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Diversity and plant distribution according to the topographical factors in Djebel Messaad forest (M'Sila - Algeria)

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ABSTRACT

Background : Djebel Messaad is an Aleppo pine natural forest in Ouled Nail mountains (Saharan Atlas). It is located in M'sila province (Algeria). It is submitted to a continental semi-arid Mediterranean bioclimate. Its substrate is mainly limestone. The topography seems most important on the plant diversity and the distribution of the vegetation and how is its impact of this biological entity. **Objective:** Repeated drought, fire risk in the Mediterranean forest, mostly made of Aleppo pine and overgrazing compromise phytodiversity where it remains imperative to know the existing plant diversity and vegetation distribution according to the topographical factors in order to rule on the degradation or loss future flora that can take place in that particular area for its preservation where there is actual no measure to protect this environment and its components. In this study, the methodology adopted is a non-probability sampling mixed (stratified and subjective), led by topographical three factors: exposure, altitude and slope. They were applied in a representative area with the completion of 24 floristic samples. **Results:** The floristic analysis showed that the study area includes 97 taxa distributed in 73 genera and 27 botanical families. The floristic diversity is richer and more diverse in the catchment northwest and decreases with increasing altitude and slope. They have an indirect influence on the vegetation where they play a modifying influence on other physical ecological factors that have a direct influence, including the elements of climate, the soil settings and stoniness. The stational richness and diversity show highest values in the first variants of the topographical factors studied: North-west exposure, low altitude and low slope. Also the statistical analysis results give a significant difference for the Exposure and the Slope where the average of the observed plant was higher. The numerical analysis of the phytodiversity by using Detrended Correspondence Analysis (DCA) gave a result of behavior topographical factors and the individualization of sample subgroups encompassing species subsets which reflects different environmental conditions quite special to the study area where vegetation appeared much more adapted to the environment**. Conclusion:** The diversity and the plant distribution appear much be influenced by topographical factors that showed a floristic richness more pronounced in the northwest side and decreases with altitude and slope. These results are directly a response to the ecological requirements of the plants but also indirectly by conditioning other factors which will impose a particular presence and distribution of vegetation.

KEYWORDS: Diversity, plant distribution, topographical factors, Djebel Messaad forest, Algeria.

INTRODUCTION

The position of the Mediterranean between Europe and Africa, its geography and its role as shelter for altitude cash during the ice ages have contributed to its immense biodiversity and at high endemism [50]. Mediterranean forests are of outstanding interest listed plant species richness, both in terms of species that constitute, as species that participate in the procession of habitats they individualize [57,6]. The Mediterranean basin is one of the world's major centers of plant diversity, the second important hot spot of the world and the

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largest of the five Mediterranean climate regions of the planet [48,40]. This basin is the third hot spot of the world's richest plant diversity [41] where the Mediterranean countries hold almost 4.5% of the world's endemic flora [49]. This region contains almost 50% of its total specific flora endemism [39]. The plant richness is due to the great topographic diversity of the environments of the region and has resulted in a wide range of local climates [41,9]. During this time, the Mediterranean forests have shrunk in area and have lost both biomass and biodiversity [45]. Natural factors, such as the relief (exposure, slope, altitude), climate (light, temperature, precipitation, evaporation, wind, frost) and soil (humidity, limestone rate, soil depth, organic and mineral nutrients, biological activity, soil type …), package installation species according to their own requirements and determine the vegetation in particular places [64]. The geographical location of Algeria between two empires floral, Holarctis in the north and Paleotropis in the south, holds the leash flora includes 4000 taxa meadows spread over 131 botanical families and 917 genera which 464 are national endemic taxa including 387 species, 53 subspecies and 24 varieties [71]. The Djebel Messaad study area is a forest of the chain of Algerian Saharan Atlas located in M'sila province. This environment is home to a typical continental natural pine forest. This forest stand is a natural protective barrier and contributes to the maintenance and conservation of the north steppe highlands from the southern desert harboring influences [25]. Variation in the topographical features directly influences to the microclimatic conditions of the area [47]. This study aims to show the influence of topography on the plant diversity and the distribution of the vegetation where three factors, that characterize this environment, were selected: exposure, altitude and slope. Do not forgot that the forest ecosystems are extremely rich in plant species [66] and the geographical distribution of species and diversity of plant communities are strongly influenced both by the diversity of biophysical environments and human impacts [55].

MATERIALS AND METHODS

I.1. Study Area:

The study area is a natural pine forest located in the Djebel Messaad forest. It's situated in the far east of Ouled Naïl Mountains in the Saharan Atlas of Algeria. It belongs to M'sila province and is far of 3 Km East Djebel Messaad City, 15 km south Bousaada City and 40 km south west the saline dry lake Chott El Hodna, a Ramsar Conservation Wetland (Fig. 1).

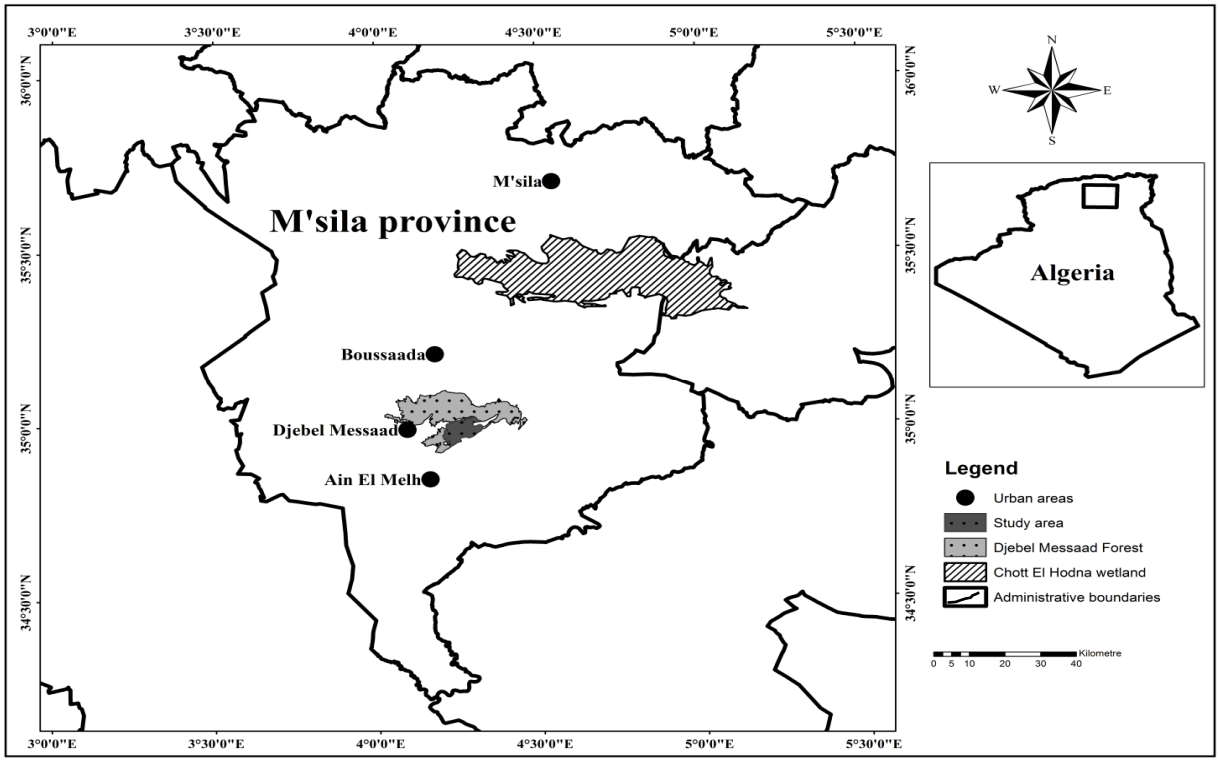

Fig. 1: Study area location

The Djebel Messaad forest presents many small mounds arranged into three main structures oriented Northeast to the Southwest, where the presence of three lines of substantially parallel ridges which left the dominance of two major exposures opposite: northwest and southeast. Elevations range from 1000 m to 1672 m.

For the slopes, they are slightly flat at the foothills and increase with altitude. In this evergreen forest, the Aleppo pine is the main essence and represents 51.35% of the total forest area. It is either mixed with the green oak in the northwest exposures or the Phoenician juniper in the opposite ones. The vegetation of the forest undergoes natural order constraints, a greater importance especially in last years in Algeria by the cumulative effect of the drought [16] and anthropogenic (overgrazing, uncontrolled tourism, illegal logging...). The substrate is formed of material mainly Cretaceous and forest soils are generally thin and based in majority on the limestone rocks [7]. The river system is sporadic and active with the rainfalls.

The climate is Mediterranean and typically continental. It is characterized by:
- Average temperature of the coldest month (m) = -1,19 °C,
- Average temperature of the warmest month (M) = 32,47 °C,
- Average annual rainfall : 411,14 mm/year
- Emberger quotient (Q_2) = 41,89.

These data let this forest belongs to Mediterranean semi-arid bioclimatic stage with cold winter.

I.2. Sampling and data analysis:

Environmentalist relies on sampling to provide an idea of the composition of the community [34]. The variability of the vegetation is primarily determined by the topographic heterogeneity [64]. The sample (floristic releve) is defined as a fragment taken to try all because it contains the majority of plant species inventory [14]. To understand the influence of topographical factors on the diversity and plant distribution, a sample was selected using a representative area of the stand we have taken into account the floristic homogeneity of vegetation [5].

I.2.1. Sampling:

The sample design adopted is a mixed non-probability sampling: stratified and subjective sampling. Stratified sampling of the topographic factors was used to divide our study area into homogeneous strata (units). These reflect the reality of existing combined units course [62,74] where the selected topographic factors are: exposure, altitude and slope (Table 1).

Table 1: The stratified topographical factors

Stratified topographical factors classes and the determination means	Variants	Nomination and level	Caracteristics
Exposure (Compass)	North-West Exposure	E1	Wettest, belongs to northern exposure
	South-East Exposure	E2	Driest, belongs to southern exposure
Altitude (meter) (Altimeter)	Low altitude	A1 ≤ 1200 m	Temperate altitude
	High altitude	A2 > 1200 m	Cold and fresh altitude
Slope (%) (Clinometer)	Low slope	S1 ≤ 10 %	Relatively flat ground
	High slope	S2>10 %	Sloping ground

After the thematic maps of the three stratified topographical factors of our study (scale of 1/10 000): exposure map, altitude map and slope map where each stratified factor contains two variants [14] and after their superimposition, we have obtained the polythematic map where are identified the homogeneous units or strata (Table 2).

Table 2: The stratified topographical factors and the distribution of floristic samples

Stratified factors		**Variants**							
Exposure "E"		E1				E2			
Altitude "A"		A1		A2		A1		A2	
Slope "S"		S1	S2	S1	S2	S1	S2	S1	S2
Floristic Samples	Homogeneous units or strata (Stations)	E1A1S1	E1A1S2	E1A2S1	E1A2S2	E2A1S1	E2A1S2	E2A2S1	E2A2S2
	Repetitions	R1	R2	R13	R15	R16	R7	R9	R8
		R4	R3	R14	R19	R21	R12	R11	R10
		R5	R6	R18	R20	R22	R17	R23	R24

The stratification gives eight (08) homogeneous units (stations) where three (03) repetitions were done in each one. Concerning the subjective sampling, related to the first, it was used on land to implement the floristic samples in the most homogenous and representative stations. The total number of the floristic samples therefore amounts to 24 = 08 units X 03 repetitions (Table 2). The execution of the samples took place during the month of April 2014. They were conducted according to conventional methods, through the establishment of a list of all plant species (vascular) present on a predetermined unit area within a homogeneous station: it is the minimum area [21]. For all of our samples, this area was 120 m^2. This is the minimum area of a sample [19].

This is the Braun-Blanquet method [17]. It involves the taking of all plant species in this minimal surface and where each species was assigned by a semi-quantitative coefficient: abundance-dominance [15]. This minimal surface really expresses the area needed for a floristic sample [29]. The nomenclature used for the plant species is that available, complete and covering the entire territory of our study [58,59].The collected plants were identified and determined by the use of the flora available at our level [36,54,58,59]. The voucher specimens of the plants were deposed in the Botanical Laboratory of Agricultural Sciences Department - Mohamed BOUDIAF University of M'Sila (Algeria).

I.2.2. Data Analysis:

After identification of the collected plants, data analysis focused on:

a- The handling of the floristic samples and taxa from our study of classification, ordination and calculation of biodiversities (α, β, γ, and δ) were made by the Excel for Windows 2007 Software.

b- For numerical analysis of the plant diversity, two techniques were used:

- The first, an analysis of variance (ANOVA), concerns the data samples analyzed and discussed through the means of statistical analyses of the Statistical Package of Social Sciences (SPSS).

- Concerning the second analysis of our results, we used the Detrended Correspondence Analysis or DCA where we used the free program PAST (Paleontological Statistics) Version 3.05 (1999-2015). In this analysis, we used binary data of species [24,23,11,8,13,26,38,22,72,73]. The semi-quantitative data of abundance-dominance in our possession was transformed into qualitative presence-absence data [15].

RESULTS

II.1. Taxonomic analysis:

The overall flora of Djebel Messaad pine forest includes a list of 97 species. These taxa are distributed in 27 botanical families and belonging to 73 genera (Fig. 2).

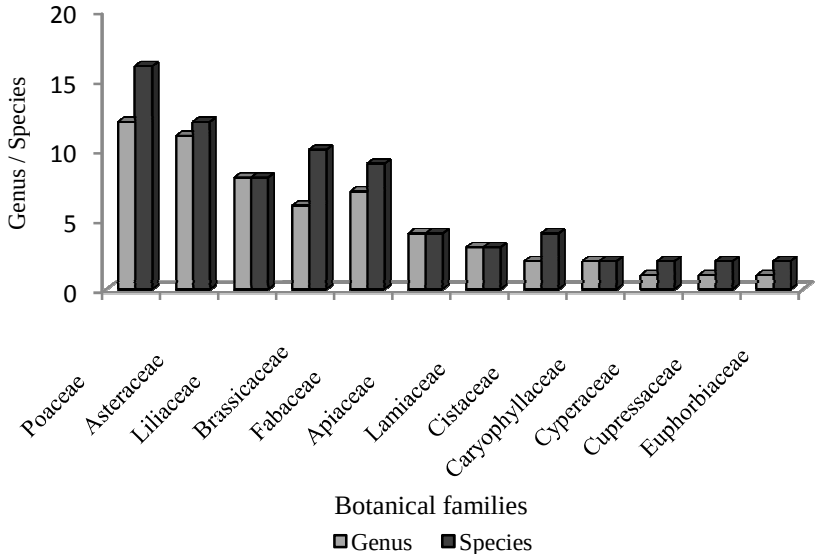

Fig. 2: Genera and species distribution according to the most represented botanical families at Djebel Messaad forest

II.2. Stational richness and diversity:

The stational richness means the species richness met and subservient to the studied station or site [72]. The highest values are encountered in the first variants of the topographical factors studied: North-west exposure, low altitude and low slope (Table 3).

Table 3: Stational richness and diversity based on the topographical factors of study

Factors	Variants	Stational richness	Diversities			
			α	β	γ	δ
Exposure "E"	E1	49	75	1,58	97	26
	E2	22	48			
Altitude "A"	A1	49	74	1,59		25
	A2	23	48			
Slope "S"	S1	41	79	1,44		38
	S2	18	56			

The first variants of the topographical factors have recorded:

- Exposure: Northwest (E1) = 49 taxa (50,52%) : Exposure cooler and wetter.
- Altitude: low (A1) = 49 taxa (50,52%) : Temperate altitude and less cold.
- Slope: low (S1) = 41 taxa (42,27%) : relatively flat slope.

The γ diversity or diversity of the landscape, which includes all diversities, is the total diversity across a landscape [70]. It is equal to our study area to 97 species. The α diversity as species richness within a local ecosystem [33] seems higher at the first variants of topographical factors. Concerning the β diversity, which is given by the simple formula: $\beta = \gamma / \alpha$ [3]. Its low values (Table 3) are interpreted as reflecting a strong similarity between the compared sites [28,18] means that the sites have many species in common. The values found for this diversity ranging from 1,44 to 1,59.This denotes the presence of plant species according to the topographical factors object of this study appear almost identical. Indeed the low values of the β diversity are inversely proportional to the cross-site diversity or diversity δ that reflects the common fund corresponding to those species present simultaneously in investigative environments [68].

II.3. Statistical analysis:

The data analyzed are related to the presence of taxa encountered in the study area according to the sampling adopted in the eight (08) investigation stational units and following the three (03) repetitions performed in each. If significant differences were detected, means were compared between the observations at the p=0.05.

According to the results (Table 4), the Exposure factor "E" has got a significant difference where the northwest exposure, relatively more humid, showed an average attendance of 19,50 against 13,17 for its

Table 4: Phytodiversity analysis of variance according to the topographical factors

Source of variation	*SS*	*Df*	*MS*	*F- test*	*P value*	*Signification*
Exposure "E"	240,67	1	25,54	27,77	0,00009	S
Altitude "A"	28,17	1	240,67	3,25	0,08715	NS
Slope "S"	96	1	28,17	11,08	0,00424	S
Exposure x Altitude	60,17	1	96	6,94	0,01731	S
Exposure x Slope	6	1	60,17	0,69	0,42234	NS
Altitude x Slope	13,5	1	6	1,56	0,22833	NS
Exposure x Altitude x Slope	4,17	1	13,5	0,48	0,50437	NS
Within groups	138,67	16	4,17			
Total	587,33	32	8,67			
S: Significant and NS: Not significant						

counterpart the southeast exposure which is relatively dry. It should be noted also that the exposure northwest harbors a wealth of plant species than its opposite exposure: 75 against 48 taxa. Regarding the Slope factor "S", we had a very significant difference. The low slope shows a plant species presence better than the steep slope. This slope variant gave an average of 18,33 against 14,33 of presence for its opposite slope encountered on steep slopes. In our case study, the low slopes are home to more plant species richness than the steep slopes: 79 against 56 taxa. For the Exposure-Altitude interaction, showed a significant difference too where the average of the observed presence of plant species was higher in the northwest exposure in the low and high altitude: E1A1 and E1A2 than the southeast ones according the two kinds of altitude E2A1 and E2A2 (Fig. 3).

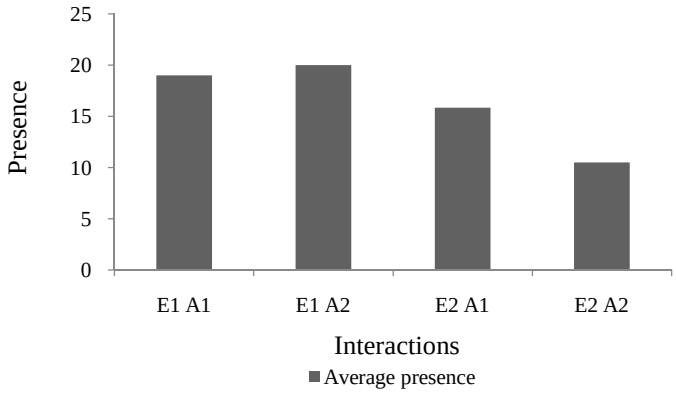

Fig. 3: Plant species presence of the exposure-altitude interactions (Exposure: "E" and Altitude "A")

II.4. Numerical Analysis:

The DCA is a technique of multivariate numerical analysis which aims to reduce data and research gradients [4,46,67]. The apprehension of possible gradients allows the understanding distribution of the floristic samples and corresponding species [73]. Following the DCA analysis, floristic samples fall and hint at three distinct subgroups (Fig. 4 a). A first subgroup (1) encompasses the floristic "R16, R17, R21 and R22." These statements are characterized by southeast exposures "E2" and low altitudes "A2". A second subgroup (2), which includes the floristic samples "R13, R14, R15, R18, R19 and R20", made in the northwest exposures "E1" and high altitudes "A1". Finally, a last subgroup (3) includes the remaining samples. This set, not very homogenous, gives a compact subgroup of samples (3'): "R8, R9, R10, R11, R23 and R24". These last have been taken in southeast exposures "E2" and high altitudes "A1". Many species were found in the study area (Fig. 4 b). They show different site conditions. A subset (A) concerns the remaining samples which is in the southeast exposure and high altitude. The subset (B) concerns the floristic samples conducted in the northwest exposure and high altitude. Between these two subsets (A and B), a last subset of species (C) appear. It collects the floristic samples characterizing the southeast exposure and low altitude.

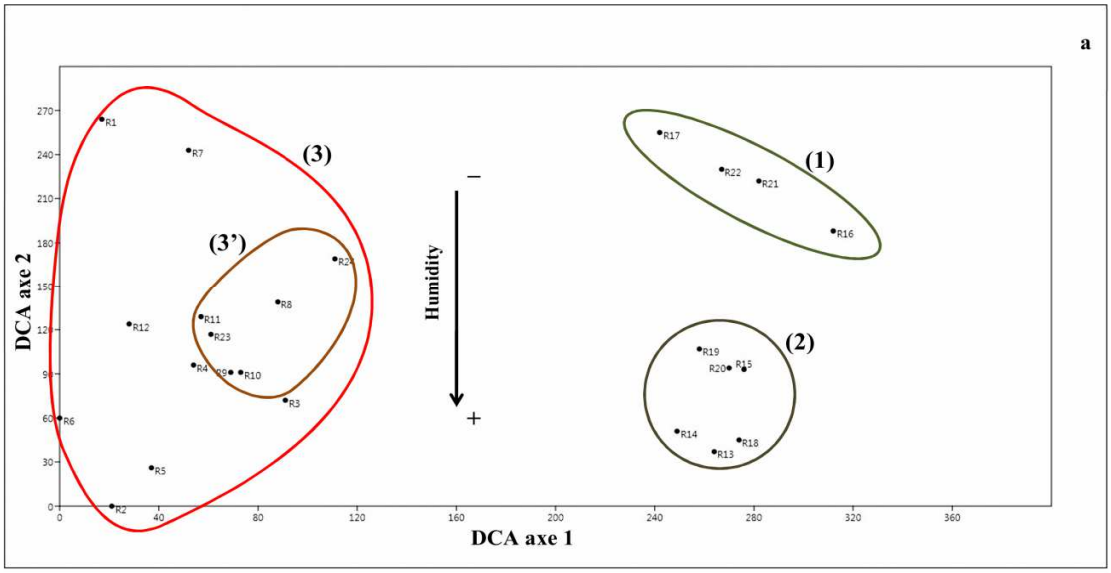

Fig. 4a: DCA ordination of the samples and species: Site affiliation of the 24 samples.

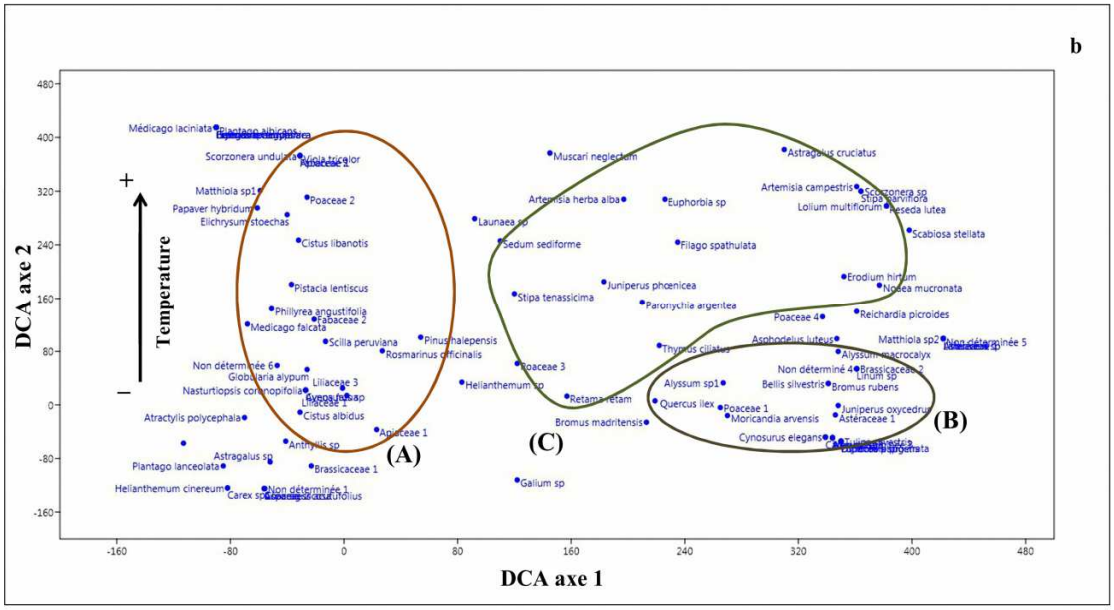

Fig. 4 b: DCA ordination of the samples and species: Positioning of the 97 species in the samples.

DISCUSSION

The Asteraceae family is the most represented in the Algerian flora [56]. For our case study, the Poaceae family is the dominant one and which is essential to emphasize that the majority of species are annual (therophytes) and abound. This fact translated into reality stationary conditions particular where there is the presence of water for a period and its failure of the rest of the year. The abundance of therophytes in comparison to other forms of life is important like the Algerian steppe [10], in the Moroccan wetland vegetation [20,21] and in the flora of Chott El Hodna in Algeria [72]. This abundance of therophytes can be explained by:

- The presence of seasonal habitats for the development of annual plants with germination and rapid growth [20].
- A strategy of adaptation in unfavorable conditions and a form of resistance to climatic rigors [1].
- The opening of the plant's cover [2].
- The aridity of the environment [51].

For the stational richness's species, the highest values are encountered in the first variants of the topographical factors studied (Table 3): North-west exposure, low altitude and low slope. This illustrates that it met the optimal conditions of plant development. Concerning the diversities, the total diversity of the landscape (γ) is equal to our study area richness and the species richness (α) seems higher at the first variants of topographical factors which appear more favorable to the vegetation establishment. The values of the common diversity (β) and the cross-site diversity (δ) are inversely proportional. The low values of the first reflected a strong similarity between the investigated study areas where many species are in common. The second gives us the common fund of species which is interpreted as a richness of the investigative environments [70,68]. The northwest exposure, which is relatively more humid, showed a stational richness more important against its counterpart the southeast exposure where this last appears relatively driest. The northern exposures are much watered than those located on the southern ones [27]. It should be noted also that the exposure northwest harbors a wealth of plant species than its opposite one. This difference can be explained by:

- First, the local climate "wet and cool" created by the Foehn effect that may play a more important role locally [32]. This effect is manifested by humid winds northwest that bring rain clouds causing precipitations on northwest exposures. When crossing the ridges, they become less wet on southeast exposures. Identically at the Lauragais (Haute Garonne, France), the exposure is divided into two groups as a result of the global orientation of exposures Northwest / Southeast where the South overall exposure presents strong sunlight and high evaporation and a generally north facing marked by lower temperatures and lower evaporation [64].
- Second, in North Africa, the northern exposures are much watered than those located on the southern exposure [27].
- Third, the winds of South and southeast from the Sahara, are hot and dry and have a negative action on vegetation [25].

The low slope shows a plant species presence better than the steep slope. It is subservient to the relatively flat terrain. In our case study, the low slopes are home to more plant species richness than the steep slopes. Indeed the slope influences the runoff conditions and flow of water surfaces and consequently determines the water supply of vegetation [37]. The relatively flat terrain causes deep soils and water infiltration is more important: the basement gets wetter and the vegetation will enjoy better, where the slope is correlated to soil humidity -a result of a growing flow of water with the slope- the water will influence environmental conditions and vegetation settles there [64]. Also the gentle slopes are home to more plant species than their opposite variant. Indeed steep slopes favor runoff and accentuate the phenomenon of soil erosion that constitutes the support of the floristic diversity. They leave also appear significant stoniness (Personal observation in the study environment). When we take the Exposure and Altitude together (the interaction), it let's think that the northwest exposure remains impressive and displays the highest attendance rate of plant species in both altitude variations. As against, the southeast exposure remains relatively poorer at the two altitudinal variations because the firsts are wetter and presented a highest stational richness of plant than the seconds which are more dry. Water plays a fundamental role in the life of plants [75]. Don't forgot that altitude determines environmental conditions especially the climates [47].

This is related to the decrease in temperature from the plain to the mountain peaks where also the species richness decreases with elevation in altitude [42,43] also the South exposure models high radiation than in the North one and it is responsible for that of determinism of the distribution of plant formations associated [37]. The distinguished subgroups (1, 2, 3 and 3') shown by the DCA analysis (Fig. 4 a), let them in different statements. They are: spaced, contained many species and let appear different ecological conditions. A gradient occurs along the DCA axis 2 (Fig. 4 a), reflecting an increasing humidity (moisture) from up to down induced by the passage from southern exposure to a northern exposure and from low altitude to high altitude. These subgroups: 1, 2, 3 and 3', correspond respectively to the subsets: C, B and A (Fig. 4 b). The subset (A) is composed of taxa, such as: *Pinus halepensis* Mill, *Globularia alypum* L., *Pistacia lentiscus* L., *Phillyria angustifolia* L., *Rosmarinus officinalis* L. and *Cistus libanotis* L., illustrates the Aleppo pine formations in Algerian Saharan Atlas [25,65]. Note that *Pinus halepensis* Mill is the dominant plant and it belongs to the Mediterranean area [52]. These plants are heliophilous and colonize areas where lack of water (drought) is mitigated in part by the high altitude recorded. These particular species illustrate the floral vegetation of the Aleppo pine formations of continental areas. This subset belongs to the thermomediterranean floor [60] and can be placed it in the lower mesomediterrannean one [53]. It is consisting with the report subgroup (3') shown by the DCA graph (Fig. 4 a). The subset (B) belongs to semi-arid bioclimate with cold winter and an altitude above 1000 meters. It is composed of : *Erinacea pungens* Boiss., *Quercus ilex* L. and *Juniperus oxycedrus* L. It is similar to the upper mesomediterrannean [53] and mesomediterrannean [63]. We recall, however, that our study area is situated beyond 1000 meters in the semi-arid bioclimatic stage with cold winter. Firstly, *Quercus ilex* L. and *Juniperus oxycedrus* L. belong to the primitive forest vegetation of the semi-arid zone of high altitude [30,31], secondary these shrubs are classified in the semi-arid bioclimatic stage with cold winter [10]. *Quercus ilex* L. belongs to the mountains [12] and *Juniperus oxycedrus* L., which is a Mediterranean shrub or small tree, is also found in higher elevations in wetter forests [69]. Concerning *Erinacea pungens* Boiss., it colonizes areas with cold and very cold winters at high (above 1000 meters) altitudes [30,31,44]. This subset coincides with the subgroup of samples (2) shown by the DCA graph (Fig. 4 a) and manifests a northern exposure and high altitude. The subset (C) includes species: *Stipa tenacissima* L., *Juniperus phoenicea* L., *Artemisia herba alba* Asso., *Artemisia campestris* L., *Stipa parviflora* Desf., *Noaea mucronata* (Forsk.) Asch. and Schw., *Paronychia argentea* (Pourr.) Lamk., *Astragalus cruciatus* Link. and *Retama retam* Webb., characterizes a semi-arid area with cool winter: the Steppe [10]. Note also that *Retama retam* Webb. is a spontaneous species of the Saharan flora [35] which appear more adapted to drought.

Another gradient occurs along the DCA axis 2 (Fig. 4 b) caused by the exposure change and increasing altitude: It indicates a decreasing temperature from top to bottom.

Knowing the distribution of plants and their diversity in terms of stational factors may contribute fully to efforts to protect vulnerable plant habitats, preservation of endangered species where biology, adaptation and maintains such species in this environment reflects the ecological balance of the ecosystem and its evolution through time. This area must be preserved and protected especially from anthropogenic stresses.

CONCLUSION

As a result of this study, we can conclude that the diversity and the plant distribution in the Djebel Messaad forest at M'sila province (Algeria) appear much be influenced by topographical factors that showed a floristic richness more pronounced in the northwest side and decreases with altitude and slope where they determine the soil humidity conditions and temperature most advantageous. Their role on this vegetation distribution, in agreement with the results of botanical diversity, stational richness of the plant species and according to the

numerical analysis, can be expressed directly in response to the ecological requirements of the plants, but also indirectly by conditioning other factors which will impose a particular presence of vegetation such as the rate of limestone, soil depth, richness in organic and mineral nutrients, biological activity of the soil...

The individualization of floristic samples of groups lets appear some subsets of species which identifies and reflects different environmental conditions and the ecological specificity of the study area where two gradients were identified. A rise of humidity and a decreasing temperature induced by the passage from southern exposure to a northern exposure (change in exposure) and altitude up (from low to high altitude).

This kind of forest is a rare forest ecosystem where it acts as a natural biological barrier against desertification especially since it's a southern natural forest whose research perspectives can affect the animal-plant relationship, plant-microbe relationship and plants medicinal interest...

Preserving and maintaining this habitat and its flora must be register in emergency concerns like preservation programs, conservation and sustainable management of natural resources.

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