14	*Drimia numidica*, *Hyacinthoides lingulata*
Maritime cliffs	12	*Drimia numidica*, *Cyclamen africanum*
Zenaie oak forest	11	*Cyclamen africanum*, *Drimia numidica*, *Hyacinthoides aristidis*, *Platanthera bifolia*, *Hyacinthoides lingulata*

Tabla 3. Riqueza florística de los hábitats muestreados en el área de estudio. (No. spp: Número de species).

Table 3. Floristic richness of the sampled habitats in the study area. (No. spp: Number of species).

Heritage Value of the listed species

The recorded flora was found to be very rich by endemic taxon (13 taxa), which are either endemic of the regional hotspots «Kabylies-Numidia-Kroumirie» (Véla & Benhouhou 2007) or sub endemic of this sector with a supplementary separated area (Table 4):

Algerian-Tunisian endemics include six species: *Allium duriaeanum*, *Bunium crassifolium*, *Hyacinthoides aristidis*, *Ophrys numida* (Fig. 4h), *Platanthera bifolia* (Fig. 4g) and *Serapias stenopetala* (Fig. 4d). Véla & Benhouhou (2007) and Hamel *et al.* (2013) argue that these endemic borders with Tunisia correspond less to areas of specialized hyperendemism than to large areas of biogeography where endemic species are locally rare or even abundant.

Algerian-Tunisian/Spain endemics include mainly one taxon (*Drimia numidica*) which is commonly known in north-eastern of Algeria with less important distribution areas (Quézel & Santa 1962);

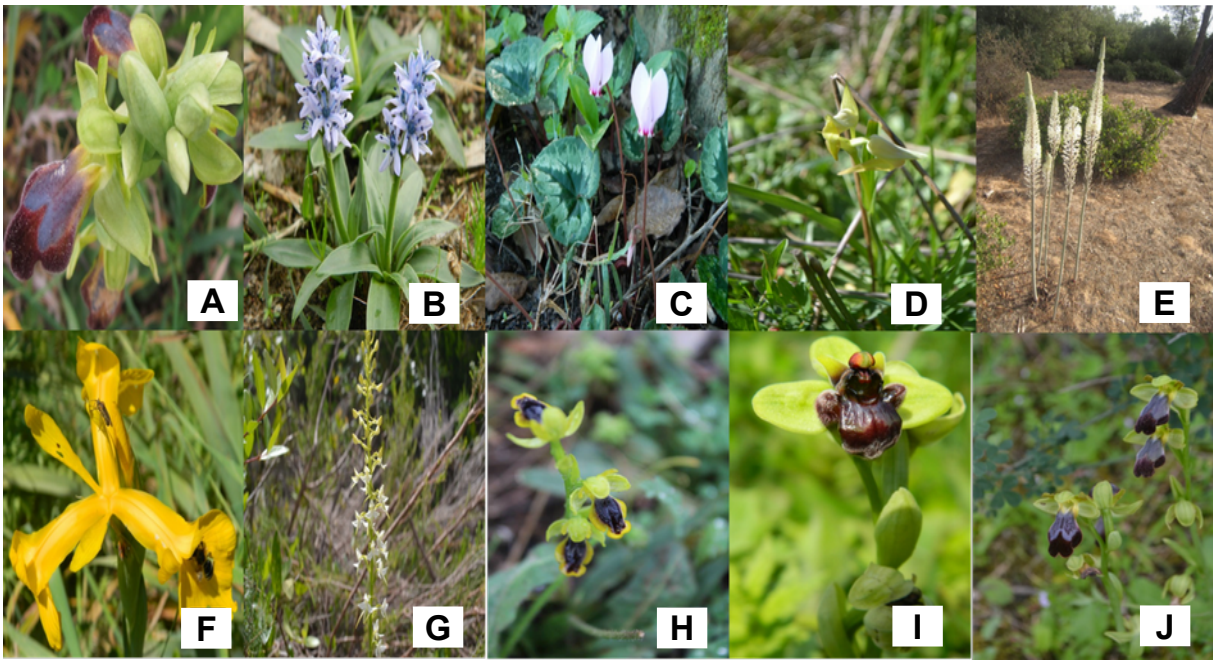
Maghreb endemics include three taxa: *Cyclamen africanum* (Fig. 4c), *Hyacinthoides lingulata* (Fig. 4b) and *Bellevalia mauritanicae*.

Algerian-Tunisian endemic, Boreal / Libya include only one taxa: *Barnardia numidica*.

Sub-endemics: include two taxa (*Ambrosinia bassii* and *Aristolochia navicularis*). The presence of endemic Tyrrhenian strain (2 taxa) could be explained by the terrestrial connections passed through the Algerian coast Tell with the Tyrrhenia (Quézel 1964, Hamel & Boulemtafes 2017).

Compared to the work of Hamel *et al.* (2013), carried out on the rare and endemic flora of Edough Peninsula, the endemic numbers found in our region could be considered as important, and showed about 17.1% of endemic flora of sector "K3", including 76 taxa (Véla & Benhouhou 2007). Nevertheless, two endemic plants are classified as typical species in the identification of Algerian ZIP (El Kala 1): *Serapias stenopetala* and *Bunium crassifolium* (Yahi *et al.* 2012).

The rare or threatened taxa amount to 19, as 28.35% of the studied flora. These rare species are therefore of great value and have a high value in terms of conservation, either for heritage reasons or because of their risk of extinction (Pimm *et al.*



Figura/Figure 4. A: *Ophrys fusca* subsp: *lupercalis*; **B:** *Hyacinthoides lingulata*; **C:** *Cyclamen africanum*; **D:** *Serapias stenopetala*; **E:** *Drimia numidica*; **F:** *Xiphion junceum*; **G:** *Platanthera bifolia*; **H:** *Ophrys numida*; **I:** *Ophrys bombyliflora*; **J:** *Ophrys iricolor*.

1988, Gaston 1991, Hamel *et al.* 2013, Miara *et al.* 2017).

In fact, three recorded species are listed among the authoctonous and protected plant species, and three others are listed in the red list of IUCN (2017). This flora requires strict protection.

Mosaic of the studied vegetation

The plant mosaic of the studied area was found to be structured by three dominant environmental gradients; the rainfall, altitude and anthropogenic disturbances.

The habitat features are helpful to determine the plant distributions, and this is due to reason to their usually complex interactions with organisms (Gaston 1991). It seems that the precipitation abundance in the study area promoted the appearance of 38 bulbous species and 29 tuberous species, leading to population variation of every observed taxon.

The altitude determines the distribution of the observed species, since the low and the high altitudes are relatively poor in species, although average altitude stations were proved to be quite rich in floristic biodiversity. The presence of new populations of *Allium commutatum* in the maritime cliffs of Vielle Calle distanced 3 km from the first site «Medjez Ecchaïr» (de Bélair *et al.* 2012), leads us to suggest that the other leek populations could be found in the western-coast, and even to the eastern of El-Kala city. The site of El-Ghora, distanced 820 m, is the highest one among our sites, and thus it is indicated as the sole site of *Hyacinthoides aristidis* and *Platanthera bifolia*. The later has already been indicated in the same site by de Bélair *et al.* (2005). This Algerian-Tunisian endemic taxon was observed in Edough peninsula found in high maquis at 594 MASL, in *Pinus pinaster* Aiton forests (Hamel *et al.* 2013, Kreutz *et al.* 2014, Hamel & Meddad-Hamza 2016). Its presence on the Babor Mountain (North-Eastern of Algeria) with altitude of 1,935 MASL is being confirmed (Madoui *et al.* 2017).

Threats and conservation

As reported by Verlaque *et al.* (2001), the therophytes and the geophytes (bulbous and tuberous) are highly damaged either by the harvests or pastoral pressure. Indeed, the damages on the habitats are significantly high. These damages are frequently due to the humans and his expansion (flocks). According to Allem *et al.* (2017) these effects are direct, damaging habitats and species and they modified their groups of associated species.

The total elimination of pasturage in the long-term period, could lead to the removal of the environment and the development of competitive mono-specific communities (Belouahem et al. 2011), and this is not desirable.

Code	Station	Habitat	Coordinates	Altitude	Substratum	Slope (%)	Exp	Trli (%)	Trhe (%)	Surf. (m^2)	N spp
R1	Ain El Assel	Eucalyptaie	36°48'0.16"N 8°23'0.73"E	30	Numidian sandstone and clay	4	N	18	35	35	9
R2	Bog of Lake Noir	Cork oak forest	36°51'0.20"N 8°12'0.33"E	36	Sand	7	NW	24	40	20	8
R3	Ain El Kebir	Cork oak forest	36°38'0.86"N 8°25'0.68"E	580	Numidian sandstone and clay	17	NW	34	82	60	11
R4	Ain Kechba	Cork oak forest	36°39'0.24"N 8°24'0.18"E	452	Numidian sandstone and clay	15	NW	27	80	55	10
R5	Bougous	Cork oak forest	36°41'32.84"N 8°23'6.19"E	331	Numidian sandstone and clay	11	S	30	39	80	11
R6	El Fedjej	Cork oak forest	36°38'0.91"N 8°22'0.97"E	382	Numidian sandstone and clay	13	NW	26	66	50	6
R7	El Toual	Zenaie oak	36°39'0.16"N 8°21'0.94"E	201	Numidian sandstone and clay	10	NE	22	51	50	7
R8	Lhdeb	Lawn	36°38'0.82"N 8°25'0.73"E	595	Numidian sandstone and clay	18	NE	20	47	82	12
R9	Biological plot El Ghora	Zenaie oak	36°41'3.21"N 8°27'13.76"E	445	Numidian sandstone and clay	22	S	40	81	100	4
R10	Bourdim	Lawn	36°47'0.79"N 8°14'0.85"E	19	Numidian sandstone and clay	3	S	10	72	36	5
R11	El Aioun	Lawn	36°49'0.39"N 8°36'0.18"E	252	Numidian sandstone and clay	9	SE	5	40	49	7
R12	Oued Djenan	Lawn	36°49'0.31"N 8°37'0.46"E	299	Numidian sandstone and clay	12	SE	4	90	200	28
R13	Brabtia	Cork oak forest	36°51'0.74"N 8°20'0.27"E	6	Numidian sandstone and clay	3	NW	40	81	90	17
R14	Chemin des Oiseaux	Cork oak forest	36°52'0.33"N 8°29'0.39"E	47	Numidian sandstone and clay	6	NE	61	42	50	9
R15	Djebel El Korsi	Cork oak forest	36°51'32.56"N 8°15'57.62"E	125	Numidian sandstone and clay	4	NW	33	53	25	7
R16	El Kala City	Cork oak forest	36°53'0.20"N 8°26'0.09"E	86	Numidian sandstone and clay	3	SE	4	14	10	10
R17	Feid El Allag	Cork oak forest	36°50'0.24"N 8°28'0.07"E	5	Numidian sandstone and clay	7	SE	14	30	12	9
R18	Mellah	Lawn	36°53'0.15"N 8°20'0.55"E	5	Sand	3	NW	10	77	20	13
R19	Oubeira	Cork oak forest	36°51'0.99"N 8°22'0.96"E	30	Numidian sandstone and clay	5	SW	32	52	40	10
R20	Point of Chacal	Marine bangs	36°53'0.84"N 8°26'0.05"E	1	Numidian sandstone and mixed series	1	N	1	20	5	2
R21	Souk Reguibat	Cork oak forest	36°53'0.97"N 8°17'0.33"E	15	Sand	3	NE	9	31	14	6
R22	Tonga	Lawn	36°52'0.77"N 8°30'0.81"E	9	Numidian sandstone and clay	6	NE	11	75	50	8
R23	Vieille Calle	Maritime cliff	36°55'8.27"N 8°19'38.47"E	9	Numidian sandstone and mixed series	11	N	20	40	10	10
R24	Ain Khiar	Cork oak forest	36°48'0.26"N 8°19'0.27"E	36	Numidian sandstone and clay	4	NE	38	53	10	9
R25	Ain Smail	Cork oak forest	36°47'0.76"N 8°35'0.20"E	289	Numidian sandstone and clay	15	NE	19	28	6	6
R26	Oued El Hout	Cork oak forest	36°49'0.37"N 8°30'0.04"E	9	Numidian sandstone and clay	3	NE	11	33	60	9
R27	R'mel Souk	Eucalyptaie	36°47'0.66"N 8°30'0.10"E	90	Numidian sandstone and clay	4	SE	16	29	45	11
R28	Hadada	Cork oak forest	36°53'0.63"N 8°37'0.15"E	179	Numidian sandstone and clay	22	NE	39	86	100	15
R29	Segleb	Cork oak forest	36°56'15.64"N 8°36'18.75"E	9	Numidian sandstone and clay	25	NE	70	51	15	4
R30	Souarekh	Cork oak forest	36°52'0.29"N 8°36'0.14"E	118	Numidian sandstone and clay	11	NE	19	30	36	7

Tabla 4. Ubicación geográfica de los sitios muestreados a nivel; Tasa de cobertura arbórea (Trli); Tasa de recuperación de la hierba (Trhe); Superficie ocupada por las bulbosas (m^2); Exp: Exposición; Surf: Superficie; Nsps: Número de especies colectadas.

Table 4. Geographical location of sites sampled at the PNEK level. Tree cover rate (Trli); Herb recovery rate (Trhe); Bulb surface area (m^2); Exp: Exhibition; Pent: Slope; Surf: Surface; N sp s: Number of species surveyed.

Therefore, an integrated strategy for the conservation of threatened taxa or showing heritage interest must absolutely be based on a good knowledge of the auto-ecology and biology of rare species (Quézel & Médail 2003).

Conclusions

The results obtained reveal a high species richness (67 species), characterized by a relatively high rate of endemism (28.35%), a large number of rare, endangered and endemic species (19 species, 10 of which are rare to very rare) and a great biogeographical diversity, marked by the coexistence of elements of Mediterranean, Nordic, endemic and introduced origin.

This inventory allowed us to discover and refer new stations of geophytes by indicating a new species for the region in question (*Ophrys fusca* subsp. *lupercalis*).

In terms of conservation, it is necessary to recall the need to rapidly implement measures to protect the stations of the species observed in the study area, by announcing the degraded state of the bulbous habitats and to be concerned about threats to these plants, because indeed human activity modifies and restricts the environments in which the geophyte species develop spontaneously and thus jeopardizes the diversity of these taxa, for that a control of overgrazing and fires is necessary.

Finally, an important step must be taken in the protection of species. The lists of protected species need to be revised to include newly described taxa that are already in danger and those that are newly threatened.

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