

Contribution to a morphological study of the leaves and fruits of red juniper (*Juniperus phoenicea*)

Messaouda MESSELM^{1*}, Touati BAKRIA ²

Abstract

A study of the intra- and inter-population variability of morphological characters for leaves and fruits (galls) in the taxon *Juniperus phoenicea*. *phoenicea* was carried out at three stations (Djelfa, Boussaâda and Sétif) characterised by different bioclimates. The number of trees randomly selected was thirty (30) for the leaves and thirty (30) for the fruits (galls), from each of the three stations. The sampled twigs and galls were dried and preserved in the laboratory. A total of nineteen quantitative and qualitative morphological characters were studied, nine (9) for the leaves and ten (10) for the galls. Comparative analysis using different statistical methods (Descriptive Elements, ANOVA, PCA) showed highly significant variability for the majority of the variables included. This variability is probably due to the climate or linked to the genetics and age of the sample trees.

Keywords: *Juniperus phoenicea*, scales, galls, variability, morphology, stations.

Contribution à l'étude morphologique des feuilles et des fruits du genévrier rouge (*Juniperus phoenicea*)

Resumé

Une étude de la variabilité intra- et inter-population des caractères morphologiques des feuilles et des fruits (galles) du taxon *Juniperus phoenicea* subsp. *phoenicea* a été réalisée sur trois stations (Djelfa, Boussaâda et Sétif), caractérisées par des bioclimats différents. Le nombre d'arbres sélectionnés de manière aléatoire était de trente (30) pour les feuilles et trente (30) pour les fruits (galles), dans chacune des trois stations. Les rameaux et les galles échantillonnés ont été séchés et conservés au laboratoire. Un total de dix-neuf caractères morphologiques, quantitatifs et qualitatifs, ont été étudiés : neuf (9) pour les feuilles et dix (10) pour les galles. L'analyse comparative à l'aide de différentes méthodes statistiques (éléments descriptifs, ANOVA, ACP) a révélé une variabilité hautement significative pour la majorité des variables étudiées. Cette variabilité est probablement due au climat ou liée à la génétique et à l'âge des arbres échantillonnés.

Mots clés : *Juniperus phoenicea*, écailles, galbule, variabilité, morphologie, stations

¹ Ziane Achour University, Djelfa, Algeria, messaoudamesselmi@gmail.com, ORCID: 0009-0007-6498-2938

² Centre de Recherche en Agropastoralisme(CRAPast) Djelfa (Algérie), touati.bakria@crapast.dz, ORCID : 0000-0002-2325-0606

INTRODUCTION

Mediterranean forests are a fragile ecosystem, subject to multiple anthropogenic and climatic pressures. For thousands of years, these ecosystems have undergone major fluctuations in their surface area as a result of demographic growth, pastoralism, logging and climate change. These factors have contributed to successive phases of regression and regeneration of forest formations (Quézel and Barbero, 1990). One of the most characteristic species of these environments is juniper, a resinous conifer belonging to the *Juniperus* genus of the Cupressaceae family.

The *Juniperus* genus comprises around 70 species spread across the northern hemisphere, occupying a variety of environments from arid zones to high mountains. It is distinguished by its distinctive cones, called galbules, whose scales are fused together, forming a fleshy or woody structure depending on the species (Rameau et al., 2008). These species play a major ecological role in soil stabilisation, forest regeneration and maintaining biodiversity.

Five juniper taxa have been recorded in Algeria: *Juniperus oxycedrus* (ssp. *macrocarpa* and sp. *rufescens*), *J. phoenicea* (var. *eu-phoenicea* and var. *turbinata*), *J. thurifera* var. *africana*, *J. communis* ssp. *hemisphaerica* and *J. sabina* var. *sabina* (Quézel et Médail, 2003). Of these, *J. phoenicea* is widely distributed in the Mediterranean region, particularly in North Africa, Spain and Italy. It grows mainly in difficult edaphic and climatic conditions, particularly on calcareous or sandy soils and in arid to semi-arid areas.

Previous studies have focused on the morphological and genetic variability of *J. phoenicea* in different regions of the Mediterranean basin. For example, Acherar et al (1991) analysed the physiological adaptation of the species to water stress conditions, while Bartolo et al (2000) examined the morphological differences between *J. phoenicea* var. *turbinata* and var. *eu-phoenicea*. In addition, genetic studies using molecular markers have revealed significant intra-specific differentiation between populations in different regions (Migliore et al., 2012).

However, despite this work, the taxonomy and identification of *J. phoenicea* remain open to debate due to the great morphological variability observed within natural populations. In Algeria, where this species occurs in a variety of forms, data on its morphological and genetic diversity is still limited.

Our study therefore aims to contribute to a better understanding of the inter- and intra-population variability of *Juniperus phoenicea* ssp. *phoenicea* in Algeria. We are analysing the morphological characteristics of leaves and galls from samples collected at three representative stations: Dar Chioukh (Djelfa), Djebel Messaad (M'Sila) and Djebel Boutaleb (Sétif).

The main objective is to refine the taxonomic identification of this species and to assess its genetic diversity in order to gain a better understanding of its adaptation and conservation mechanisms in a context of climate change and degradation of natural habitats.

MATERIAL AND METHODS

1. Sampling

Leaf and fruit sampling of three natural Algerian populations of red juniper (*Juniperus*

phoenicea) (Figure 1) : Dar Chioukh, Djebel Messaad in Boussaâda and Boutaleb (Oued Soubella), which are located in the interior of

the country in mountainous areas above 1000 m altitude and in the wilayas of Djelfa, M'sila and

Sétif respectively. These sampling sites have different ecological characteristics. (Table 1).

Figure 1: Photographs showing the general appearance of *J. pheonicea*. from the Dar Chioukh station (Djelfa) in Algeria (A, upright tree; B, galls and C, scaly leaves).

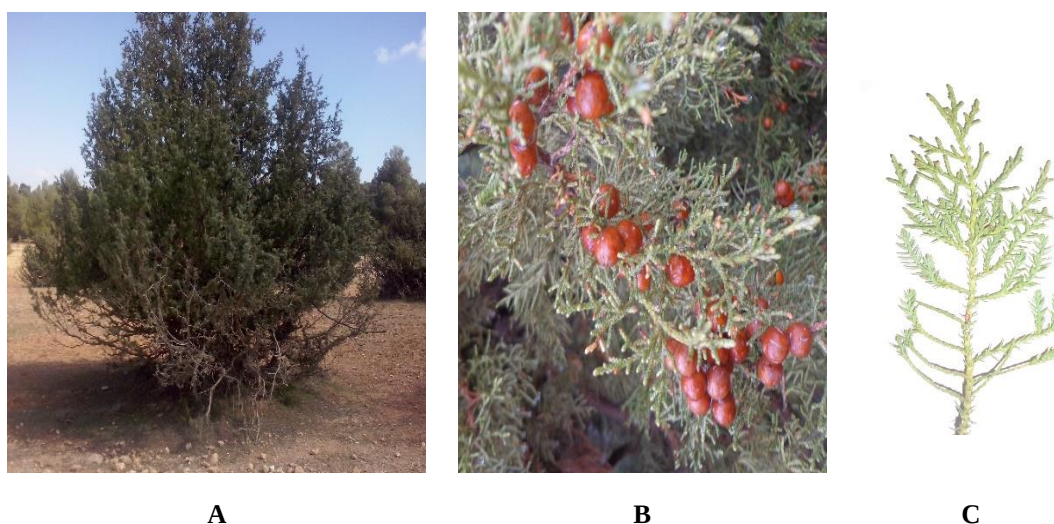


Table 1. Ecological data for the study sites

Wilaya	P (mm)	T° Min	T° Max	Station	GPS coordinates	Alt.
Djelfa	326,65	1,12	33,97	Dar chioukh	34°56'N 03°23'E	1103
M'sila	348,39	0,56	34,27	Djebal Messaad	35°02'N 04°12'E	1219
Sétif	402,69	1,68	34,33	Djebal Boutaleb	35°44'N 05°21'E	1401

2. Method

2.1. Harvesting twigs and galls

The number of trees randomly selected was 30 feet for leaves and 30 feet for fruit (Galbules), from each of the three stations. Thirty twigs from the previous year were then sampled from each tree; a total of 2700 twigs and thirty mature fruits were taken from each tree; a total of 2700 fruits. The sampled leaves and galls were stored in paper bags in the laboratory.

2.2. Measurements and observations

Measurements were taken in the laboratory using a calliper and a binocular zoom magnifier. To determine the morphological variability between the three stations,

morphological characters were chosen for the leaves and fruits.

3. Study of leaf morphology

A total of 09 quantitative and qualitative characteristics were measured: (1) Total length of main branch (LRp) (mm), (2) Number of primary branches (NRp) (mm), (3) Total length of basal branch (LRb) (mm), (4) Thickness of basal branch (ERb) (mm), (5) Number of basal secondary branches (NRSb) (mm), (6) Number of scales on the basal branch (NERb) (mm), (7) Thickness of the basal branch (ERf) (mm), (8) Number of scales on 5mm of the final branch (NERb) (mm), (9) Colour of the shoot (C) (green, light green and dark green) . (Table 2).

Table 2. Quantitative and qualitative morphological characteristics.

	Variables	Code
Quantitative	Total length of main branch (mm)	LRp
	Number of primary branches (mm)	NRp
	Total length of basal branching (mm)	LRb
	Basal branch thickness (mm)	ERb
	Number of basal secondary branches (mm)	NRSb
	Number of scales on the basal branch (mm)	NERb
	Basal branch thickness (mm)	ERf
	Number of scales on 5mm of the final branch (mm)	NERb
Qualitative	Twig colour: 1- green 2- light green 3- dark green	C

3. Study of fruit morphology

Observations and measurements were carried out on ten (10) quantitative and qualitative characteristics of the fruit, namely :

Quantitative morphological characteristics: Seven quantitative characteristics were measured, as shown in Table 3.

Qualitative morphological characteristics: Three qualitative characteristics were measured: shape of the gall (Fg), colour of the gall (C), shape of the scar on the gall envelope (Fci). (Table 3).

Table 3. Quantitative and qualitative morphological characteristics measured for galbules.

Characters	Variable	Code	Variants
Qualitative	Shape of the galbule (Fg)	Fg	1 Rounding
			2 Ovoid
			3 Lying down
			4 Tailpiece
	Galbule colour (Cg)	Cg	1 Brown
			2 Red
			3 Dark red brown
			4 Bright red brown
	Shape of the scar on the envelope of the galbule (Fci)	Fci	1 Triangular
			2 Single sort
			3 Two parallel lines
			4 Complete polygonal
			5 Incomplete polygonal
			6 Other
			7 Absence
Quantitative	Galbule length (mm)	Lng	
	Pebble width (mm)	Lrg	

Length/width ratio (mm)	Lng/ Lrg
Roller thickness (mm)	Eg
Pebble weight (g)	Pg
Weight of 100 pebbles (g)	Pd 100
Number of galls in 100 g (g)	Nbr100

4. Statistical processing of data

Descriptive statistics, correlation coefficient of measured variables with station parameters (altitude and aridity), two-factor analysis of variance (ANOVA).

Principal Component Analysis (PCA) is used to highlight the spatial distribution of

individuals (typology) according to their morphological and ultra-structural characteristics, and also to identify the markers that contribute to their discrimination. This analysis was carried out using STATISTICA version 10 software.

RESULTS

1. Quantitative characteristics at leaf level

1.1. The length of the main branch

The length of the main shoot averaged 25.37 mm, ranging from 12.57 to 48.95 mm at Dar Chioukh. At Djebel Messaad, the average is 27.60mm with a range between 5.91 and 48.41mm. On the other hand, Djebel Boutaleb recorded an average of 30.14mm with a range of 9.65 - 46.93 mm. The standard deviation and coefficient of variation were 5.26 mm and 20.76%, 6.86 mm and 24.87%, and 5.79 mm and 23.80% for Dar Chioukh, Djebel Messaad

and Djebel Boutaleb respectively. Analysis of variance revealed a highly significant difference between trees at each station for this characteristic. The average recorded for the species was 30.14 mm. The branches are longer at Djebel Boutaleb than at the other two stations. This indicates a highly significant difference between the three stations, while the multiple comparison of Fisher's LSD means reveals the presence of three distinct heterogeneous groups for this variable. (Table 4).

Table 4: Characteristics of the quantitative characteristics measured for the leaves of the three stations

Characters	Mean±ET; range (C.V.)			
	Dar Chioukh	Djebel Messaad	Djebel Boutaleb	Average
Length of main branch	25,37***a±5,26 (12,57-48,95)20,76	27,60***b ±6,86 (5,91-48,41)24,87	30,14***c±5,79 (9,65-46,93)23,80	27,70***±6,49 (5,91-39,93)22,80
Number of branches on the main branch	9,80***a±2,60 (3-21)26,59	10,03***a±2,7 (3-23) 27,55	11,38***b±2,71 (4-21)33,98	10,40***±2,85 (3-23)26,74
Length of basal branch	9,80***a±3,58 (2,45-24,72)36,54	12,49***b±4,93 (1,61-29,12)39,52	12,89***b±4,38 (2,83-32,33)33,98	11,73***±4,67 (1,61-32,22)38,76
Thickness of basal branch	0,56***a±0,04 (0,47-0,89)8,10	0,54***b±0,02 (0,47-0,60)4,00	0,54***c±0,02 (0,42-0,65)4,36	0,55***±0,03 (0,42-0,89)5,99

Number of secondary branches on the basal branch	0,49***a±0,74 (0-3)150,06	0,57***ab±0,81 (0-3)141,63	0,44***b±0,70 (0-3)157,39	0,50***±0,77 (0-3)149,62
Number of scales on the basal branch	43,48***a±15,11 (4-96)34,76	49,70***b±18,41 (8-124)37,04	51,88***c±17,57 (12-148)33,87	48,35***±17,92 (4-148)36,08
Thickness of final branch	0,64***a±0,03 (0,41-0,95)5,69	0,63***b±0,02 (0,58-0,7)3,52	0,64***c±0,02 (0,37-0,69)4,07	0,64***±0,03 (0,37-0,95)4,78
The number of scales over 5mm of the final branching	20,67***a±3,86 (12-40)18,69	20,02***b±4,25 (12-32)21,02	18,51***c±3,70 (12-32)20,01	19,72***±4,16 (12-34)20,52

Mean: Moy ; Standard deviation: S.D. ; Range: Min-Max ; C.V: Coefficient of variation (%) ; significance*** at threshold $\alpha = 0.001$; significance** at threshold $\alpha = 0.01$; significance* at threshold $\alpha = 0.05$; NS: not significant. a,b,c, Fisher's test separation.

1.2. The number of branches on the main branch

The number of branches on the main branch averages 9.80 and 10.03, with a range of 3-21 branches and 3-23 branches at Dar Chioukh and Djebel Messaad, respectively. On the other hand, Djebel Boutaleb recorded the highest average for the species, which was 11.38 branches with a range of 4-21 branches.

The standard deviation and coefficient of variation are 2.60 ramifications and 26.59% and 2.7mm and 27.55% and 2.71mm and 33.98% respectively for Dar Chioukh, Djebel Messaad and Djebel Boutaleb. The average recorded for the species was 11.38 branches. The analysis of variance revealed a highly significant difference between the trees at each station, even between stations, although the Fisher test indicated the presence of two distinct heterogeneous groups.

The first group consists of the two homogeneous stations Dar Chioukh and Djebel Messaad. On the other hand, the Djebel Boutaleb station represents the second group. (Table 4).

1.3. Length of basal branch

Basal branch length recorded an average of 9.80 mm with a range of 2.45-24.72 mm at Dar Chioukh, while at Djebel Messaad the average was 12.49 mm with a range of 1.61-29.12 mm. On the other hand, Djebel Boutaleb shows the highest average for this species, equal to 12.89 mm with a range of 2.83-32.33 mm. The standard deviation and coefficient of

variation are 3.58 mm and 36.54%, 4.93 mm and 39.52% and 4.38 mm and 33.98% respectively for Dar Chioukh, Djebel Messaad and Djebel Boutaleb. The average recorded for the species was 12.89mm. ANOVA revealed a highly significant difference in basal shoot length between trees at each station and between the different stations themselves. Multiple comparison of Fisher's LSD averages revealed two distinct heterogeneous groups, the Djebel Messaad and Djebel Boutaleb stations being homogeneous (first heterogeneous group) and differing from the Dar Chioukh station (second heterogeneous group). (Table 4).

1.4. The thickness of the basal branch

The thickness of the basal branch gave us the following averages: 0.56 mm; 0.54 mm and 0.54 mm with their minimum and maximum values of 0.47-0.89 mm; 0.47-0.60 mm and 0.42-0.65 mm for the Dar Chioukh, Djebel Messaad and Djebel Boutaleb stations respectively. With regard to the standard deviation and the coefficient of variation, the values recorded are 0.04mm and 8.10% at Dar Chioukh, 0.02mm and 4% at Djebel Messaad and 0.02mm and 4.36% at Djebel Boutaleb. The average recorded for the species is 30.14 mm, and the basal branches are thicker at Dar Chioukh than at the other two stations.

The analysis of variance for this trait showed a highly significant difference between the trees at each station and also between the stations studied, as well as the Fisher LSD test

grouping together three heterogeneous classes. (Table 4).

1.5. Number of secondary branches on the basal branch

The number of secondary branches on the basal branch averaged 0.49, 0.57 and 0.44 secondary branches. Their extent is the same, with a single value of 0-3 secondary branches for the Dar Chioukh, Djebel Messaad and Djebel Boutaleb stations respectively. The standard deviation is equal to 0.74, 0.81 and 0.70 secondary branches, while the coefficient of variation is 150.06%, 141.63% and 157.39% for Dar Chioukh, Djebel Messaad and Djebel Boutaleb respectively. The average recorded for the species is equal to 0.57 secondary branches, the largest being at the Djebel Messaad station. Analysis of variance for this variable showed a highly significant difference between the trees at each station and between the three stations selected. The Fisher LSD test showed three homogeneous groups (Table 4).

1.6. The thickness of the final branch

At Dar Chioukh, the thickness of the final branch recorded an average of 0.64 mm with a range of 0.41-0.95 mm, while at Djebel Messaad, the average was 0.63 mm with a range of between 0.58 and 0.70 mm. At Djebel Boutaleb, on the other hand, an average of 0.64 mm was recorded, with a range of 0.37-0.69 mm. The standard deviation and coefficient of variation were 0.03mm and 5.69% at Dar Chioukh, 0.02mm and 3.52% at Djebel Messaad and 0.02mm and 4.07% at Djebel Boutaleb. Highly significant differences were reported between the three stations, even between trees at each station, but the multiple comparison of Fisher's LSD averages separates three distinct heterogeneous groups (Table 4).

1.7. The number of scales over 5mm of the final branching

Concerning the number of scales over 5mm of the final branching is on average 20.67

scales in a min max range of 12-40 scales at Dar Chioukh. Subsequently Djebel Messaad which indicated the average is 20.02 scales with its range of 12-32 scales and Djebel Boutaleb which revealed the average of 18.51 scales between a minimum of 12 and a maximum of 34 scales. The standard deviation and coefficient of variation were 3.86 scales and 18.69%, 4.45 scales and 20.01% and 4.16 scales and 157.39% respectively for Dar Chioukh, Djebel Messaad and Djebel Boutaleb. The ANOVA test indicates a highly significant difference between the trees at each station for the number of scales over 5mm of the final branching. The average for the species is 20.67 scales, with the highest value recorded at Dar Chioukh. These differences are also highly significant between stations, and the multiple comparison of Fisher's LSD mean shows the presence of three distinct heterogeneous groups (Table 4).

1.8. Quantitative characteristics of the galls

1.8.1. Galbule length

The length of the gall is highly significant between the trees at each of the three stations. At Dar Chioukh, it varies between 6 mm and 12.69 mm, with an average of 9.14 mm; on the other hand, at Djebel Messaad, an average of 8.26 mm was recorded, varying between 5.01 mm and 12.73 mm, while at Djebel Boutaleb it varies between 6.26 mm and 13.03 mm, with an average of 9.08 mm. The galbules measure an average of 8.83 mm for our species, the longest being at Dar Chioukh (9.14 mm). With regard to the ANOVA, this test revealed a highly significant difference, both between stations and between trees at each station. In addition, the Fisher LSD test shows the existence of two distinct heterogeneous groups, with the two stations of Djebel Messaad and Djebel Boutaleb showing homogeneity between them and heterogeneity with the Dar Chioukh station (Table 5).

Table 5: Characteristics of quantitative characteristics measured for fruit at the three stations

Characters	Mean±ET ;range (C.V.)			
	Dar Chioukh	Djebel Messaad	Djebel Boutaleb	Average
Shingle length	9,14***b±1,03 (6-12,69)11,26	8,26***a±1,34 (5,01-12,73)16,29	9,08***a±0,97 (6,26-13,03)10,77	8,83***±1,11 (5,75-12,81)13,58
Shingle width	8,15***b±1,05 (1,02-11,83)12,61	7,55***a±1,28 (4,45-11,12)16,99	8,20***a±0,88 (6-11,73)10,79	7,97***±0,94 (3,82-11,56)14,12
Length/width ratio	1,13***a±0,23 (0,76-1,42)20,69	1,09***a±0,9 (0,78-1,67)9,09	1,11***b±0,1 (0,71-1,59)9,06	1,11***±0,41 (0,75-1,56)14,25
Shingle thickness	8,82*** a±1,04 (6,12-12,31)11,84	8,13***a±1,34 (1,48-11,89)16,57	8,82***b±0,95 (1,48-11,45)10,82	8,59***±1,11 (3,02- 11,83)13,65
Shingle weight	0,45***a±0,15 (0,10-1,80)33,99	0,34***a±0,16 (0,098-0,98)48,26	0,44***b±0,1 (0,18-1,03)24,59	0,41***±0,13 (1,12-1,27)37,21
100 peas	34,35***a±4,18 (31,14-39,75)7,51	33,08***b±3,75 (31,14-34,38)3,95	38,55***c±2,03 (38,04-39,75)1,83	35,33***±4,18 (31,14-39,75)7,51
Number of pebbles in 100g	310,80***a±29,12 (298-320)3, 26	311,6***b±35,11 (297-330)3,92	256***c±34 (242-269)4,62	293,80*** ±45,64 (242-330)9,88

Mean: Moy ; Standard deviation: S.D. ; Range: Min-Max ; C.V: Coefficient of variation (%) ; significance*** at threshold $\alpha = 0.001$; significance** at threshold $\alpha = 0.01$; significance* at threshold $\alpha = 0.05$; NS: not significant. a,b,c, Fisher's test separation.

1.8.2. Galbule width

The values recorded for the width of the galbule are highly significant between the trees at each station: At Dar Chioukh we have the mean (8.15 mm) which varies between 1.02 mm and 11.83 mm with a standard deviation of and a coefficient of variation; while at Djebel Messaad, the mean, range, standard deviation and coefficient of variation recorded are (7.55 mm; 4.45 -11.12 mm; on the other hand at Djebel Boutaleb mean is equal to 8.20 mm it varies between 6 mm and 11.73 mm. The average value for the species is 7.97 mm, but the highest value is at Djebel Boutaleb (8.20 mm). The differences recorded are highly significant between the stations, but the Fisher LSD test indicates two distinct heterogeneous groups (Djebel Messaad; Djebel Boutaleb) and (Dar Chioukh). (Table 5).

1.8.3. Galbule length to width ratio

The length/width ratio was highly significant between trees for the three populations, with an average of 1.13 mm at Dar Chioukh, 1.09 mm at Djebel Messaad and 1.11

mm at Djebel Boutaleb, with their extents varying (0.76-1.42 mm, 0.78-1.67 mm and 0.75-1.59 mm respectively). Highly significant differences between stations were also recorded (ANOVA). Two distinct heterogeneous groups, illustrated (Dar Chioukh; Djebel Messaad) and (Djebel Boutaleb), were identified by Fisher's LSD multiple comparison of means (Table 5).

1.8.4. Galbule thickness

This variable is highly significant between the three stations, as well as between the trees at each. At Dar Chioukh, we have the mean (8.82 mm), which varies between the minimum value of 6.12 mm and the maximum value of 12.31 mm. At Djebel Messaad, the average is equal to 8.13 mm within a range (min-max) equal to 1.48- 11.89 mm at Djebel Boutaleb, the average is 8.82 mm The galls measure an average of 8.59 mm, The Fisher LSD Test reveals two distinct heterogeneous groups. (Table 5).

1.8.5. Weight of the galbule

The weight of the gall is highly significant within a population (between trees)

and between populations (between stations). The average weight of galbules was 0.45g at Dar Chioukh, 0.34g at Djebel Messaad and 0.44 at Djebel Boutaleb. The range, standard deviation and coefficient of variation are 0.10-1.80g, 0.15g and 33.99%, respectively, for Dar Chioukh, 0.098-0.98g, 0.16g and 48.26%, respectively, for Djebel Messaad and 0.18-1.03g, 0.1g and 37.21%, respectively, for Djebel Messaad. Two well-distinguished heterogeneous groups were observed (Fischer LSD test). (Table 5).

1.8.6. Weight of 100 pebbles

The weight of 100 galls is significant, both between subjects within each of the three populations and between the populations themselves. In Dar Chioukh, the average weight was 34.35g, with a range of 31.14-39.75g, while in Djebel Messaad the average was 33.08g, with a range of 31.14-34.38g. These values are higher in Boutaleb, which has an average of 38.55g and a range of 38.04-39.75g. We recorded a mean value for the species of 35.33 g. (Table 5).

1.8.7. Number of pebbles in 100g

The number of galbules in 100g is not significant within the stations. They are numerous, 310.80 galbules/ 100g at Dar Chioukh, 311.6 galbules/ 100g at Djebel

Messaad and 256 galbules/ 100g at. Minimum and maximum values varied between the three stations (298-320 galbules, 297-330 galbules and 242-269 galbules) at Dar Chioukh, Djebel Messaad and Djebel Boutaleb respectively. We recorded an average of 293.80 bolls for the species. Separation of the Fischer LSD test revealed the presence of three distinct heterogeneous groups (Table 5)

1.9. Qualitative characteristics at leaf level

1.9.1. The colour of the branches

According to the results obtained, the green colour of the leaves was uniform at 84%, 96% and 98% respectively for the Dar Chioukh, Djebel Messaad and Boutaleb stations. The other colours: light green and very light green have slight proportions.

1.10. Qualitative characteristics of the galls

1.10.1. The shape of the galbule

At each station, two main shapes were found: rounded (with 50.66% for Dar Chioukh, 39.11% for Djebel Messaad and 45.55% for Djebel boutaleb) and ovoid (with 24.55% for Dar Chioukh, 22.88% for Djebel Messaad and 34.07% for Djebel boutaleb), while the rounded shape (45.09%) is the most widespread for the species. (Table 6).

Table 6: Frequencies (%) for qualitative characteristics of galbules by station.

		Stations			Average
Characters		Dar Chioukh	Djebel Messaad	Djebel Boutaleb	
Shape	Rounded	50,66%	39,11%	45,50%	45,09%
	Ovoid	24,55%	22,88%	34,07%	27,17%
	Lying down	8,11%	2,77%	1,66%	4,18%
	Tailpiece	16,66%	35,22%	18,64%	23,51%
Colour	reddish brown	36,11%	7,22%	15,42%	19,58%
	Reddish	37,77%	73,00%	60,93%	57,23%
	Brown	25,88%	19,66667	23,19%	23,91%
	Other	0,22%	0,11%	0,33%	0,22%
Healing	Triangular	16,55%	11,00%	16,75%	14,77%
	Single trait	9,66%	7,77%	3,55%	6,99%

Two parallel lines	22,33%	13,33%	14,98%	16,88%
Complete polygonal	26,88%	46,88%	41,73%	38,50%
Incomplete polygonal	23,77%	10,88%	11,20%	15,28%
Other	0,77%	9,00%	11,43%	7,07%
Absence	0,00%	1,11%	0,22%	0,44%

1.10.2. The colour of the galbule

At the level of each population, a single colour was indicated, with reddish representing the highest percentage (37.77%) in Dar Chioukh, (73%) in Djebel Messaad and (60.93%), with an average of 57.23%. (Table 6).

1.10.3. Shape of the scar on the envelope of the galbule

The complete polygonal shape of the galbule scar is predominant with an average of (38.50%) for this species and variations of (26.88%, 46.88% and 41.73%) were recorded per station between Dar Chioukh, Djebel Messaad and Djebel Boutaleb, respectively. Triangular, two parallel lines and incomplete polygonal forms had lower percentages. The

absence recorded for this variable has an average value of 0.44%.

1.11. Principal component analysis

The most common use of PCA is to provide flat representations of data described by a large number of quantitative variables that are as faithful as possible. To do this, the data is projected onto factorial planes. Each plane is defined by a pair of principal components.

By examining these projections, the analysis will attempt to extract information about the structure of the data.

1.11.1. On the leaves

The PCA eigenvalues explain a total inertia of 43.99% for the quantitative variables. The first principal component indicates 16.17% and the second 17.82% (Table 7).

Table 7: PCA eigenvalues for leaves.

	Val. Own	Total var.	Cumulative - Val. Own	Cumulative - % of total
1	2,093604	26,17005	2,093604	26,1700
2	1,425956	17,82445	3,519560	43,9945

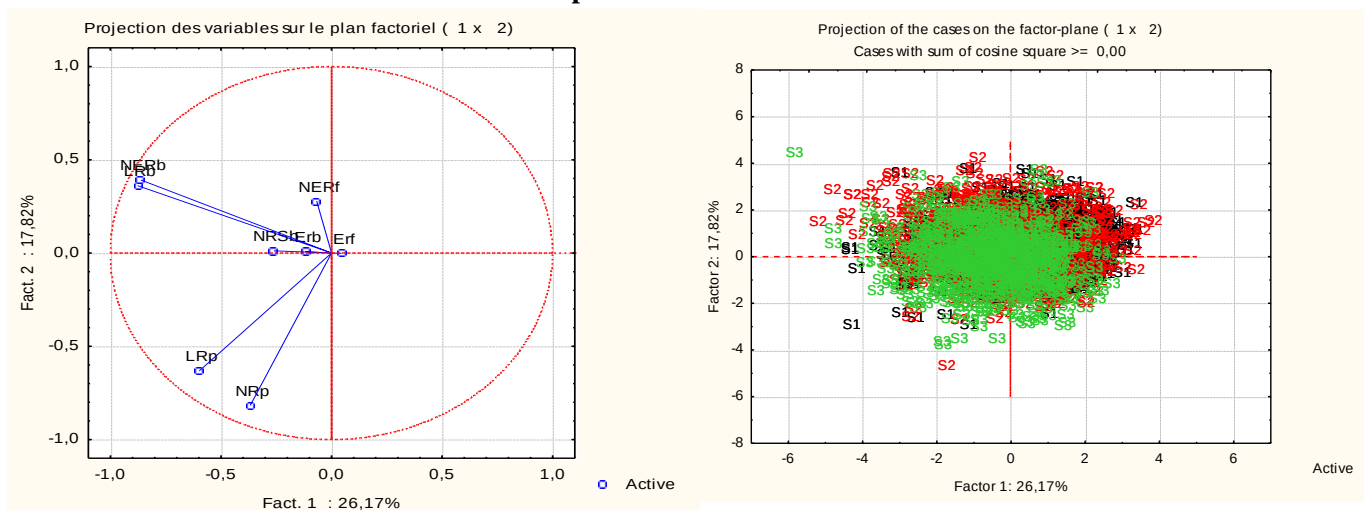
We can see that the length of the main shoot is negatively correlated with both axes (-0.59) and (0.63). Subsequently, the length of the basal branch and the number of scales were negatively and perfectly correlated with axis 1

with values of (-.87) and (-0.86) respectively. The number of secondary branches on the main shoot was negatively correlated with axis 2, recording an eigenvalue of (-0.81). (Table 8 and Figure 2).

Table 8: Correlations between variables on the two axes revealed by PCA for needles.

Variables	Factor	
	Factor 1	Factor 2
LRp	-0,597405	-0,630822
NRp	-0,367669	-0,816930
LRb	-0,877113	0,361230
Erb	-0,116740	0,007943
NRSb	-0,261322	0,011947
NERb	-0,862389	0,391639
Erf	0,045730	-0,001434
NERf	-0,066917	0,276711

Figure 2: Correlation circle and projection of quantitative variables and individuals on the 1-2 plane for leaves.



1.11.2. At the bubble level

The values obtained from the PCA give a total inertia of 87.5% for the quantitative shingle variables.

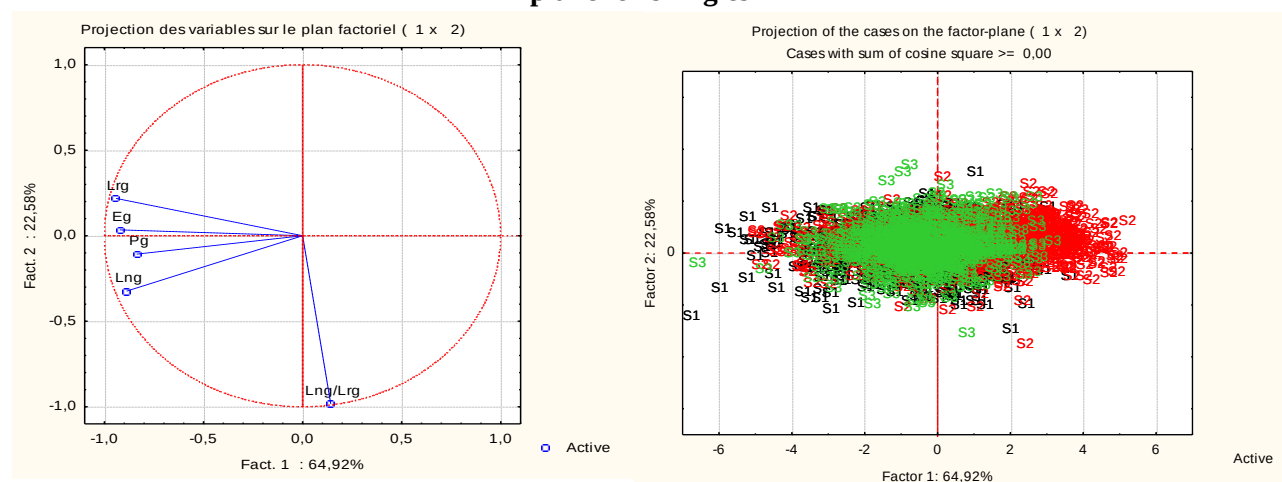
The length, width, thickness and weight of the pebbles were perfectly and negatively

correlated with respect to axis 1 with eigenvalues (-0.88) ;(-0.94) ;(-0.92) ;(-0.83) respectively. On the other hand, the ratio is negatively correlated with respect to axis 2 giving the eigenvalue (-0.98). (Table 9 and Figure 3).

Table 9: Correlations between variables on the 2 axes revealed by PCA for shingles

Variables	Factor	
	Factor 1	Factor 2
Lng	-0,888022	-0,323712
Lrg	-0,941889	0,218517
R Lng/Lrg	0,141946	-0,981698
Eg	-0,922641	0,034629
Pg	-0,835838	-0,107263

Figure 3: Correlation circle and projection of quantitative variables and individuals on the 1-2 plane for shingles



1.12. Interaction with climatic factors

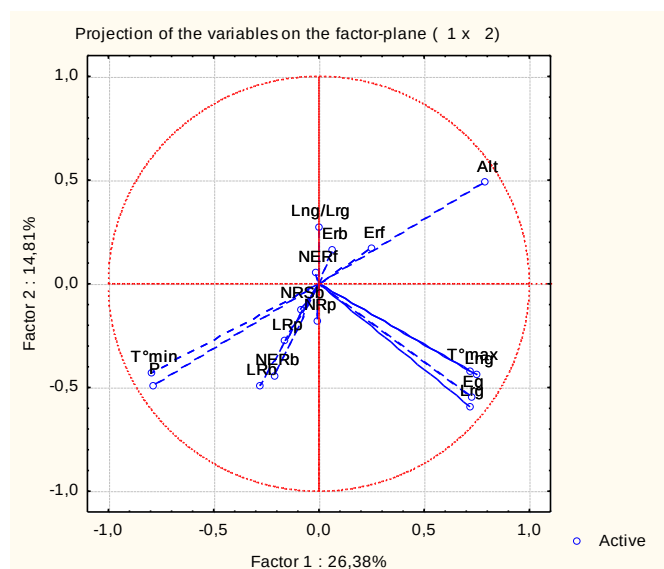
The PCA eigenvalues explain a total inertia of 41.19% on the two factorial planes (Table 10 and Figure 4).

Table 10: Eigenvalue matrix from PCA of leaves, leaflets and climatic variables

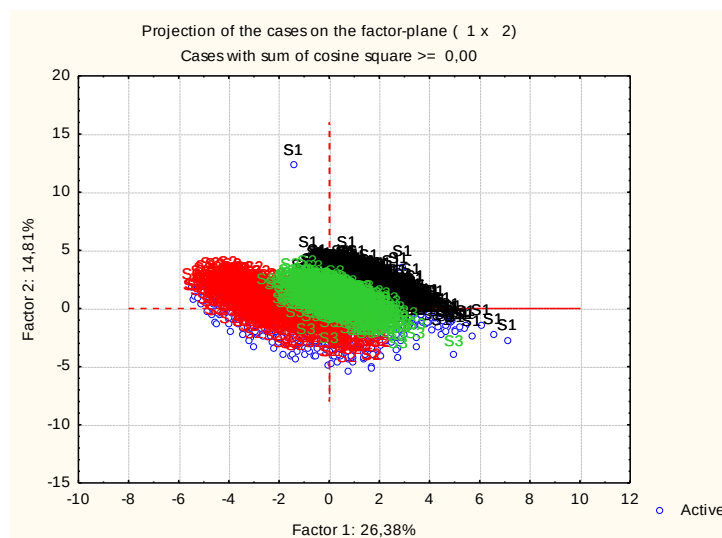
Factor	Eigenvalues	% Total - variances	Cumulative - Val.	
			Prop.	Cumulative-Tot.
1	4,86	28,60	4,86	28,60
2	2,48	14,63	7,35	43,24
3	2,03	11,93	9,38	55,17
4	1,43	8,41	10,81	63,58
5	1,15	6,76	11,96	70,34
6	1,04	6,10	12,99	76,44
7	0,99	5,84	13,99	82,28
8	0,95	5,61	14,94	87,88
9	0,80	4,70	15,74	92,58
10	0,41	2,42	16,15	95,00
11	0,36	2,13	16,51	97,13
12	0,18	1,04	16,69	98,17

13	0,13	0,76	16,82	98,94
14	0,11	0,66	16,93	99,59
15	0,07	0,41	17,00	100,00

Figure 4: Correlation circle and projections of quantitative variables and individuals with climatic factors on the 1-2 plane



By analysing these projections on the basis of climatic and morphological characteristics, we have been able to identify three distinct sub-populations. It can be seen that climatic factors and the majority of the quantitative variables concerning the dimensions and weight of the stalks are well



correlated with the I axis. This grouping into three sets is essentially due to the climatic stage, despite the fact that there are perfect correlations between the quantitative variables, which can be justified by age or genetic variability.

DISCUSSION

The study of morphological characteristics revealed a high degree of intra- and inter-population variability in *Juniperus phoenicea*, observed in most of the quantitative variables measured. The ANOVA test revealed highly significant differences ($p < 0.001$) between individuals from the same station (intra-population variability), as well as between stations (inter-population variability). These results are in line with those of Bartolo et

al (2000), who reported significant morphological heterogeneity between Mediterranean populations of *J. phoenicea* var. *turbinata* and var. *eu-phoenicea*.

The homogeneity observed for the green colour of the leaves at the three stations studied, in particular at Djebel Messaad (96%) and Djebel Boutaleb (98%), confirms the observations of Rameau et al. (2008) that this characteristic shows little variability within a

taxon. However, the morphological variability of the galls - in particular their size, shape and weight - suggests a local adaptation to the ecological conditions specific to each station.

The rounded and ovoid shapes of the galls are the most frequent, while the reddish colour dominates in all the stations, which is also reported by Migliore et al. (2012) in a study on the morphological diversity of *J. phoenicea* in the western Mediterranean. These characters may be influenced by genetic and environmental factors.

Principal component analysis (PCA) was used to identify spatial groupings of individuals according to morphological and bioclimatic parameters. The interaction between climatic variables (rainfall, temperature and altitude) and morphological characteristics, revealed by the PCA,

corroborates the work of Quézel and Médail (2003), who showed that climatic gradients strongly influence the distribution and morphology of Mediterranean forest species.

The high correlation between gall variables indicates a consistent morphological structure between stations, probably reflecting phenotypic adaptation to similar conditions or a common genetic base. However, the inter-station differences also suggest local differentiation processes, possibly linked to ecological selection pressures or genetic drift.

Finally, the intra- and inter-population variability observed could also be attributed to the age of the subjects sampled, as mentioned in the studies by Acherar et al. (1991), who showed morphological plasticity according to developmental stages in *Juniperus* species.

CONCLUSIONS

This morphological study, coupled with in-depth statistical analysis, revealed significant intra- and inter-population variability in *Juniperus phoenicea ssp. phoenicea* at three ecologically contrasting sites in northern Algeria. The differences observed in the quantitative characteristics of leaves and galls, confirmed by analysis of variance and principal component analysis, reflect the combined influence of environmental (climate, altitude) and biological (age, genetics) factors.

These results are in line with those of Migliore et al. (2012) and Bartolo et al. (2000), who reported a marked morphological

differentiation between Mediterranean populations of *J. phoenicea*. The correlation between certain morphological variables and local climatic conditions suggests an eco-physiological adaptation of the species to the constraints of its environment, as already proposed by Acherar et al. (1991).

In this context, the great variability observed, particularly in the characteristics of the galls, represents a significant adaptive potential for the species, which could be exploited for conservation and reforestation strategies adapted to different bioclimates (Quézel et Médail, 2003).

To gain a better understanding of this variability, further research should integrate anatomical, genetic (using molecular markers), physiological and biochemical approaches, as suggested by Rameau et al (2008). Particular attention could also be paid to other organs, such as pollen and stomata, in order to improve

the taxonomic identification of the species and better understand its adaptive capacities.

REFERENCES

- ACHERAR, M.; RAMBAL, S.; LEPART, J. Evolution de la résistance au stress hydrique chez des semis de *Quercus coccifera* L. issus de provenances différenciées. *Annales des Sciences Forestières*, v. 48, n. 3, p. 301-317, 1991.
- ACHERAR, M.; RAMBAL, S.; JOFFRE, R. Water and nitrogen use efficiency by cork oak (*Quercus suber* L.) seedlings. *Annales des Sciences Forestières*, v. 48, n. 1, p. 1-20, 1991.
- BARTOLO, A.; CUBELLI, R.; DELLA SALA, S.; DREI, S. Pantomimes are special gestures which rely on working memory. *Cortex*, v. 37, n. 3, p. 383-394, 2001.
- BARTOLO, G.; BRULLO, S.; PAVONE, P. A taxonomic study on the *Juniperus phoenicea* complex (Cupressaceae). *Taxon*, v. 49, n. 4, p. 775-782, 2000.
- MIGLIORE, J.; BAUMEL, A.; MÉDAIL, F.; VERLAQUE, R. From Mediterranean shores to central Sahara: Contrasting phylogeographical patterns in *Juniperus phoenicea* (Cupressaceae) and *Tetraclinis articulata* (Cupressaceae). *Annals of Botany*, v. 109, n. 4, p. 861-873, 2012.
- MIGLIORE, M.; MESSINEO, L.; CARDACI, M.; AYALA, G. F. Quantitative modeling of perception and production of time intervals. *Journal of Neurophysiology*, v. 86, n. 1, p. 275-282, 2001.
- QUEZEL, P.; BARBERO, M. Les forêts méditerranéennes, problèmes posés par leur signification historique, écologique et leur conservation. *Acta Botanica Malacitana*, n. 15, p. 145-178, 1990.
- QUEZEL, P.; MEDAIL, F. *Écologie et bioogéographie des forêts du bassin méditerranéen*. Paris: Elsevier, 2003. 571 p.
- QUEZEL, P.; MEDAIL, F. *Écologie et bioogéographie des forêts du bassin méditerranéen*. Paris: Elsevier, 2003. p. 134-136.
- RAMEAU, J. C.; MANSION, D.; DUME, G. *French forest flora. Volume 3: Mediterranean region*. Paris: IDF, 2008. 421 p.