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Theme:

Study of *Atriplex halimus* leaves polymorphism belonging to two floors bioclimatic conditions of the Tebessa region

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بسم الله الرحمن الرحيم

Thanks

First of all, we thank Almighty God for having given us the energy and will to carry out this study.

This work would not have been possible without the help of all those who contributed directly or indirectly to its development.We would like to express all our recognition and gratitude to our Protractor Doctor ***Fatmi Hindel****, for encouraging us and valued, as well as to Doctor* ***Dekak Ahmed*** *for his precious help and the having agreed to be part of the jury, our sincere gratitude goes also to Professor* ***Mekahlia Mohamed Nacer*** *for the honor he gives us in agreeing to chair the jury.We also extend our sincere thanks to all our teachers who never hesitated to give us the chance to benefit from their experiences.*

Dedication

I dedicate the fruits of my labor to

The one I value above myself.

The greatest reason for my success, thank you. Without God's grace and your support, I would not have achieved this.

With my mother, I triumphed and succeeded. With my mother, I graduated and accomplished so much.

To my kind father, who toiled tirelessly and taught me that success comes only through patience and perseverance.

To my brother Afif, the best friend one could have throughout life.

Finally, to my steadfast companion, Monia Masoudi, thank you for always standing by my side. Your presence is a tremendous support to me, and I hope we never part ways.

Mahieddine Khouloud

Dedication

يقول تعالى:(وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ) [التوبة:105]

“First of all, I want to thank myself who patiently persevered and worked hard until I achieved,who pushed me forward , thank you to myself who made me stand after every stumble”

“To my mom,the first and the last supporter of my ambitions, who was my right hand in my studies”.

“My father , who strived for my comfort and success, and taught me that , knowledge and education are weapons in this world”

“Thank you youngest sister Isra , I dedicate this research to you as you are the only one who endured my busyness , exhaustion, and worries throughout my study period.”

My childhood friend Salsabil and companion in the journey of life, to the greatest support no matter how things turn out, you will always remain the greatest love.”

“To my compainion Khouloud in the first and last step, thank you for trust in me and for standing by my side so we can achieve this ambition together”.

Bouzid imene

Abstract

This work consists in the study of leaf polymorphism in Atriplex halimus, in two bioclimatic stages of the region of Tebessa.

Initially, a sampling was carried out followed by observations and then comparisons with the keys for determining the leaves.

The results showed that the species studied presents a great diversity when it comes to the morphology of the leaves where several forms were recorded, like the followings: obovate, Orbicular and rhomboidal.

This variable was noticed both at the inter-population level and even at the same individual level.

The natural ecological areas of the Atriplexes are very vast, and studies on these plants must be more interested in their diversity in order to find new variants and thus unite the keys of morphological determination and enrich the databases.

Keywords: Atriplex halimus, polymorphism,morphplogy, leaves, Tebessa.

Résumé

Ce travail consiste à l'étude du polymorphisme folial chez Atriplex halimus, dans deux étages bioclimatiques de la région de Tébessa.

Dans un premier temps, un échantillonnage à été effectué suivie des observations puis de comparaisons avec les clés de détermination des feuilles.

Les résultats obtenus montrent que l'espèce étudiée présente une grande diversité quand à la morphologie des feuilles où plusieurs formes ont été enregistrées, à l'instar des formes : obovales, orbiculaires et rhomboïdales.

Cette variabilité à été remarquée aussi bien au niveau inter population et même au niveau du même individu.

Les aires écologiques naturelles des Atriplex sont très vastes, et les études sur ces plantes doivent s'intéresser encore plus à leurs diversités afin de trouver de nouvelles variantes et d'unir ainsi les clés de détermination morphologiques et enrichir les banques de données.

Mots clés : Atriplex halimus, polymorphisme,morphologie, feuilles, Tébessa.

الملخص:

يتضمن هذا العمل من دراسة تعدد الأشكال الورقية في نبات القطف في منطقتين بيو مناخيتين في تبسة. في البداية، تم إجراء عينة تلاها ملاحظات ثم مقارنات مع المفاتيح لتحديد الأوراق. أظهرت النتائج أن النوع المدروس يقدم تنوعًا كبيرًا فيما يتعلق بمورفولوجيا الأوراق حيث تم تسجيل عدة أشكال، مثل: البيضوي المقلوب، الدائري، والمعيني. لوحظ هذا التنوع على المستوى السكاني وبين الأفراد نفسهم. تعتبر المناطق البيئية الطبيعية لنبات القطف شاسعة جدًا، ويجب أن تركز الدراسات على هذه النباتات وتنوعها من أجل العثور على متغيرات جديدة، وبالتالي التوصل لتوحيد مفاتيح التحديد المورفولوجي وإثراء قواعد البيانات .

الكلمات المفتاحية: القطف البحري، تعدد الأشكال، الأوراق، تبسة

Summary

Summary

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Introduction

Introduction

The genus Atriplex belongs to the Chenopodiaceae family. In Algeria, Atriplexes represent nearly a million hectares (Ouadah, 1982), they are found in coastal areas, chotts and steppe areas (Ghezlaoui, 2001) including the region of Tebessa, which is considered to be a steppe space belonging to a recent collapse basin forming part of semi-arid zones with insufficient water supply (Benmahmoud, 2012) where the most representative species is A.halimus.

The literature devoted to this genus shows that A.halimus presents greater polymorphism than that of other species of the same genus (Quezel and Santa., 1962; Maire, 1962). This species is often cited as a very polymorphic species, probably in relation to its great ecological amplitude and its dominant allogamous reproduction (Abbad, 2004). However, there is significant morphological polymorphism in Atriplex, which is manifested in the size and shape of leaves, fruiting valves and seeds, as well as polymorphism in biomass production (Ben Ahmed, 1996).

The description of the polymorphism of a species is, most often, based on comparative observations carried out at different periods on individuals belonging to several populations, but more rarely on individuals of the same population, or on a particular individual. Furthermore, and despite the fact that several studies have treated the botany of the genus Atriplex in general and the species A. halimus in a particular way, there remain many points of dispute; such as the unification of leaf morphological keys, the characterization of floral morphology and the sexuality of flowers and inflorescences (Abbad et al.,2003).

In this work, we were interested in the analysis of the diversity of Atriplex halimus leaves, plants belonging to indigenous populations at the level of two bioclimatic stages of the Tébessa region, based on keys for leaf morphological determination. , the results obtained show that a large polymorphism characterizes the accessions studied.

How is the morphological diversity of the leaves of Atriplex halimus, a species representative of the semi-arid zones of the Tébessa region in Algeria, influenced by local bioclimatic conditions, and what are the implications of this polymorphism for the characterization and management of this species in its natural habitat?.

Chapter 01:

Bibliography part

1.1 *Atriplex*

1.1.1*Generaliti*s

Atriplex, commonly referred to as saltbush, comprises a genus of plants within the family Chenopodiaceae. These plants are notable for their adaptation to saline environments, thriving in arid and semi-arid regions across the globe, including the Mediterranean basin. They play a significant ecological role due to their halophytic nature, enabling them to grow and reproduce in conditions where many other plant species struggle to survive **(Le Houérou,1992) .**

The *Atriplex* plant is considered the most suitable plant for the development of degraded lands and the organization of agricultural production in a semi-arid and arid climate. This plant removes salt from its tissues and can withstand the negative effects of salinity from the inside. These species are characterized by their morphology. Few studies have been conducted so far on the assessment of the polymorphism of Atriplex plants.

The five main types offer real practical utility :

Atriplex Canescens: Pursh James Shad Scale fruiting bracts are 5-15mm long, with a spherical center and four large wings. The fruit has a coarse scaly tomentum, while larger bracts have smoother surfaces and prominent veins. Seed is retained in the bracts, with one dark brown form. Radicle apical is 1.5mm wide. by E Nelson in Wyoming.

Atriplex Nummularia: Lindl Round Leaved Saltbush has fruiting bracts united at the base, measuring 4-10 mm in length. The free apical portion is thin and appressed, with margins irregularly toothed or entire. Seeds are retained in the bracts near the base, with two forms of seed varying in size and color. Radicles are subapical or apical.

Atriplex glauca. This subshrub species is unique due to sessile, rounded oval leaves, reddish-white color, and short, reddish quilted branches. Found in Languedoc, maritime places, and Saint-Hourens near Toulouseuse, it's infused with wine and used for colic pain relief. (Mm of Lamarck and Candolle)

Atriplex mollis. This plant, similar to the atriplex portulacoides, has straight stems, soft, fuccullent leaves, and large calyxes. It's a branchy shrub with cylindrical whitish branches, lanceolate leaves, and transparent obtules. Its flowers are small, numerous, and agglomerated. Discovered by Mr. Defson-taines. (Mr. Lamarck)

1.1.2.Classification of the Atriplex genus:

Table 01: Classic classification

Classical classification	
Kingdom	Plantae
Phylum	Tracheophyta
Class	Magnoliopsida
Order	Caryophyllales
Family	Amaranthaceae
Genus	Atriplex L
Species	Atriplex halimus L

1.1.3.Physiology of atriplex halimus

A. halimus is a halophytic shrub present- both C4 photosynthesis (MARTINEZ et al., 2003). C4 plants have anatomical characteristics mics allowing them a high metabolism photosynthetic efficiency (increase in the rate of CO_2). The leaf anatomy of C4 plants is of type “Kranz”, presenting a sheath of large cells dimensions that surround the vascular tissues.C4 plants have better efficiency of use water than C3 plants in drought conditions and high temperatures (MARTINEZ et al., 2003).

1.1.4. Presentation of Atriplex halimus :

Saltbush is a densely tufted halophytic shrub that grows to a height of 2-3 m and spreads to 2.4 m in width (OEP, 2012; Tutin et al., 1993). It is deeply rooted (Walker et al., 2014b). The leaves are silvery white in colour. The erected stems bear alternate leaves very variable in shape and dimensions (up to 4 cm in length). The inflorescence is born on leafless twigs, it is a more or less dense terminal panicle of small, yellowish or green flowers (OEP, 2012; Tutin et al., 1993). The fruits are numerous, horizontally spreading, coriaceous, kidney-shaped, 3.5-4 x 5-6 mm (Flora of Pakistan, 2018; OEP, 2012). The seeds are 1.5 mm, brown to dark brown (Flora of Pakistan, 2018).

There are 2 subspecies of Atriplex halimus: halimus and schweinfurthii. Atriplex halimus subsp. halimus is shorter (1-2 m) than Atriplex halimus subsp. schweinfurthii (1-3 m). It has a higher leaf/stem ratio and it has erect and scorpoioides leafy twigs while those of subsp. schweinfurthii are rigid and reddish in colour (Le Houérou, 1992). Subsp. halimus is commonly found in semi-arid and sub-humid Mediterranean zones, occasionally in the arid zone, Mediterranean, Atlantic and North Sea Shores while subsp. schweinfurthii is adapted to arid areas, gypsoferous marls and saline depressions, occasionally in desert depressions having a water table, often in abandoned cropland (Franclet et al., 1971).

1.1.5. Polymorphism of Atriplex :

5.1 Morphology :

This is a bushyshrub from the base,reaching a height of 1 to 2.5 meters. Its stem is woody with gray-whitish bark ; the leaves are alternate, evergreen, slightly leathery and silver-gray on both sides. With a variable shape, ranging from oval-rhomboidal to lanceolate. measuring between 1 and 3 cm in lengthand 0.5 to 2 cm width. tapering into a short petiole at the base.

It blooms from July to October. While generally described as monoecious,some individualsof A. halimus are reported to be polygamous.exhibiting both male and female unisexualflowers, as well as some bisexual flowers, making them trimonoecious(Talamali et al 2001)

The male flowers are small and yellowish,with 5 tepals and 5 stamens; while the female flowers are greenish, without perianth, and have two opposite bracteoles. The inflorescences measure from 20 to 50 cm and are in compound clusters, either bare or slightly leafy at the base.

The valves surrounding the whitish fruits are entire, rounded in shape like kidney, wider (4-5mm) than tall (3-4mm) . The seeds are reddish and, measure between 1.5 and 2 mm.

Picture 1: a bush of Atriplex halimus

5.2 Structure:

5.2.1 Roots :

Deep root system: The Atriplex halimus is known for developing a deep root system that can reach depths in the soil,allowing it to exploit the water reserves available at depth, even in arid environments. This adaptation is often observed in plants from semi-arid regions.(Djerroudi .Z, Moulay.O, Belkhodja.S) .

Picture 2 : Roots of Atriplex halimus

5.2.2 Stems:

In general, the stem is erect, with more or less fewer ramifications depending on the environmental conditions.the stems are lined with small leathery leaves, . It naturally rises between 1.50 and 2 m high depending on the species.flowers towards the tip.

This gives the stems a pale greenish-browncolour during flowering. (Journal of Arid Environmentsby Elsevier);

The stem is woody with whitish-gray bark at the base andherbaceous in its upper part (Guillaume Fried).

Picture 3 : Stems of Atriplex halimus

5.2.3 Leaves:

The evergreen leaves are whitish-green in color. They are alternate, variable in shape, oval or rhomboidal, with a short petioleat their base ; covered with hairs. Their maximum size is 4 cm in length for 2 cm in width. They are slightly ribbed.(LAMARE Véronique, PAVON Daniel) . With a matte silvery white on both sides, its leaves are persistent, succulent and silvery, which allows it to survive in arid and saline environments. (R Nègre)

Picture 4 : Leaves of Atriplex halimus

1.1.6 .Geographical distribution and habitat

A. halimus grows naturally throughout Macronesia, the Medi-terranean basin and beyond into western Asia: including southern Portugal, France, southern and eastern Spain (and the Canary Islands), Italy, Greece, Malta, Turkey, Cyprus, Israel, Syria, Lebanon,Jordan, Tunisia, Morocco, Algeria, Libya, Egypt and Saudi arabia . A few small populations are present in Brittany (France) and on islands such as Belle-Ile, Jersey and Guernsey . Due to its varied uses, particularly as livestock forage, it has been introduced elsewhere: for example, Oman, Iran, Iraq,Pakistan, South Africa, Chile, Argentina, New Zealand and the U.S.A. In countries closer to the Equator where it has been introduced, like Kenya and Ethiopia, the small photoperiod variation during the year means that it does not flower.

Table 2. Numerical distribution of Atriplex species world wide

Country or region	Number of species	Country or region	And/or sub species
UNITED STATES	110	Baja California (Mexico)	25
Australia	78	North Africa	22
Basin Mediterranean	50	Texas	20
Europe	40	South Africa	20
Ex. USSR	40	Iran	20
Middle East	36	Syria	18
Mexico	35	Palestine et Jordanie	17
Argentina	35	Algeria and Tunisia	17
California	32	Bolivia and Peru	16
Chile	30		

1.1.7.Distribution in Africa:

In North Africa the genus Atriplex includes 15 spontaneous species, 2 naturalized species and2 introduced species. These species are divided into 9 perennial species, a biannual species and9 annual species

Table 03: Atriplex in North Africa

Spontaneous species		Naturalized species		Introduced species
Perennials	Perennials	Perennials	Biennials	Perennials
	A. colorei	A. inflata	A.semibaccata	A. nummularia
A.chenopodioi des				
A.dimorphoste gia	A. coriacca			A. lentiformis
A. hastata	A. glauca			
A. littoralis	A. halimus			
A. patula	A. malvana			
A. rosea	A. mollis			
A. tatarica	A.portulacoi des			
A. tornabeni				

1.1.8.Distribution in Algeria:

In Algeria, the natural homogeneous layers of Atriplex are composed mainly From Atriplex halimus.A.glauca and A.portilacoides; they are used as rangeland for herds particularly in arid and semi-arid areas.

Statistics from the Ministry of Agriculture (1974) report that these layers in association with the olaceous sals cover an area of 1,000,000 ha. These layers have not been the subject of a precise cartographic inventory and must certainly be revised downwards.

However, the largest areas would be found between the isohyets; which corresponds to the so-called pastoral and agropastoral zones (Tébessa, Batna, M'sila, Boussaâda, Oum El Bouaghi, Biskra Djelfa, Tiaret, Saida…)

Table 04: Distribution of different species of Atriplex in Algeria

Species	Name	Location
Annuals (Usually differ by the shape of the leaves, port and valves fruiting)	A. Chenopodioid es Batt.	Bouhanifia (Mascara) (very rare)
	A. littoralis L.	Around Algiers (rare)
	A. hastata L.	Fairly common in Tell And very rare elsewhere
	A. patula L.	Fairly common in Tell And very rare in Aflou
	A. tatarica L.	Annaba and Sétif (very rare)
	A. rosea L.	Biskra and on the coast from Algiers and Oran (very rare)
	A. dimorphostegia Kar and Kir	Northern Sahara (enough commune), Sahara central (rare).
	A. tornabeni Tineo	Sahel of Algiers, Golfe D'Arzew (very rare).
Perennials	A. portulacoides L.	Fairly common in Tell
(Usually differ by the shape of the leaves, the size of the shrub, the stem habit and appearance of the perianth)	A. halimus L.	Common in all Algeria
	A. mollis Des f.	Biskra and Oued El-Khir (very rare).
	A. coriacea Forsk.	
	A. glauca L. Common in Algeria.	

1.1.9. Exposure to stress:

1.1.9.1 Temperature and light:

Atriplex centralasiaticaplants that are adapted to salt have better heat resistance, allowing them to maintain higher levels of photosynthesis at high temperatures. This ability can play an essential role in the survival of this plant in areas with high salinity and high temperature.**(Qiu and Lu 2003**).

Due to the mutual shading of the leaves and the reflection of light from the surface of the leaves by a layer of salt crystals formed after the collapse of the vesicular hairs (Mozafar and Good in, 1970), A. halimus can withstand a high light intensity, which gives it a greenish-gray tint.**(David J. Walkerand Stanley Lutts)**.

1.1.9.2 Salt stress:

Sodium chloride treatment stimulates plant growth and increases the production of organic substances, which indicates a positive response of Atriplex halimus to this particular environmental situation**.(Ben Ahmed H, 1995**),

The Atriplex halimus seems to resist salt stress due to its ability to accumulate salt in trichomes that cover the surfaces of the leaves**.(Jean-Marie Kinet, Fatima Benrebiha, Sadok Bouzid, Sergio Lailhacar, Pierre Dutuit).**

1.1.10.Biological activities of Atriplex halimus:

1.1.10.1. Antibacterial activity

Some work is based on the study of the antibacterial activity of extracts of this Plant, they indicate its effectiveness against multiple pathogenic bacterial strains (Abdel Rahman et al., 2011; Ounaissia et al., 2020; Ziane et al., 2020). Which proves its use in traditional medicine to treat bacterial infections.

1.1.10.2.Insecticidal activity

Consists of the use of natural substances extracted from the plant (from phytosanitary preparations), in order to demonstrate its insecticidal power against insects pests.

A work was based on a toxicological study of the aqueous extract of A. halimus in the aim of determining its insecticidal effect on the eggs and L5 larvae of Ectomeylois ceratoniae Zeller (Boukhalfa and Bouraya, 2019). What reveals effects toxic effects perceptible on this insect, it could be a good alternative to pesticides chemicals, while preserving human health and the environment.

1.1.11. Environmental impact

- **Erosion control, windbreak and soil improver**

Atriplex halimus has a deep, strongly developed taproot that can go as deep as 10 m below ground surface. It can bind the soil and prevent erosion (Ortiz-Dorda et al., 2005; Abbad et al., 2004; Chisci et al., 1993; Le Houérou, 1992). Saltbush is a pioneer species on sandy soils and a very good windbreak: it reduces wind speed at ground level and runoffs. These properties can be useful for dune stabilization and against desertification (PFAF, 2014; Nedjimi et al., 2013; Wills et al., 1990). The important biomass provided by saltbush helps restoring soil fertility: it is adding organic matter that increases soil stability and improves permeability, hence rain-use efficiency but also soil microbial activity (Le Houérou, 1992).

- **Soil reclamation**

Saltbush (Atriplex halimus) can draw salt out of the soil and has thus been used in soil-reclamation projects to de-salinate the soil in marginal and degraded soils (PFAF, 2014; Wills et al., 1990).

1.1.12.Ecological interest :

The salinization, frequently linked to water limitations, decreases arable land and jeopardizes the food balance of these regions. One of the ways of valorizing degraded soils consists in introducing drought-

resistant forage shrubs, in particular species of the genus Atriplex, which have an ecological and pastoral interest.

The Atriplex species has attracted particular attention from state agencies and NGOs, who have stressed the importance of Atriplex halimus as a crucial genetic resource for North Africa, due to the significant ecological risks. In 1994, the European Union approved a research project on Atriplex halimus with the aim of improving this plant.(Jean-M, Benrebiha F, Sadok B, Sergio L, Pierre D).

1.1.13.Economic interest :

Forage and Livestock Feed:

The resistance of the plant to drought is high and it can withstand high levels of salinity, which makes it suitable for specific environments.

The plantations of Atriplex halimus are easily accessible to animals, which makes them an accessible food source.

The exploitation of plantations should not be undertaken before the third year after planting, to allow the plant to settle well . The leaves can be collected and distributed to the animals, either individually or in combination with other plants such as cacti and acacias, to diversify the livestock's diet.(B. Nedjimi, B. Guit, M. Toumi, B. Beladel ,A. Akam1Y. Daoud).

1.1.14. Medical interest:

Traditional medicine regularly uses Atriplex halimus due to its hypoglycemic and lipid-lowering properties.(Yaniv et al., 1987 ; Mirsky et Nitsa, 2001).

Atriplex halimus is also used in the treatment of urinary tract inflammations (cystitis) and urolithiasis. (Belouad, 2001 ; Emam, 2011)

In Western Sahara, A. halimus residues increase the effectiveness of insulin.(Shani et al., 1972 ; Mertz et al., 1973 ; McKell et al., 1994 ;Mirsky et Nitsa., 2001)

They are also used to treat gastric acidity. The seeds are eaten raw and crushed as a vomitive. (Bellakhdar, 1997).

The roots, are cuted into strips like the siwak, are used for mouth and teeth care. The leaves are used in the treatment of heart conditions and diabetes. (Bellakhdar, 1997 ; Said et al., 2000).

Chapter 02:

Material and methods

2. Materials and methods

2.1. Description of the study site:

Tébessa is located in the east of Algeria (35°20' N, 8°6' E, Altitude: 960 m). Its area is of the order of 13878 km2, it is limited to North by Souk Ahras, to the South by El Oued, to the West by Oum El Bouaghi and Khenchla, and to the East by the border Algerian-Tunisian (Figure 1). Tebessa covty It is divided by 28 municipalities, the wilaya is made up of several geographical zones:

In the North: the Tébessa Mountains which are part of the Atlas, the High Plateaux and the High Plains.

In the South: the Saharan domain made up of a Saharan plateau.

The wilaya of Tébessa is a meteorological transition zone, it is distinguished by four bioclimatic stages [2]:

- The Sub-humid (400 to 500 mm/year), very small, it is limited to the tops of a few reliefs (Djebel Serdies and Djebel Bouroumane);
- Semi-arid (300 to 400 mm/year), covers the entire northern part of the wilaya;
- The Sub-arid (200 to 300 mm/year), covers the steppe plateaus;
- The arid or mild Saharan (less than 200 mm/year), extends beyond the Saharan Atlas.

The wilaya of Tébessa is made up of seven different regions, and we studied the ATriplex

halimus in two zones:

Zone 2: Thermo-Mediterranean Short season.

Zone 3: Thermo-Mediterranean Long season.

The coordinates of the sampling sites are presented in Figure 2.

The latter is made up of geographical maps of the Wilaya. Table 5 and Table 6

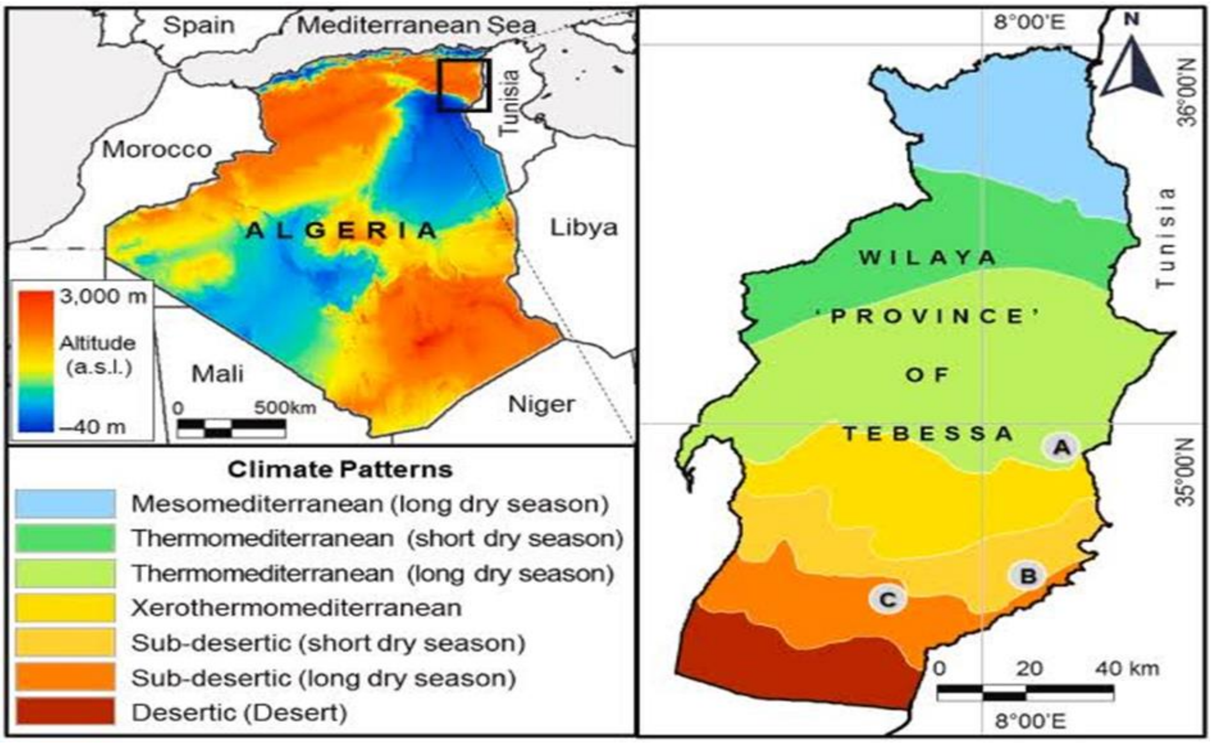


Figure 5: Map of bioclimatic zones of the wilaya of Tébessa

Table 05: Coordinates of sampling sites in zone 02

Site	Sample	Geodesic Tips
Thermo-Mediterranean (short season)	1	35° 28′ 09″→ 812 m
	2	35° 27′ 08″→ 812 m
	3	35° 27′ 12″→ 814 m
	4	35° 26′ 48″→ 870 m
	5	35° 26′ 65″→ 885 m
	6	35° 26′ 23″→ 830 m
	7	35° 25′ 88″→ 820 m
	8	35° 24′ 10″→ 800 m
	9	35° 24′ 10″→800 m
	10	35° 24′ 75″→810 m

Table 06: Coordinates of zone 03 sampling sites

Site	Sample	Geodesic Tips
Thermo-Mediterranean (long season)	1	35° 21′ 57″ →915 m
	2	35° 21′ 75″ →917 m
	3	35° 21′ 12″ →920 m
	4	34° 57′ 13″→ 905 m
	5	34° 57′ 26″→922 m
	6	34° 57′ 98″→930 m
	7	34° 22′ 12″→885 m
	8	34° 12′ 12″→875 m
	9	34° 12′ 70″→895 m
	10	34° 11′ 33″→867 m

2.2.Sampling

In the region known as Tébessa plain, random sampling was carried out in two different sites where Atriplex halimus grows. We took a sample of leafy branches of 20 plants of A. halimus, then we randomly took 10 samples of leaves, from each branches. These were chosen as the subject of this study .

2.3.Plant material

The plant material used in this study corresponds to plants of native species and spontaneous of A. halimus belonging to the Chenopodiaceae family .

2.4.Visualization and photography

Plant leaves were photographed by using Samsung Galaxy 03, then these images were processed by computer using Microsoft Office Picture Manager 2013 program.

2.5.Morphological characterization

Using the morphological determination keys we characterized leaf shapes and of the summit Appendix I and II It should be noted that one or more keys can be used to constitute a single character of the leaves.

Results

3. Results

3.1. Analysis of leaf diversity:

3.1..Leaf morphology of Atriplex halimus population from region 02:

The leaves of plants region (02) are characterized by great variability very important in terms of their shape of the blade and the apex. Indeed, at this area, several leaf forms were observed (Appendix 01).

In the first plant, we noticed a different variety of leaves, and some of their shapes were repeated more than once (Table 01)

Tables 7: Photos of leaves of plant 01 from zone "02"

Plant number	shapes	leaves
Plant 01	Leaf 1 **Linear**	
	Leaf 2 **Elliptic**	
	Leaf 3 **Deltoide**	
	Leaf 4 **Oval**	

	Leaf 5 **Linear**	
	Leaf 6 **Deltoide**	
	Leaf 7 **Oblong**	
	Leaf 8 **Oval**	
	Leaf 9 **Lanceolate**	
	Leaf 10 **Lanceolate**	

For plant 02, we counted five different leaf shapes right from the top different (table 09)

Tables 8: Photos of leaves of plant 02 from zone "02"

Plant number	shapes	leaves
Plant 02	Leaf 1 **Oval**	
	Leaf 2 **Obovate**	
	Leaf 3 **Orbicular**	
	Leaf 4 **Elliptic with Emarginated summit**	
	Leaf 5 **Lanceolate**	

	Leaf 6 **Oblong with high cut summit**	
	Leaf 7 **Lanceolate**	
	Leaf 8 **Slightly asymmetrical oval**	
	Leaf 9 **Orbicular**	
	Leaf 10 **Elliptic**	

At the third level, 03, we noticed three leaf shapes that were completely different from the previous plant. (Table 10)

Tables9: Photos of leaves of plant 03 from zone “02”

Plant number	shapes	leaves
Plant 03	Leaf 1 **Elliptical**	
	Leaf 2 **Obcordate**	
	Leaf 3 **Ovate**	
	Leaf 4 **Linear**	
	Leaf 5 **Reniform**	

	Leaf 6 **Oblong**	
	Leaf 7 **Oval**	
	Leaf 8 **Obovate**	
	Leaf 9 **Oblong**	
	Leaf 10 **Asymetrical obovate**	

At the level of the fourth plant 04, we observed four completely different symmetrical shapes for each leaf. (Table 11)

Tables 10: Photos of leaves of plant 04 from zone "02"

Plant number	shapes	leaves
Plant 04	Leaf 1 **Asymetrical Obovate**	
	Leaf 2 **Asymetrical oval**	
	Leaf 3 **Elliptical**	
	Leaf 4 **Asymetrical Obovate**	
	Leaf 5 **Asymetrical obovate**	
	Leaf 6 **Oblongate**	

	Leaf 7 **Lanceolate**	
	Leaf 8 **Asymetrical oblanceolate**	
	Leaf 9 **Asymetrical Spatulate**	
	Leaf 10 **Oblanceolate**	

We also noticed at the plant level five shapes that are unique in type from the rest of the shapes (Table 12)

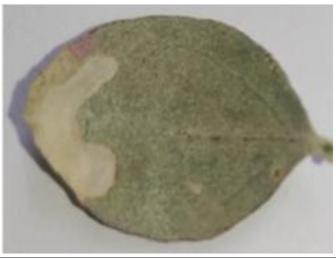
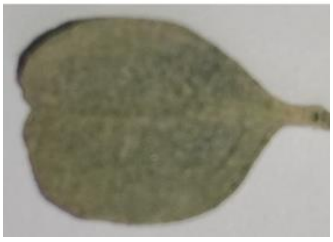
Tables11: Photos of leaves of plant 05 from zone "02"

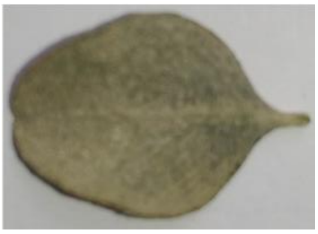
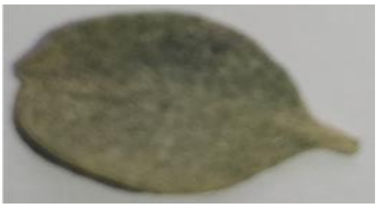
Plant number	shapes	leaves
Plant 05	Leaf 1 **Oblong**	
	Leaf 2 **Oval**	
	Leaf 3 **Asymetrical**	
	Leaf 4 **Asymetrical Ovale**	
	Leaf 5 **Orbicular with emarginated summit**	

	Leaf 6 **Asymetrical oblongate**	
	Leaf 7 **Oblongate**	
	Leaf 8 **Asymetrical Spatulate**	
	Leaf 9 **Orbicular**	
	Leaf 10 **Oblongate**	

We also noticed at the plant level five shapes that are unique in type from the rest of the shapes (Table 12)

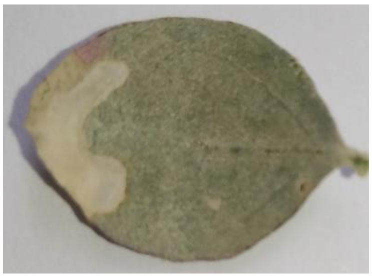
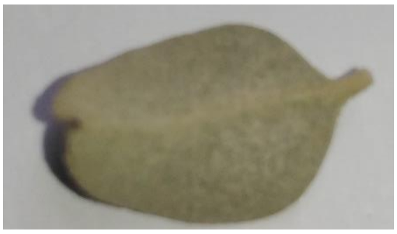
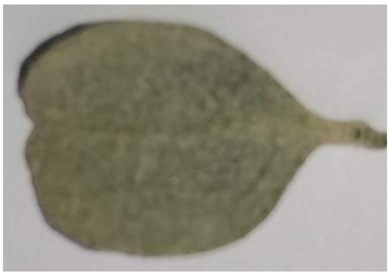
Tables 12 : Photos of leaves of plant 06 from zone "02"

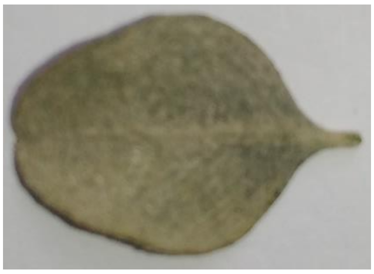
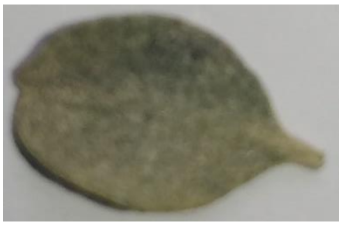
Number of plants	shapes	leaves
Plant 06	oval	
	oblong with a mucronate apices	
	obovate with a slightly emarginated tip	
	Oval with emarginated tip	
	Obcordate with emarginate tip	
	Obovate with emarginate apices	

	Obovate	
	Elliptic	
	Oval	
	Oblong	

At the level of the sixth plant 06, we observed seven different forms.with a totally different vertex, for each leaf.

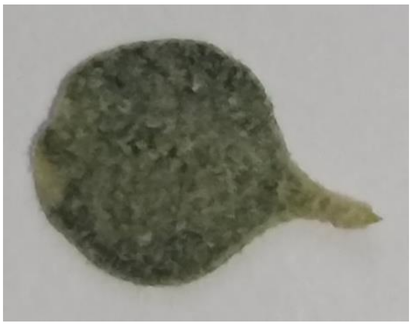
Table 13: Photos of the leaves of plant 07

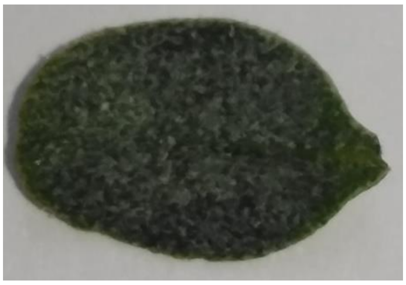
Number of plants	shapes	leaves
Plant 07	oval	
	oblong with a mucronate apices	
	obovate with a slightly emarginated tip	
	Oval with emarginated tip	
	Obcordate with emarginate tip	

	Obovate with emarginate apices	
	Obovate	
	Elliptic	
	Oval	
	Oblong	

At the level of the seventh plant 07 we observed six different forms.with a totally different vertex, for each leaf.

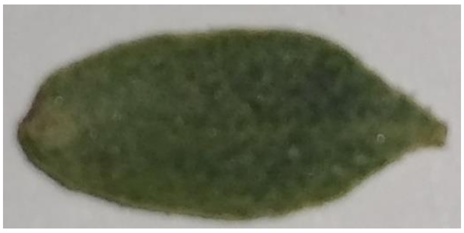
Table 14 : Photos of the leaves of plant 08

Number of plants	shapes	leaves
Plant 08	Elliptic with Obtuse Tip	1 
	Lanceolate	
	Lanceolate	
	Elliptic	
	Elliptic	
	Oval	

	Elliptic with Obtuse Tip	
	Oblong with Obtuse tip	
	Obovate	
	Lanceolate with obtus tip	

At the level of the eighth plant 08 we observed six different forms.with a totally different vertex, for each leaf.

Table 15: Photos of the leaves of plant 09

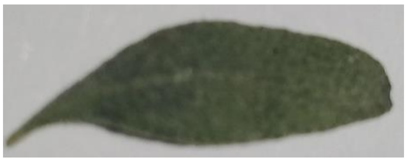
Number of plants	shapes	leaves
Plant 09	Oblong	
	Oblanceolate	
	Spatulate	
	Ovale with echancrate tip	
	Lanceolate	
	Orbicular	
	Orbicular with Emarginated tip	

	Oblong with Emarginated tip	
	Orbicular	
	Lanceolate	

At the level of the ninth plant 09 we observed four different forms.with a totally different vertex, for each leaf.

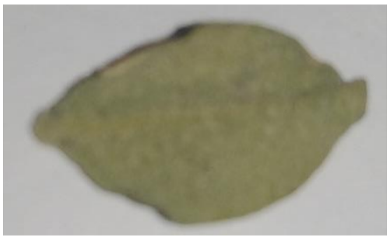
Table 16 : Photos of the leaves of plant 10

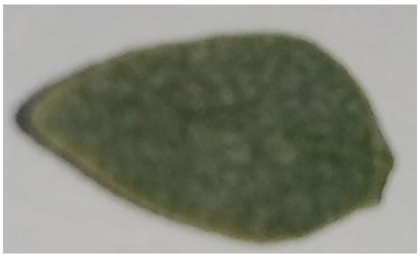
Number of plants	shapes	leaves
	Linear	
	Lanceolate	
	Spatulate slightly asymmetrical	

Plant 10	Spatulate slightly asymmetrical	
	Oblanceolate	
	Linear with obtuse tip	
	Obovate	
	Lanceolate	
	Linear	
	Oblanceolate	

At the level of the tenth plant 10, we observed seven different forms.with a totally different vertex, for each leaf.

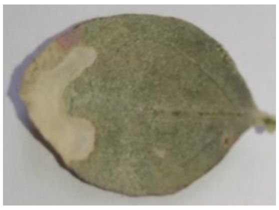
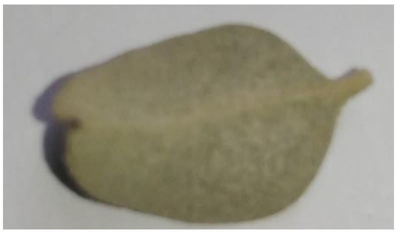
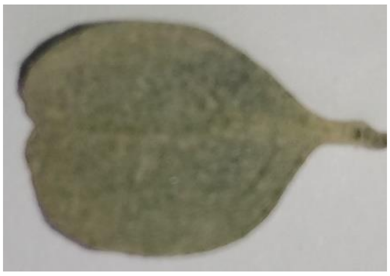
Table 17: Photos of the leaves of plant 11

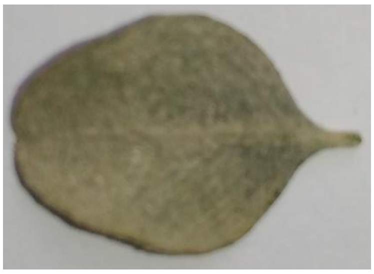
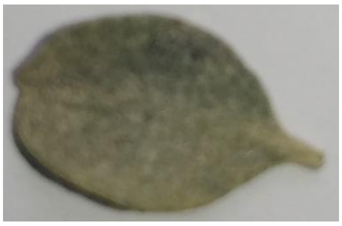
Number of plants	shapes	leaves
Plant 11	Obovate slightly asymmetrical	
	Oval	
	Lanceolate	
	Deltoid	
	Oval with Emarginated Tip	
	Elliptic	
	Oblanceolate	

	Oval with echancrated tip	
	Obovate	
	Deltoid	

At the level of the sixth plant 06, we observed seven different forms.with a totally different vertex, for each leaf.

Table 18: Photos of the leaves of plant 12

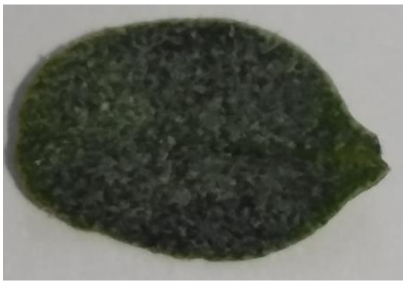
Number of plants	shapes	leaves
Plant 12	oval	
	oblong with a mucronate apices	
	obovate with a slightly emarginated tip	
	Oval with emarginated tip	
	Obcordate with emarginate tip	
	Obovate with emarginate apices	

	Obovate	
	Elliptic	
	Oval	
	Oblong	

At the level of the seventh plant 07 we observed six different forms.with a totally different vertex, for each leaf.

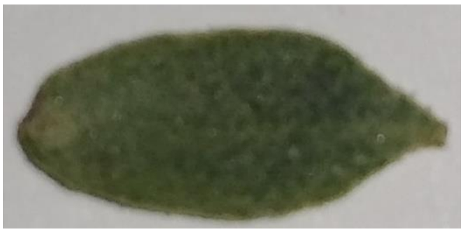
Table 19 : Photos of the leaves of plant 13

Number of plants	shapes	leaves
Plant 13	Elliptic with Obtuse Tip	
	Lanceolate	
	Lanceolate	
	Elliptic	
	Elliptic	
	Oval	

	Elliptic with Obtuse Tip	
	Oblong with Obtuse tip	
	Obovate	
	Lanceolate with obtus tip	

At the level of the eighth plant 08 we observed six different forms.with a totally different vertex, for each leaf.

Table 20: Photos of the leaves of plant 14

Number of plants	shapes	leaves
Plant 14	Oblong	
	Oblanceolate	
	Spatulate	
	Ovale with echancrate tip	
	Lanceolate	
	Orbicular	
	Orbicular with Emarginated tip	

	Oblong with Emarginated tip	
	Orbicular	
	Lanceolate	

At the level of the ninth plant 09 we observed four different forms.with a totally different vertex, for each leaf.

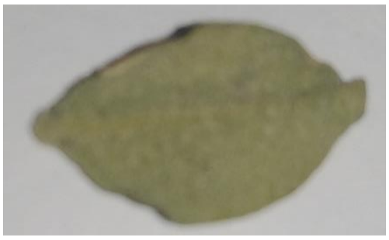
Table 21 : Photos of the leaves of plant 15

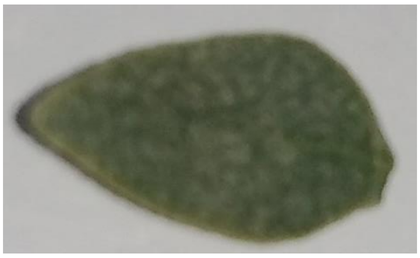
Number of plants	shapes	leaves
Plant 15	Linear	
	Lanceolate	
	Spatulate slightly asymmetrical	
	Spatulate slightly asymmetrical	

	Oblanceolate	
	Linear with obtuse tip	
	Obovate	
	Lanceolate	
	Linear	
	Oblanceolate	

At the level of the tenth plant 10, we observed seven different forms.with a totally different vertex, for each leaf.

Table 22: Photos of the leaves of plant 16

Number of plants	shapes	leaves
Plant 16	Obovate slightly asymmetrical	
	Oval	
	Lanceolate	
	Deltoid	
	Oval with Emarginated Tip	
	Elliptic	
	Oblanceolate	

	Oval with echancrated tip	
	Obovate	
	Deltoid	

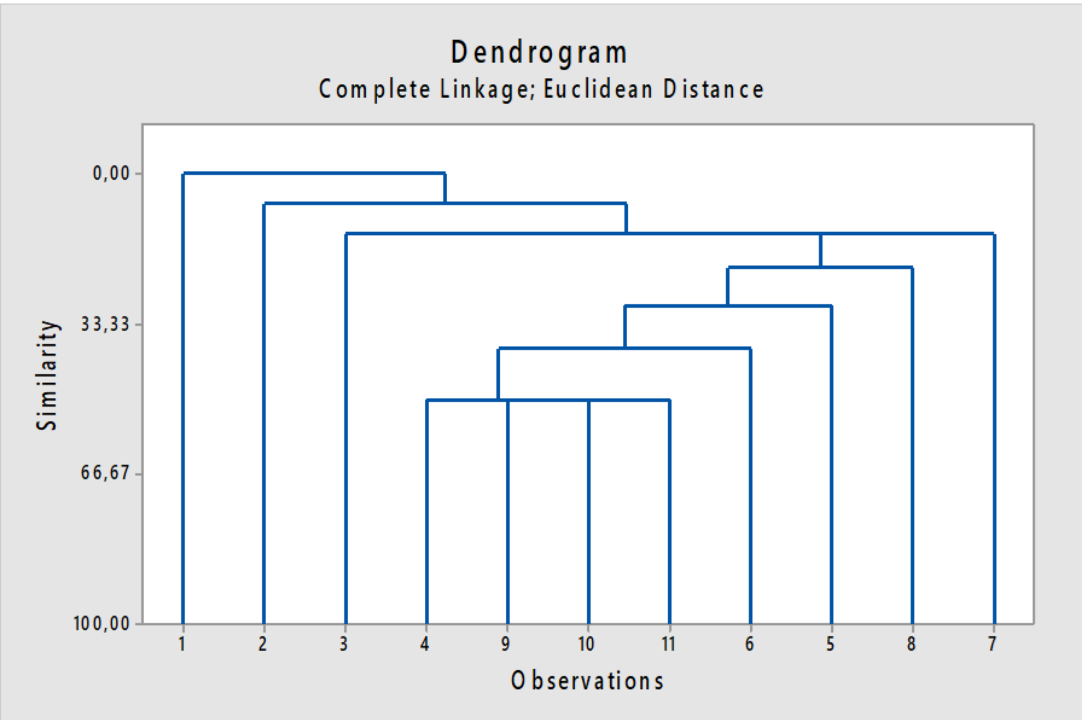
Cluster Analysis of Observations: 1; 2; 3; 4; 5; 6; 7; 8; ...

Euclidean Distance, Complete Linkage
Amalgamation Steps

Step	Number of clusters	Similarity level	Distance level	Clusters joined		New cluster	Number of obs. in new cluster
1	10	50,0000	1,41421	10	11	10	2
2	9	50,0000	1,41421	9	10	9	3
3	8	50,0000	1,41421	4	9	4	4
4	7	38,7628	1,73205	4	6	4	5
5	6	29,2893	2,00000	4	5	4	6
6	5	20,9431	2,23607	4	8	4	7
7	4	13,3975	2,44949	4	7	4	8
8	3	13,3975	2,44949	3	4	3	9
9	2	6,4586	2,64575	2	3	2	10
10	1	0,0000	2,82843	1	2	1	11

Final Partition
Number of clusters: 1

	Number of observations	Within cluster sum of squares	Average distance from centroid	Maximum distance from centroid
Cluster1	11	22,7273	1,39899	1,86530



Picture 6: Heatmap of the forms of Atriplex halimus collected on the study sites

3.3.Biodiversity analyses of individuals:

The ascending hierarchical classification **figure 06** of the analyzed samples reveals the existence of 8 different groups, the first one is made up of samples 4, 9, 10 and 11 similar at 50%, this cluster is joined by accession 6 which represents a group on its own at the similarity threshold 38.76%, the whole is associated with membership 5 which forms the third group at 29.28%. Furthermore, observation 8 joins the previous groups at 20.94%.

We have noted that accessions 3 and 7 which respectively form groups 5 and 6 join the group cited above at 13.39%.

On the other hand, accession 2 which forms the group seven is associated with the other clusters at 6.45%.

Chapter 04: Discussion

In Atriplex, leaf shape is very diverse, the shape of each leaf changes as it develops (Chitwood and Sinha.,2016), and it can be influenced by biotic and abiotic stresses(Tsukaya,2018).).

According to (Sugkee et al., 2010), the lanceolate leaves produce a better distribution of light, which can explain its large presence in the first study area. For their part, (You et al. 1995), stipulate that elliptical leaves (encountered very often in this study), are favorable to

producing a good yield with a population of plants at low density.

The numerous forms recorded could help enrich the determination keys as well as the understanding of taxonomic mechanisms in Atriplex halimus.

Contour variation:

The outline of leaves, can be described by the absence or presence of serrations along the edge. Many taxonomic characters of leaf shape can be attributed to the nature of the curvature.

The nature of the apical tip, which can be caudate (tailed), pointed, late-apical (tapered to a short and slender point), acuminate (tapered to a long point), obtuse, rounded, etc. (Appendices…) .

Nature of curvature in the apical and basal halves is generally different, the articulation of the apical and basal halves also varies: some leaf shapes appear to be made by a direct joint between the two halves, while others have a partial intermediate which manifests itself as oblong leaves (also found in this study).

Other leaf shapes (not found here, but recorded in previous work), such as reniforms, are the result of combinations of different curvatures in the apical and basal halves.

Basis of development of leaf outline variation:

Variation in leaf contour may be attributed to changes in the acceleration and deceleration of leaf cell proliferation; on the other hand, genetic controls of cell elongation and distribution/proliferation contribute to this. development (Tsukaya, 2018).

Furthermore, the position of the meristematic region in the leaf meristem is also an important factor, many angiosperms have their leaf meristems at the basal part of the leaves(Ichihashi et al., 2011; Tsukaya, 2014).

According to Tsukaya (2018), in many leaf forms, cell proliferation decreases shortly after reaching a maximum, thus the decrease in proliferation forms the basal half of the leaf. Yin and Tsukaya (2016), state that major cell divisions in the leaf meristem occur randomly.

Therefore, most variation in leaf shapes is attributable to leaf meristem position, acceleration and deceleration of cell division, and oriented cell proliferation.

Acceleration and deceleration: Rates of acceleration/deceleration of cell proliferation can alter leaf contours, in this sense cell cycle regulators and ribosome-related genes can also influence leaf contour, indeed loss of function of ribosomal proteins produces leaves with a pointed tip (Byrne, 2009).

Furthermore, Runions et al (2017) stipulate that a wide range of variations in leaf shapes could be linked to the following elements: the design of the serrations, the lobes, the design of the vascular system, etc..

According to these two authors, we still do not know whether the structuring of the vascular system plays an important role in the regulation of leaf shape.

Adaptive meaning of leaf contour variation:

Certain contour variations have been discussed in terms of environmental adaptation. According to Tsukaya (2018), a slender leaf base is necessary to minimize leaf area overlap, which is necessary for photosynthesis.

To conclude this discussion, we can mention that leaf contour varies considerably among angiosperms, and most variations involve minor differences in leaf curvature, which can be described by a combination of curves: one for the apical half and another for the basal half, the nature of the curvature also depends on the position of the leaf meristem, the acceleration and deceleration of cell proliferation.

Conclusion

Conclusion

This study on leaf polymorphism in Atriplex halimus is a continuation of other similar works previously carried out on indigenous accessions of this species growing in Tebessa region.

The leaves showed significant phenotypic variability on the study sites belonging to two different bioclimatic stages. This variability, whether inter, intra-specific or inter-site, testifies to the great polymorphism that exists within the same plant.

This polymorphism is very important for the adaptation of the species to difficult conditions such as very low temperatures in winter, and very high ones in summer as well as the high salinity rate which characterizes these areas.

Furthermore, and in light of the results obtained, we believe that the leaf forms encountered in Atriplex halimus far exceed the polymorphism that can characterize any other plant species.

This variability is due on the one hand to the acceleration and deceleration of cell proliferation in the leaf meristem, and on the other hand it can be of genetic origin.

Concerning this last point, further research on a larger number of samples, belonging to other regions of Algeria , or why not to other countries in this region, and/or other species of Atriplex, using genetic marking techniques such as SNP (Single Nucleotide Polymorphism) or Mini-Satellites could constitute an additional and advantageous means to better understand the evolution of these species as well as their populations genetics.

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Appendix

Appendix 01: Data relating to the LEAVES parameter

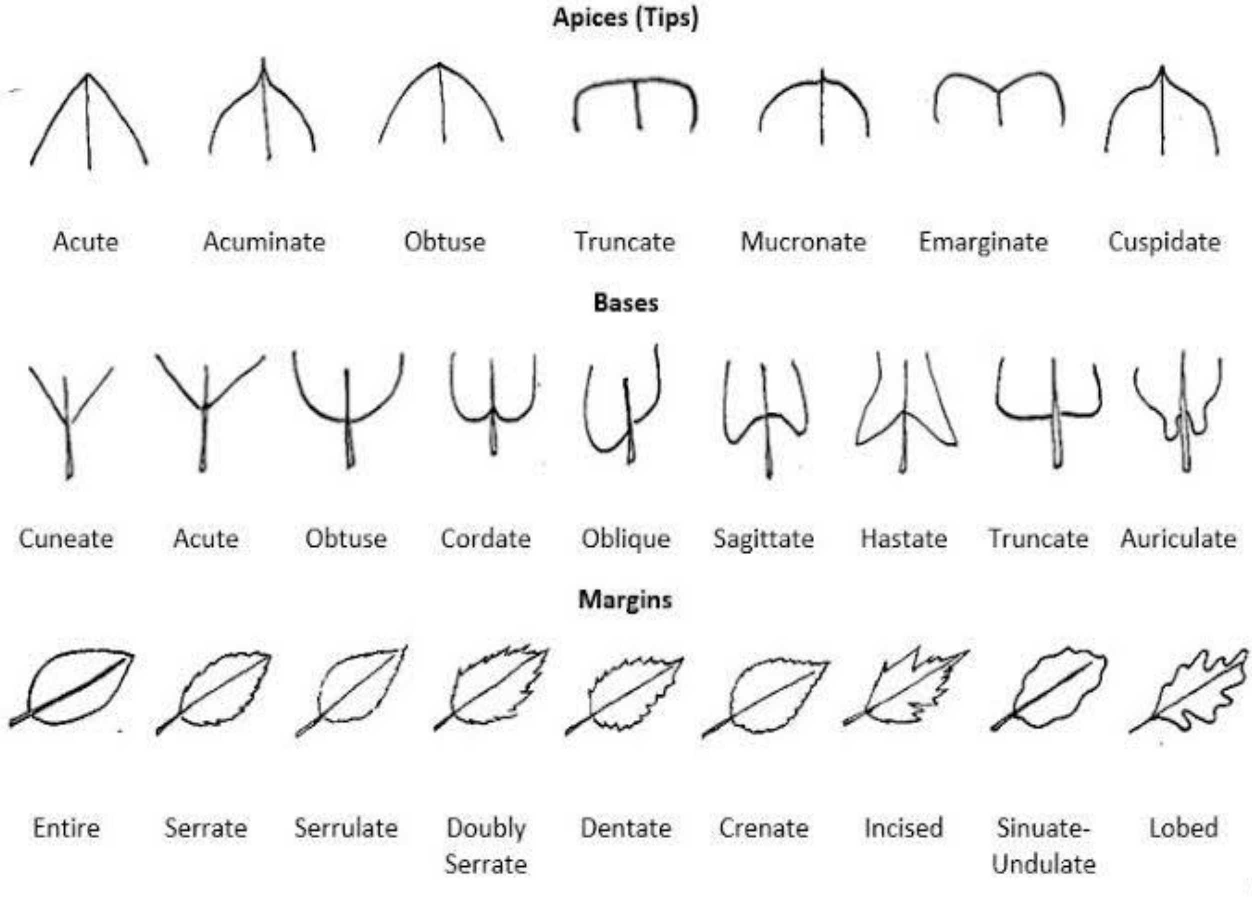

Figure 01: leaf morphological determination key

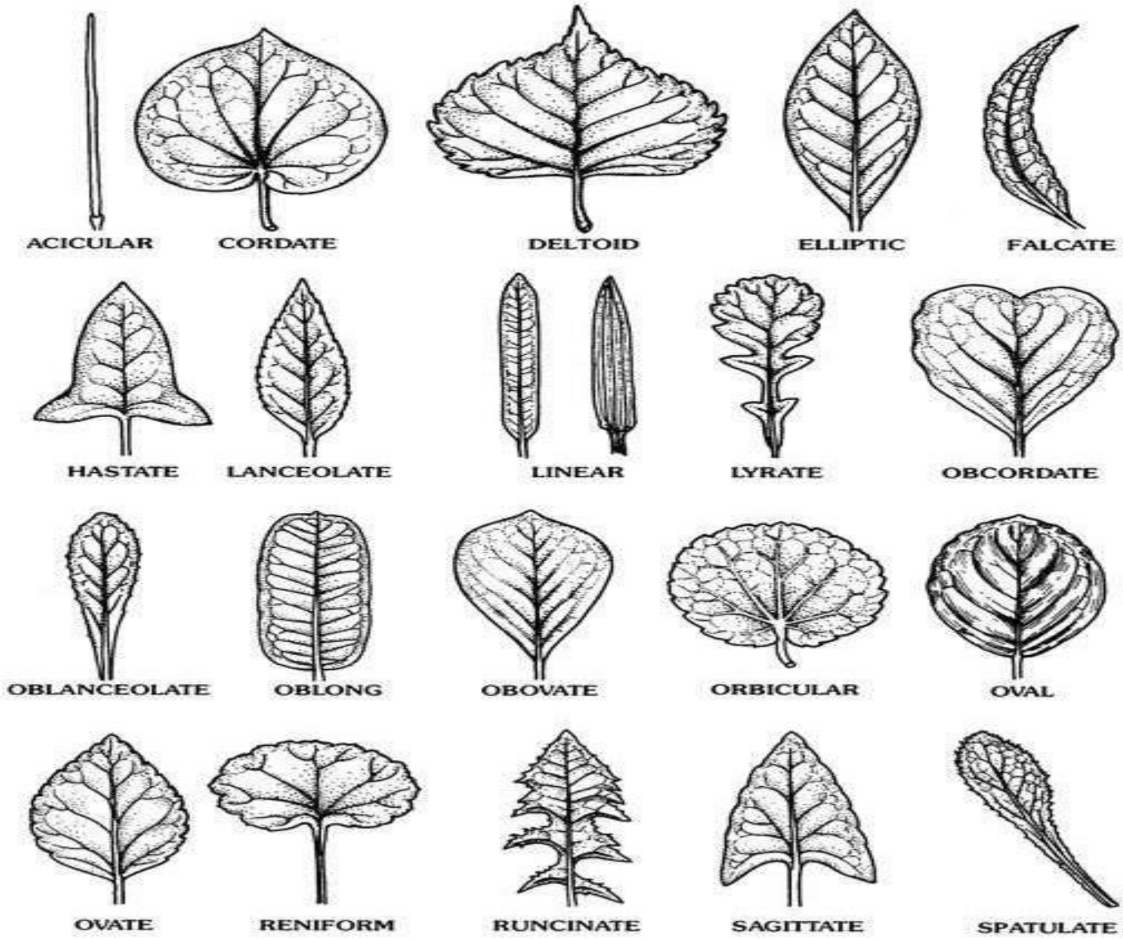

Figure 02: leaf morphological determination key

Plants	Ovate	Oval	Obovate	Oblong	Elliptic	Linear	Lanceolate	Orbicular	Obcordate	Oblanceolate	Spatulate	Reniform	Deltoid
Plant 01	1	1	0	1	1	1	1	0	0	0	0	0	1
Plant 02	1	0	1	1	1	0	1	1	0	0	0	0	0
Plant 03	1	1	1	1	1	1	0	0	1	1	0	1	0
Plant 04	0	1	1	1	1	0	1	0	0	1	0	0	0
Plant 05	0	1	0	1	0	0	0	1	0	0	1	0	0
Plant 06	1	1	1	1	1	0	0	0	1	0	0	0	0
Plant 07	0	1	0	0	1	0	1	0	0	0	0	0	0
Plant 08	0	0	0	1	0	0	1	1	1	1	1	0	0
Plant 09	0	1	0	0	0	1	1	0	0	1	1	0	0
Plant 10	0	1	1	0	1	0	1	0	1	0	0	0	0

Forms / shrubs	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Oval	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lanceolate	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Oval with emarginated tip	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
oblong with a mucronate apices	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Obovate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Obcordate with emarginate tip	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oblong	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elliptic	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
obovate with a slightly emarginated tip	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elliptic with Obtuse Tip	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oblong with Obtuse tip	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lanceolate with obtus tip	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oblanceolate	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Spatulate	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Oval with echancrated tip	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Orbicular	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Orbicular with Emarginated tip	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Linear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Spatulate slightly asymmetrical	0	0	0	0	0	0		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Linear with obtuse tip	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Oblong with emarginated tip	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Obovate slightly asymmetrical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Deltoid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0