

PHYTOECOLOGICAL CHARACTERIZATION OF THE *PISTACIA ATLANTICA* COMMUNITY IN THE SAHARAN ATLAS OF NAÂMA (ALGERIA)

Abdelkrim Benaradj^{1*}, Hafidha Boucherit¹, Djamel Anteur², Brahim Babali³

¹Laboratory of Sustainable Management of Natural Resources in Arid and Semi-Arid Areas, Salhi Ahmed University Center of Naama, Algeria. *E-mail: kbenaradj@yahoo.fr; benaradj@cuniv-naama.dz

²Research Laboratory of Water Resources and Environment, Dr. Tahar Moulay University of Saida, Algeria

³Laboratory of Plant Ecology and Management of Natural Ecosystems, University of Tlemcen, Algeria

ORCID number: Abdelkrim Benaradj – 0000-0001-6555-6008; Hafidha Boucherit – 0000-0001-6618-0727;

Djamel Anteur – 0000-0002-2337-9645; Brahim Babali – 0000-0001-6788-2069

Abstract

This study focuses on the phytocological characterization of Pistacia atlantica in the Saharan Atlas of Naâma (western Algeria). A floristic inventory, conducted through 32 field surveys, identified significant biological diversity. The results reveal a systematic structure composed of 103 plant species, distributed across 81 genera and 30 botanical families. This floristic richness testifies to the importance of diversity and ecological plasticity in this pre-forest community within the Saharan Atlas. The Pistacia atlantica community exhibits unique floristic diversity, combining endemic Mediterranean and Saharan species adapted to the arid bioclimatic environment. This drought-resistant and structurally rich vegetation constitutes a valuable biological resource requiring conservation measures in the face of anthropogenic and climatic threats.

Keywords: Pistacia atlantica; groupement, ecology; Naâma; Algeria

1. INTRODUCTION

The Saharan Atlas of southern Oran harbors remarkable biodiversity distributed across plains, mountains, salt flats (chotts), and pre-Saharan zones. These ecosystems support adapted species such as the Atlas pistachio (*Pistacia atlantica*) in the dayas and mountains, forming a major ecological barrier. It constitutes a true biological transition zone between the Mediterranean climate and the Sahara, which explains its great diversity [1,2]. In the Saharan Atlas of Oran, stands of *Pistacia atlantica* cover a vast area, although they are strictly localized to humid and strategic zones such as valleys, dayas, and breaks in the volcanic crust.

Despite its ecological importance, this habitat paradoxically remains excluded from Algerian national forest inventories. Yet, *Pistacia atlantica* is emerging as a species of the future for western Algeria. Its exceptional resilience to climatic hazards gives it a privileged status compared to other species in the South [1,3]. *Pistacia atlantica* Desf. (*P. atlantica*) is commonly called the Atlas pistachio or Bétoum.

As its name suggests, it is the most characteristic plant species of the Algerian Saharan Atlas. *P. atlantica* is a species protected by Algerian legislation [4]. *P. atlantica* is a woody species, belonging to the Anacardiaceae family, a dioecious tree with compound leaves.

It is widespread in the western part of the Saharan Atlas [1]. The aim of this study is to conduct a floristic analysis of the *Pistacia atlantica* community from a biological, taxonomic, and chronological perspective in order to establish its ecological significance in the Saharan Atlas of Naâma.

2. MATERIALS AND METHODS

2.1. Study area

The Ouarka study station is located in the commune of Asla (Naâma wilaya), 13 km from the town of Asla and near the wilaya road no. 3. It is located precisely at 32° 49'06.2'' North latitude and 0°13'54.1'' West longitude, this site culminates at an altitude of 1145 meters in the heart of the Saharan Atlas. According to the classification of Quézel and Santa [5], the station falls within the biogeographical sub-sector AS1, thus marking the westernmost limit of this mountain range. The study area focuses on a natural stand of Atlas pistachio trees (*Pistacia atlantica*) located on the lower slopes of the Saharan Atlas, characterized by a marked dispersion in thalwegs, on rocky outcrops, and in wadi beds.

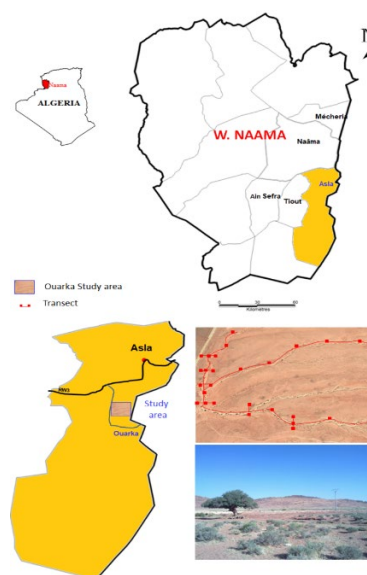


Figure 1. Geographical location of the "Ouarka" study area

2.2. Methodological approach

This study focused on establishing a descriptive inventory of the current state of the *Pistacia atlantica* community within its natural range. It aims to characterize the phytoecological aspects of these stands in close direct relation to edaphic factors and the arid climate. The vegetation analysis is based on 32 floristic surveys conducted using a combined quantitative and qualitative approach. The quantitative analysis initially relied on counting species to assess floristic richness, a fundamental parameter for characterizing the stand through a comprehensive inventory of the plant community associated with *P. atlantica* [1,6-10]. This assessment is complemented by measuring ground cover, defined as the vertical projection of aboveground biomass onto the ground, allowing for the quantification of the spatial occupation of the vegetation layer. In addition, a qualitative approach is adopted to characterize the composition of the flora from systematic, biogeographical, and biological perspectives. This dual analysis allows for a precise definition of the structure and heritage value of the studied plant formations, in accordance with established methodological frameworks [1,2,7,10,11-14].

3. RESULTS AND DISCUSSION

3.1. Climatic aspects

The Naâma region is distinguished by a continental climate, marked by a bioclimatic gradient that decreases from north to south, evolving from semi-arid to Saharan. This environment generally belongs to the arid bioclimatic zone, characterized by highly irregular rainfall and increasing aridity. Rainfall is low and unpredictable, with annual averages generally ranging between 100 and 250 mm [1,2,15-19]. The climate of the Saharan Atlas is marked by extreme aridity, with a wide temperature range, as well as low and irregular rainfall. *Pistacia atlantica* survives in these areas thanks to its extreme resistance to drought and its ability to colonize the piedmont zones or wadi beds of the Saharan Atlas.

3.2. Edaphic aspects

Plant grouping dominated by *P. atlantica* have developed and grown in all types of relatively deep soil. These communities are confined to depressions, clay or silty soils, alluvial deposits (although it can also grow on limestone), and rocky and gravelly soils. Therefore, *P. atlantica* requires significant soil moisture along with other factors (silty-sandy and silty-clay texture, alkaline pH, and a considerable level of CaCO_3) [1].

3.3. Floristic aspects

The study of floristic characteristics (floristic richness, total vegetation cover, plant diversity, biological spectrum, etc.) is considered essential for describing the structure and functioning of vegetation in order to assess ecosystem potential [20].

Floristic characterization involves a dual approach: quantitative (cover, floristic richness) and qualitative (analysis of biological types, phytogeographic and systematic spectrum) to understand the structure of these arid steppe ecosystems, their adaptation to arid conditions, and their biogeographic origin, often marked by species adapted to water stress and degradation [15,21]. It should be emphasized that the analyses carried out were multifactorial, based on biosystematics, the biogeographical and biological belonging of the species, the number of species, the value of the flora, the abundance-dominance of the species, the floristic richness with the means of geostatistics.

3.3.1. Vegetation Cover

The overall vegetation cover rate averages between 20 and 35% across the Ouarka study area.

This improvement in the cover rate is due to the process of biological recovery. According to Le Houérou [22], "biological recovery encompasses all the processes that reverse those of steppe formation and desertification."

3.3.2. Floral Richness

The Ouarka site is distinguished by its remarkable floral richness, harboring a total of 103 plant species. This diversity reflects favorable ecological conditions and a particularly varied ecosystem within the *P. atlantica* grouping.

According to the Daget and Poissonet scale [8], the site is very species-rich, as the number of species inventoried during our investigation exceeds 60. The number of species in a plant community provides an indication of the richness and biological diversity of the overall list of plant communities.

The floristic diversity of arid zones relies primarily on the presence of annual species and the close correlation between edaphic and climatic factors [18,23,24]. This dynamic particularly favors wadi beds, which stand out as the richest biotopes due to their high proportion of ephemeral plants. This phenomenon is explained by the fact that wadis and dayas constitute catchment areas where water accumulates permanently after each rainfall [25]. Thus, thanks to a privileged water supply and a favorable clay-sand substrate, these environments offer optimal conditions for vegetation development [26]. Analyzing the floristic richness of the different plant communities, their biological and chronological characteristics, would highlight their floristic originality, their state of conservation, and, consequently, their heritage value [27].

Floral richness (total and site-specific) is determined by the nature of the soil and, more specifically, by its water retention capacity. In this respect, wadi beds constitute the most favorable environment and thus exhibit the richest and most diverse flora of *Pistacia atlantica*, encompassing a significant number of all inventoried species.

This is due to the fact that they are relatively well-supplied with water and alluvial deposits brought by floods, even irregular ones, which cross these areas.

Comparative analysis of the flora accompanying *Pistacia atlantica* communities in the Ouarka region reveals notable floristic similarities with other steppe and Atlas Mountain areas of the country. This study is based on reference inventories carried out in the main distribution areas of the Atlas pistachio tree in Algeria, notably the works of Benhassini et al. [28], Benaradj [3,15,21,29-33]; Amara [34]; Guelmani [35]; Bouderbala et al. [36]; Belaid [37]. Comparing our results with these data highlights the persistence of taxa characteristic of the Pistacio-Rhamnietalia alliance, while revealing the edaphic and bioclimatic particularities of the Ouarka region.

Table 1. Comparison of the plant community associated with the *Pistacia atlantica* grouping in Algeria

Authors	Site	Wilaya	Number of species
Benaradj [29]	Djedida	Béchar	118 species
Benaradj [29]	Daya Oum Chegag	Béchar	92 species
Benaradj et al. [33]	Bou Ayach	Béchar	127 species
Benaradj et al. [31]	Bou Yala	Béchar	131 species
Benaradj et al. [3]	Djedida	Béchar	118 species
Benhassini et al. [28]	Brézina	El-Bayadh	10 species
Benhassini et al. [28]	Ain Fezza	Tlemcen	17 species
Amara [34]	Fillaoucene	Tlemcen	100 species
Amara [34]	Hammam Boughrara	Tlemcen	88 species
Amara [34]	Béni-Snous	Tlemcen	80 species
Amara [34]	Ain Fezza	Tlemcen	87 species
Benaissa [35]	Ain Rahou-Sfissifa	Naâma	44 species
Benaissa [35]	Tenout - Asla	Naâma	49 species
Benaradj et al. [21]	Hadjadj - Ain Séfra	Naâma	135 species
Benaradj et al. [15]	Boussemghoun	El-Bayadh	107 species
Guelmani [36]	Daya Legrar	Laghouat	30 species
Guelmani [36]	Tilghimt	Laghouat	42 species
Guelmani [36]	Chaknane	Laghouat	38 species
Bouderbala et al. [37]	daya Bentoumi	Djelfa	106 species
Belaid [38]	Gaaloul	Naâma	66 species

The synthetic analysis of floristic richness associated with *Pistacia atlantica* stands reveals a significant disparity in biodiversity across the steppe regions and the Algerian Saharan Atlas. The number of recorded species fluctuates dramatically, ranging from only 10 species in Brézina (El-Bayadh) [28] to a maximum of 135 species at the Hadjadj site in Naâma [21]. This variability is explained by the combination of edaphic conditions, bioclimatic gradients, and the intensity of human pressure, particularly overgrazing and illegal logging.

The study highlights that the western areas, especially Naâma (Hadjadj) and Béchar (Bou Yala, with 131 species), constitute major biodiversity reservoirs where the Atlas pistachio tree fully plays its role as an umbrella species. Conversely, the limited plant life observed at Brézina and Ain Fezza, with only 17 species [28], indicates fragile ecosystems requiring enhanced protection measures. However, the increase in data at Ain Fezza, rising to 87 species [34], suggests either a positive natural regeneration dynamic or a methodological variation in sampling, confirming the potential resilience of these plant communities if local pressures are reduced.

3.3.3. Floral composition

3.3.3.1 Systematic Characterization

The Ouarka station is consistently characterized by the presence of 103 species distributed across 30 families and 81 genera (Fig. 2).

Analysis of floristic diversity shows a clear predominance of Asteraceae with 25 species (24%) and Poaceae with 14 species (14%), which together represent more than a third of the recorded species. These are followed by Fabaceae with 8 species (8%) and Brassicaceae (7%), confirming the major role of these four families in the structure of the studied vegetation. Conversely, the rest of the botanical community is characterized by significant fragmentation: more than half of the recorded families are represented by only a single species (monospecific), such as the Capparidaceae, Cistaceae, Convolvulaceae, Cucurbitaceae, Dipsacaceae, Xanthorrhoeaceae, Amaryllidaceae, Malvaceae, Onagraceae, Plombaginaceae, Rhamnaceae, Rosaceae, Rubiaceae, Anacardiaceae, and Thymelaeaceae, illustrating a high taxonomic diversity but a low density for the majority of the botanical groups present.

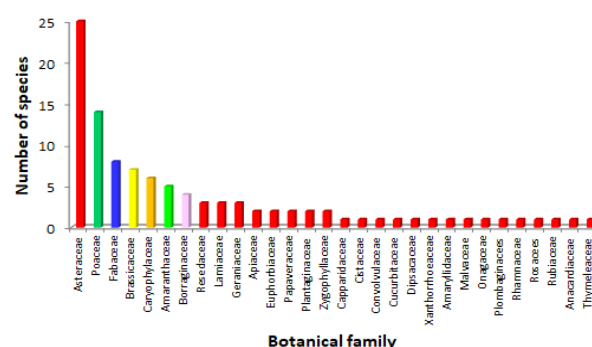


Figure 2. Systematic distribution of species

In the study area, the Asteraceae and Poaceae families predominate, representing 38% of the total flora. This prevalence is linked to their cosmopolitan nature and their strong capacity to adapt to the constraints of the Mediterranean environment.

According to Benaradj [1], these taxa are particularly resistant to anthropogenic pressures, especially overgrazing, thanks to specific mechanisms: rapid tillering and vigorous regrowth in Poaceae [39,40], and high morphological plasticity combined with ruderal strategies in Asteraceae [41]. This adaptive synergy allows these two families to thrive sustainably in semi-arid environments subject to constant ecological stress.

3.3.3.2. Biological Characterization

The figure 3 shows the distribution of plant life forms (biological spectrum) at the Ouarka station.

This biological spectrum reveals a flora dominated by Therophytes (52%), indicating a heavily human-modified, Mediterranean or arid environment where annual plants survive as seeds. The predominance of this biological type, followed by Chamaephytes (21%), suggests environmental degradation due to grazing or drought. The biological type analysis at this station shows that the biological spectrum is characterized by the pattern Th>Ch>He>Ge> Ph:

- Survival strategy: More than half of the species are therophytes. They survive the unfavorable season as seeds, an effective adaptation to drought and irregular rainfall.

- Resistance to stress: Chamaephytes (21%) and hemicryptophytes (14%) occupy significant areas. Their low-growing structure allows them to withstand wind and grazing.

- Weakness of woody plants: Phanerophytes are very rare (4%), which confirms an open environment, probably poor in deep water resources or subject to strong human pressure. This biological spectrum reflects an open, arid, and disturbed environment, typical of pre-Saharan or degraded steppe zones.

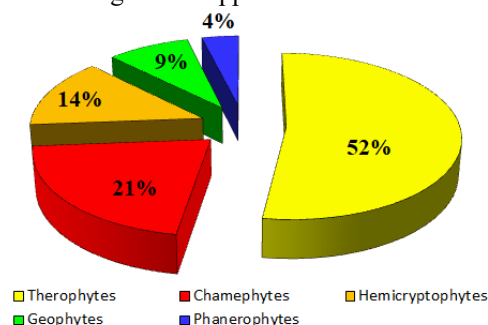


Figure 3. Distribution of species according to life form type

According to Daget [42] and Benaradj et al. [40], therophyty is a form of resistance against harsh climate and unfavorable living conditions.

In general, therophytes are the most dominant in all the studied rangelands, at least in terms of numbers.

Their presence in arid environments is linked to their adaptation strategy. Several authors emphasize that therophytes are the biological type that depends directly on rainfall [42,43].

Emberger [45] states that the therophyte abundance increases with the aridity of the environment, while for Daget [42] and Aidoud [23], therophytic development is a characteristic of arid zones and expresses an adaptation strategy to unfavorable conditions and resistance to climatic rigors.

3.3.3.3. Biogeographical Characterization

Analysis of biogeographical diversity reveals a clear dominance of the Mediterranean element, representing 28% of the total with 29 species, closely followed by the Saharan element (24%). This dual influence underscores the transitional nature of the study area.

A notable feature is the high rate of endemism (19%), reflecting the ecological uniqueness of the environment. The remaining flora comprises multiregional species (15%) and less common components such as Ibero-Mauritanian, Irano-Turanian, and tropical elements, which complete this diverse biogeographical profile.

The results suggest a dynamic of biogeographical types under the influence of ecological changes, positioning biogeographical type as a key indicator of biodiversity evolution.

The interaction between Mediterranean and Saharan flora, although known, requires detailed studies, as this highly diverse transitional zone necessitates targeted conservation, supported by specific research [22,40,46].

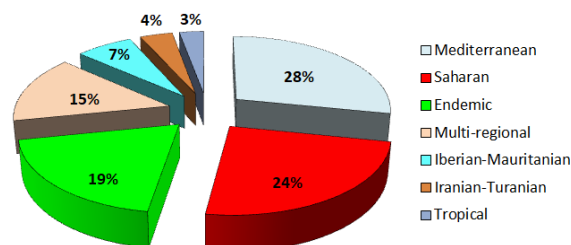


Figure 4. Distribution of Biogeographic types

3.3.4. Processing of floristic data

Correspondence Factor Analysis (CFA) of 32 surveys and 103 species revealed that the distribution of the *Pistacia atlantica* group is mainly structured by climatic and edaphic factors. Correspondence Factor Analysis (CFA) and Hierarchical Ascendant Classification (HAC) are powerful complementary tools for structuring botanical data from the *Pistacia atlantica* community.

CA visualizes the affinities between species and surveys, highlighting ecological gradients such as humidity or degradation, while HAC segments the vegetation cover into homogeneous groups, allowing the identification of specific sub-associations or facies.

The results are illustrated by a dendrogram that classifies the data according to their degree of similarity (Fig.5).

This hierarchical ascending classification (HAC) complements the factor analysis by grouping individuals with similar profiles, thus confirming and refining the identified trends.

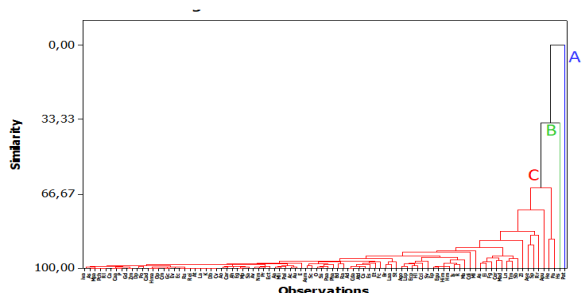


Figure 5. AHC dendrogram of all matrix species in the study area

The AHC dendrogram (Figure 5) structures the flora into three distinct cores based on AFC: Core A (Group 1) is dominated by *Pistacia atlantica* (Pat), Core B (Group 2) is characterized by the pre-steppe formation with *Hammada scoparia* (Hs), and Core C (Group 3) brings together companion species of these two groupings within the Saharan Atlas, such as the following species: *Anacyclus cyrtolopidioides*, *Evacidium discolor*, *Filago Spathulata*, *Carthamus lanatus*, *Atractylis carduus*, *Atractylis serratuloides*, *Atractylis delicatula*, *Catananche arenaria*, *Calendula aegyptiaca*, *Launaea arborescens*, *Rhantherium suaveolens*, *Picris albida*, *Reichardia tingitana*. Factor analysis reveals that the distribution of the Atlas pistachio tree and its associated flora is governed by a superposition of ecological gradients (Fig.6). Axis 1 reflects a gradient of aridity and geomorphology, contrasting Saharan-Arabian species with Mediterranean species based on topography (dayas, wadis) and the presence of therophytes, while axis 2 is specifically linked to rainfall variations. This combination highlights a contrasting plant dynamic, where substrate and water structure the landscape, allowing for the emergence of rich pastures during rainy periods despite the arid nature of the area [1,15,47].

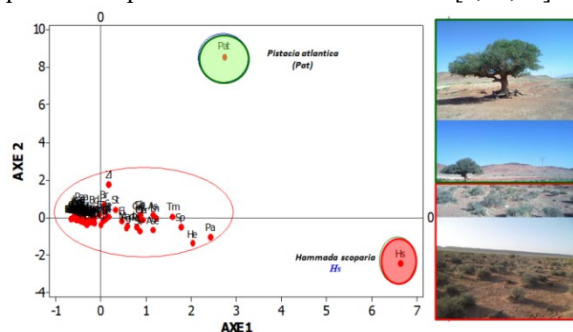


Figure 6. Distribution and projection of species on the factorial plane Matrix Plot of AXE 2 vs AXE 1 grouped according to their abundances in the study station

4. CONCLUSIONS

This contribution concerns the study of the eco-phyto-diversity of the pre-Saharan community of *Pistacia atlantica*, an emblematic species of the Saharan Atlas. This vast distribution area testifies to a remarkable progressive dynamic, where the subjects of *P. atlantica* are diffusely distributed along the thalwegs and wadi beds. Indeed, the appearance of young plants suggests an active regeneration capacity, making this site a relevant model for analyzing the evolution of the species in its natural environment. A better understanding of the problems and factors contributing to the decline of these pistachio groves would contribute to the protection of biodiversity and improved regeneration of this species. Furthermore, a better understanding of the potential of this species would allow for its wider expansion. This species deserves appropriate protection measures, particularly in its natural environment. Indeed, in addition to its forestry and ecological value, *P. atlantica* can also have a definite economic interest, in particular by serving as rootstocks for the cultivation of the fruiting pistachio tree (*Pistacia vera*) in semi-arid areas.

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