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Full Length Research Paper

Morpho-phenological characterization of *Allium roseum* L. (Alliaceae) from different bioclimatic zones in Tunisia

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***Allium roseum* (Alliaceae) is an important medicinal and aromatic plant of the Tunisian flora. It was extensively widespread in southern Tunisia, where it has been empirically used for its numerous therapeutic virtues. Twenty-two morphological and floral traits observed in a field collection of 14 populations of *A. roseum*, belonging to four different bioclimatic zones of Tunisia, were analyzed using multivariate analysis. The data underwent an analysis of variance and a principal component analysis. Significant differences have been showed between the populations for the studied characters and the cluster analysis revealed three main groups among the Tunisian *A. roseum* plants. Bioclimatic zone originality of studied population was not determinant criteria for the distribution of populations in several groups. There proved to be substantial genotypic variability in the Tunisian material for the phenotypic traits. Variation within the same bioclimatic zone was extremely important.**

Key words: *Allium roseum*, bioclimatic zones, morphological traits, phenotypic variability, Tunisia.

INTRODUCTION

The Genus *Allium* is one of the largest in the world flora. About seven hundred *Allium* species can be found in the Northern Hemisphere, from Europe and Asia to the shores of the Pacific Ocean in Northwestern America (Hanelt et al., 1992; Fritsch and Friesen, 2002; Friesen et al., 2005). With advances in systematic research the genus *Allium* belongs to the *Alliaceae* family. From the great wealth of *Allium* species, the most well-known are the garden garlic and garden onion, both of which were cultivated thousands of years ago as edible plants in our region. Such plants have been used for many centuries for the pungency and flavoring value, for their medicinal properties, and, in some parts of the world, their use also has religious connotations (Kamenetsky and Rabinowitch, 2006). They have acquired many morphological and ecological adaptations to seasonal rainfall variations and different temperature regimes (Gutterman et al., 1995).

Unlike to the cultivated garlic (*Allium sativum* L.) which has been the focus of several studies treating morphological, agronomic and molecular aspects et al., 2006; Baghalian et al., 2005; Senula and Keller, 2005; Maab and Klaas, 1995), studies on rosy garlic (*Allium roseum* L.) are, in fact, rare. However, these studies are mainly dedicated to the morphological, karyological aspects and recently to the antibacterial activity (Jendoubi et al., 2001, Ferchichi, 1997, Najjaa et al., 2007).

A. roseum L. is a species with a typically Mediterranean distribution. It belongs to *Molium* section and includes different intraspecific taxa (Marcucci and Tornadore, 1997). This species is represented in North Africa by 12 taxa: 4 varieties, 4 subvarieties and 4 forms (Cuénod, 1954; Le Floc'h, 1983). In Tunisia, three varieties have been reported (Cuénod, 1954): var. *grandiflorum* (Briq), var. *perrotii* (Maire) and var. *odoratissimum* (Regel). Considered as an endemic taxon in North Africa, the *odoratissimum* variety is a perennial spontaneous weed (Cuénod, 1954). Its oblong bulb grows about 30 - 60 cm tall (Quezel and Santa, 1963) and its flowers are wide, rosy or white coloured (Le Floc'h and Boulas, 2005).

A. roseum is mainly found in poor and sandy soils; in cultivated fields and fallows, and on roadsides. It was used since ancient times as a vegetable, spice or herbal remedy (Cuénod, 1954).

At present, the species is used in traditional pharmacopoeia for its expectorant properties. It is extensively widespread in Southern Tunisia, where it has been empirically used for its numerous therapeutic virtues against the rheumatism (Marcucci and Tornadore, 1997). It is

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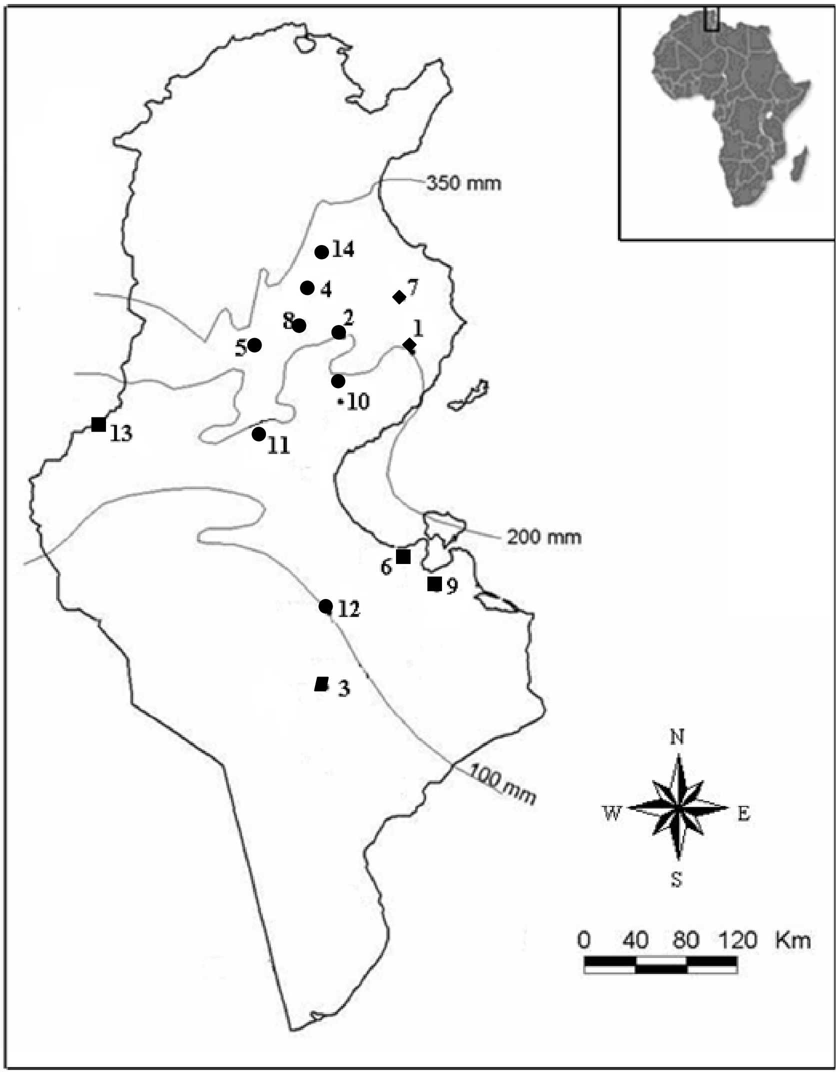

Figure 1. Map of Tunisia: geographic and bioclimatic localizations of the fourteen studied populations. 1, 2,……., 14: Allium roseum's accessions ; Symbols indicate the population bioclimatic stage: ,Lower Arid (LA); , Lower. Semi Arid (LSA); , Upper. Arid (UA) and , Upper. Saharian (US)

also used sometimes like condiment, replacing onion (Cuénod, 1954).

In the present study, morphophenological characteristics were analyzed in order to evaluate differences within and among populations of *A. roseum* in Tunisia; and to evaluate the diversity of the species according the bioclimatic originality.

Morphological traits are qualified easy to observe and it is possible to screen and categorize large amounts of germplasm at low cost, which is a great advantage when managing large germaplasm collections (Diederichsen, 2007). However, the well utilization of morphological descriptors involves the evaluation of agronomic performance in the farm (De Vicente et al., 2006). Exploitation of such traits increases our knowledge of the genetic variability available and strongly facilities breeding for wider geographic adaptability, with respect to biotic and abiotic stress (Effa et al., 2006).

MATERIALS AND METHODS

Planting material

After the complete life cycle has been observed (between April and Mai); bulbs were harvested and stored, during five months, in dry chamber at 20°C temperature and 30% humidity.

A. roseum germaplasm was planted near Arid Land Institute of Médenine (IRA) in Southern Tunisian zone. Fourteen Tunisian *A. roseum* populations, explored in the species geographical zone extending from the South to the Centre of the country, were analyzed. For subsequent analyses, these populations were coded from 1 to 14 (Figure 1 and Table 1). Analyzed Populations are belonging to four bioclimatic zones: lower Arid, lower semi Arid,

Table 1. *Allium roseum* populations collected from different localities in Tunisia.

Accession	Label	Bioclimatic zone [1]	Latitude (UTM)	Longitude (UTM)	Altitude (m)
Dokhane	1	Lower. semi Arid	34.9817	10.7463	55
Lemaya	2	Upper. Arid	35.0271	10.1626	112
Bir amir	3	Upper. Saharian	32.5871	9.9746	345
Nasrallah	4	Upper. Arid	35.4357	10.8759	168
Touila	5	Upper. Arid	35.0074	9.4051	359
El Fjèe	6	Lower. Arid	33.5000	10.3028	15
Bouali	7	Lower. semi Arid	35.9669	10.4573	37
Sidi Lefi	8	Upper. Arid	35.1626	9.7940	250
Samaeillette	9	Lower. Arid	33.3211	10.924	12
Bir Ali	10	Upper. Arid	34.8942	10.0387	141
Haddej	11	Upper. Arid	34.405	9.4525	126
Dahar	12	Upper. Arid	33.1332	10.0112	299
Elfrid	13	Lower. Arid	34.4835	8.0726	513
El Baten	14	Upper. Arid	35.6994	9.9962	55

Bioclimatic zones were defined according to Emberger's coefficient: Q^2 (1966). Q^2 coefficient was calculated for each site using P, M and m values. $Q^2 = 2000P/ (M^2 - m^2)$ where P is the mean annual rainfall (mm), M is the average maximum temperature (°K) for the hottest month (June) and m (°K) is the minimal mean temperature of the coldest month (February).

upper Arid and upper Saharan (Emberger, 1966).

Field examination

Twenty pots (18 cm height, 20 cm diameter) containing 2/3 an organic matter and 1/3 sandy soil. 75 bulbs for each population were subdivided according to size medium (4 mm Ø 7 mm) and 15 bulbs of big size (Ø > 7 mm). They have been planted at two depths (2 cm for medium bulbs and 3 cm for the big bulbs). Planting was done on 14 October 2005 at the rate of 3 bulbs of big size/pot and of 5 bulbs of medium size/pot. Which position was done indicated by the base of bulbs.The pots where placed under homogeneous environmental conditions. In order, to have least one plant by pot, twenty days after planting a few plants have been transplanted in pots where one didn't record any emergence. Therefore, the grown plants were submitted to daily surveys during a four months period (from October, 2006 - February, 2007).

Twenty two quantitative morphological characters were studied, the list focused on agronomic traits, floral descriptors and those relative to reproductive vigor (Table 2).

Bulbs produced by plant are subdivided according to their diameter in three categories: big size (NBB (Ø > 7 mm)), medium size (NMB (4 mm Ø 7 mm)) and small size (NSB (Ø < 4 mm)).

Statistical analysis

Simple statistics (such as means and coefficient of variation) were used in order to compare variation between the studied populations. A variance analysis (ANOVA) was performed and then the averages were compared by Duncan's multiple range test. Correlation analysis was then used to estimate the relationship between the studied variables.

To present data structure and relationship among populations, Principal Component Analysis (PCA) and cluster analysis by the UPGMA (unweighted pair group method using arithmetic averages) were done. PCA consist in representing the dispersion of objects in a multivariable graph containing as many axes as descriptors. Characteristics that contributed most to the variability were determined on the basis of those original variables with greater influence to component. The aim of this method was to obtain an aggregation of variables exhibiting a pattern of joint contribution of the total variation. Cluster analysis puts together varieties according to their morphological similarities and visual phylogenetic relations existing between them.

Following correlation analysis, using Pearson correlation coefficient, was used to estimate the relationship between studied variables.

RESULTS

Bulbs Emergency

As showed by Figure 2, the highest and the lowest percentage of emerged bulbs are 13.33 and 5.55 % respectively; they are related to populations 7 (Bouali) and 3 (Bir Amir) respectively. For all studied material, only 6 populations were represented by emerged bulbs percentage ranging between 10 and 13%. However, for the 8 other populations, this percentage varied from 5 - 10%.

Morphological variation

Mean, minimum, maximum and coefficient of variation of studied traits are shown in Table 2. Preliminary evaluations showed that reproductive phase display and number of big bulbs produced per plant were the characters with the highest coefficient of variation (CV = 101.18 and 99.59 respectively). Indeed, the lowest genetic variation was related to unfolding of last floral bud (CV = 13.57) and Umbel average diameter (CV = 15.13). Means and CVs are qualified as helpful indicators for selection of

Table 2. The morphological traits measured after four months survey of Tunisian *Allium roseum* populations.

Descriptors	Label	Means	Minimum	Maximum	Standard Deviation	CV
Phonological characters:						
Unfolding of first leaf (days)	V1	21.96	5.00	60.00	7.50	59.87
Unfolding of last leaf (days)	V2	80.49	16.00	146.00	13.33	22.60
Vegetative stage display* (days)	V3	58.53	8.00	118.00	15.69	32.81
beginning of reproductive stage**	V4	21.60	15.00	66.00	6.11	75.47
Reproductive stage display (days)***	V5	12.58	0.00	57.00	9.37	99.59
Unfolding of first floral bud (days)	V6	102.09	28.00	149.00	11.31	16.33
Unfolding of last floral bud (days)	V7	114.67	28.00	157.00	12.68	13.57
Vegetative traits:						
Leaves number	V8	6.93	3.00	20.00	2.36	36.09
Leaf average length (cm)	V9	26.50	12.50	40.33	3.43	22.51
Leaf average width (mm)	V10	3.91	1.00	12.50	1.31	43.01
Basis stem diameter (mm)	V11	4.61	1.43	10.23	1.58	30.68
Reproductive traits:						
Number of Umbels per plant	V12	1.85	1.00	6.00	0.62	45.69
Length scape[1] (cm)	V13	22.59	4.73	35.00	3.66	21.52
Flowering stem diameter[1] (cm)	V14	2.69	1.11	8.40	1.03	20.84
Scape diameter [1] (mm)	V15	6.77	2.67	9.79	0.88	15.33
Average Seeds produced per umbel	V16	36.24	0.00	153.00	25.12	63.84
Seeds number produced per plant	V17	66.07	0.00	396.00	52.33	82.56
Number of small bulbs produced per plant	V18	3.88	0.00	26.00	4.19	74.05
Number of mean bulbs produced per plant	V19	12.47	0.00	59.00	10.31	54.03
Number of big bulbs produced per plant	V20	1.37	0.00	7.00	0.64	101.18
Total number of bulbs produced per plant	V21	17.72	1.00	84.00	14.40	47.60
Weight of total bulbs produced per plant	V22	1.69	0.15	9.23	1.28	55.86

* the display of vegetative phase (with days) is measured while counting the difference between broadcast of the first and the last leaf respectively
** the beginning of reproductive phase is measured while counting the difference between broadcast of the last leaf and this of first floral button
*** the display of reproductive phase (with days) is measured while counting the difference between broadcast of the first and the last floral button respectively
[1] Characters 13, 14 and 15 were given as an average per plant.

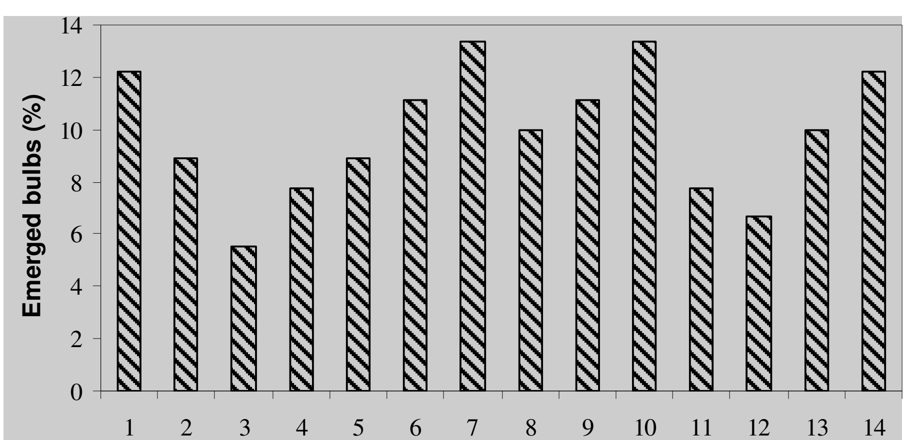

Figure 2 . Percentage of emerged bulbs for 14 studied populations of *Allium roseum* (on the basis of 90 planted bulbs).

variants of interest for breeding purposes.

The difference in these traits between several sites may be attributed to difference in altitude and climate. Nevertheless, these three populations figured in different bioclimatic zones and they are also in different altitude points (Table 2).

Duncan's multiple range tests analysis

Duncan's multiple range tests showed that the populations of *A. roseum* were significantly different in all evaluated parameters (Table 4).

The Duncan test at 5% revealed two to seven groups of means depending on the descriptors. It was found that the majority of populations always figured in the leading group, whereas populations 3, 5, 6, 10 and 13 were always in the last group. Bioclimatic zone originality of studied population was not determinant criteria for the distribution of populations in several groups. However some traits, as beginning of reproductive phase descriptors (V4), can group seventeen studied populations into two groups only. Thereby more than one bioclimatic zone could be represented in these groups.

For the number of small bulbs (V18), number of mean bulbs (V19), total number of bulbs (V21) and total weight of bulbs produced per plant (V22) descriptors; populations 9 (Bouali) can be classified out from others populations.

Simple correlation coefficients

Simple correlation between traits (Table 5) reviled that several characters were highly correlated with each other. Nevertheless, for more the third of cases, correlations between characters were significant (with critical levels of 0.05).

Basis stem diameter (V11), for example, had significant and positive correlation with leaves number (V8), Vegetative display (V3), unfolding of last floral bud (V7), leaf average width (V10), number of umbels per plant (V12), Scape diameter (V15), number of mean bulbs produced per plant (V19) and total number of bulbs produced per plant (V21). Whereas, this character (V11) had significant and negative correlation only with average seeds produced per umbel (V16).

Such result could be, probably, attributed to the allocation strategies of this species. Indeed the basis stem diameter can favorite the growth and development of all characters related to vegetative part (Arial vegetative part) and the propagation of species through vegetative pathway. In contrast, this trait (V11) progress inversely proportional face to seeds produced per umbel (V16), and consequently the propagation of species through sexual pathway. Thus, it can be strengthened by negative correlation registered between basis stem diameter and seeds number produced per plant (V17).

Table 3. Axis eigenvalues, explained proportion of variation, cumulative variation explained, and eigenvector loadings for the first three principle components (PCs) based on morphological characters of 14 *Allium roseum* populations.

	PCA axis		
Trait label	**1**	**2**	**3**
Eigenvalue	9.26	4.71	1.99
Proportion of variation	42.09	21.39	9.06
Cumulative variation	42.09	63.48	72.54
V1	0.24	-	+
V2	-0.20	-	-0.33
V3	+	-0.38	-
V4	0.22	-0.30	+
V5	-	+	0.37
V6	+	-0.41	-
V7	0.21	-0.22	0.23
V8	0.21	+	0.33
V9	+	-	0.34
V10	0.26	+	+
V11	0.30	-	+
V12	0.27	+	+
V13	-	+	0.35
V14	0.20	-	-
V15	0.22	+	+
V16	-0.22	+	+
V17	-	+	0.27
V18	+	0.26	-0.26
V19	0.26	0.21	-
V20	0.20	0.25	+
V21	0.25	0.24	-
V22	0.24	0.28	-

Eigenvalues between -0.20 and 0.20 are represented only by - or + to emphasize traits with strong relations to each PC axis.

Multivariate analysis and germplasm organization of *A. roseum*

Phenotypic diversity was estimated by using multi-variate analyses of several morphological characters. A principal component analysis involving 22 quantitative characters was performed where factors were retained when their Eigen-value exceeded the value of one. The first three axes explained 72.54% of the observed phenotypic diversity (Table 3). The first axis accounted for 42.09% of the variance and was significantly and positively associated with 8 traits: leaves number, leaf average length, basis stem diameter, umbels per plant, flowering stem diameter, scape diameter, mean bulbs and total number of bulbs produced per plant (V8, V9, V11, V12, V14, V15, V19 and V21 respectively). However, this axis was significantly and negatively associated only with average seeds produced per umbel (V16) (Table 3).

The second axis explained 21.39 % of the variance and was associated with small bulbs, big bulbs and total bulbs

Table 4. Results of Duncan's multiple range test for mean comparison of different traits of *Allium roseum* accessions collected from various parts of Tunisia (on the basis of combined data from fourteen locations).

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
1	5.4 (±1.07) e,f,g	24.7 (±12.06) b,c	89.2 (±15.27) a,b,c	64.5 (±17.81) b,c,d	24.4(±14.39) a,b	113.5(±13.05) a,b	119.9(±13.17) a,b,c,d	6.4 (±9.79)c,d,e	22.9(±6.66) c	5.9(±1.45) a,b	4.6(±1.05) c,d,e,f,g
2	8.5 (±2.60) a,b,c,d,e	19.4 (±10.91) b,c	95.5 (±18.75) a,b	76.1 (±20.67) a,b	14.4(±22.44) a,b	109.9(±15.23) a,b,c	123.0 (±9.60) a,b,c	13.1(±12.23) b,c,d,e	23.5(±6.15) c	4.3(±0.96) b,c,d,e	5.8(±1.31) b,c
3	4.0 (±0.63)G	43.8 (±7.14)A	83.6 (±10.97) b,c,d,e	39.8 (±10.24) d,e	26.0(±10.71) a,b	109.6(±13.37) a,b,c	109.6(±13.37) c,d	0.0 (±0.00)e	21.9(±4.31) c	2.4(±0.70) e	2.8(±0.80) g
4	11.0 (±2.93) a,b,d	20.3 (±8.79) b,c	112.0 (±21.19) a	91.7 (±19.14) a	8.3 (±5.87)	120.3(±20.89) a	136.3(±12.70) a	16.0(±17.52) b,c,d,e	29.9(±5.24) a,b,c	5.0(±1.84) a,b,c	6.7(±1.62) a,b
5	11.8 (±3.99) a,b	9.9 (±3.82)C	82.4 (±7.76) b,c,d,e	72.5 (±6.80) a,b,c	21.5(±10.81) a,b	103.9(±11.62) a,b,c,d	117.3(±10.35) a,b,c,d	13.4 (±9.30) b,c,d,e	33.3(±6.54) a	4.8(±1.54) a,b,c,d	6.6(±1.64) a,b
6	4.9 (±1.70) f,g	21.1 (±18.59) b,c	65.4 (±18.60) c,d,e	44.3 (±23.72) d,e	19.5 (±9.87) a ,b	84.9 (±18.00) d,e	84.9 (±18.00) e	0.0 (±0.00)e	24.6(±6.70) b,c	2.5(±2.20) e	3.1(±1.73) g
7	8.0 (±2.71) b,c,d,e,f	13.8 (±12.94) c	67.1 (±10.29) c,d,e	53.3 (±17.10) b,c,d,e	16.9(±10.50) a,b	84.0 (±10.15) d,e	120.0 (±6.82) a,b,c,d	36.0 (±9.90) a	24.9(±3.96) b,c	6.9(±1.18) a	8.3(±1.73) a
8	10.0 (±3.27) a,b,c	17.1 (±8.70)C	93.6 (±28.03) a,b	76.5 (±24.62) a,b	19.3(±13.72)a,b	112.9(±16.53) a,b,c	116.9(±20.29) a,b,c,d	4.0 (±10.46) b,c,d,e	32.1(±3.35) a,b	4.0(±1.41) b,c,d,e	5.3(±1.55) b,c,d,e
9	4.3 (±1.73)G	34.6 (±19.70) a	62.7 (±25.92) d	28.1 (±15.42) e	17.5 (±8.05) a,b	80.2 (±27.41) e	89.8 (±31.28) e	9.6 (±10.30) b,c,d,e	24.9(±3.30) b,c	2.3(±0.49) e	2.8(±0.77) g
10	9.2 (±3.98) a,b,c	20.4 (±7.12) b,c	94.2 (±12.71) a	73.8 (±17.43) a,b	14.9(±16.78) a,b	109.1(±11.15) a,b,c	132.3 (±7.44) a,b	23.2(±16.36) a,b,c,e	26.9(±5.56) a,b,c	3.7(±1.04) b,c,d,e	5.7(±1.71) b,c,d
11	5.7 (±1.28) e,f,g	19.6(±7.33) b,c	77.6 (±12.83) b,c,d,e	58.0 (±14.11) b,c,d	20.7(±16.86) a,b	98.3 (±13.58) a,b,c,d,e	101.3(±15.96) d,e	3.0 (±7.35)d,e	25.2(±5.38) b,c	2.5(±1.04) d,e	2.8(±0.79) g
12	5.3 (±1.25) e,f,g	18.8 (±7.71) b,c	68.7 (±16.03) c,d,e	49.8 (±18.48) b,c,d,e	22.0(±19.80) a,b	90.7 (±10.11) c,d,e	111.2(±12.63) b,c,d	20.5(±17.15) a,b,c,d	23.2(±5.91) c	5.2(±4.34) a,b,c	3.4(±0.52) e,f,g
13	5.7 (±1.41) e,f,g	26.7 (±17.29) b,c	73.9 (±10.74) b,c,d,e	47.2 (±18.04) c,d,e	28.8(±18.97) a,b	102.7(±22.65)C,d	117.1(±6.12) a,b,c,d	14.4(±21.37) b,c,d,e	23.6(±5.35) c	3.7(±1.47) b,c,d,e	4.7(±2.03) b,c,d,e,f,g
14	7.0 (±1.95) c,d,e,f,g	22.0 (±4.00) b,c	87.1 (±16.05) b,c,d	65.1 (±15.07) c,d	26.7(±15.60) a,b	113.8(±4.61) a,b	120.7(±7.72) a,b,c,d	6.9 (±8.11)b,c,d,e	26.1(±6.93) a,b,c	3.6(±1.77) b,c,d,e	4.0(±1.07) c,d,e,f,g

Table 4. Contd.

	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21	V22
1	1.5(± 0.66)d,e	27.0(±7.46)a,b	2.8(±0.33)b,c,d	8.4(±1.87) a	3.7(±3.47)d	3.7(±3.47)g	1.1 (±1.44)e	4.7(±3.96)f,g	1.0(±1.04)b	6.8 (±3.74) e,f	0.7(±0.30)e,f,g
2	2.3(±0.83) a,b,c,d	17.8(±2.62) d	2.6(±0.45) b,c,d	7.7(±0.68) a,b	13.5 (±0.50) c,d	41.0(±22.17)d,e,f,g	2.8 (±2.77) d,e	15.4(±5.43)c,d,e	1.4(±1.32) a,b	19.5(±5.98) c,d	2.0(±0.57) c,d,e
3	1.2(±0.40) d,e	18.6(±5.13) d	2.6(±0.16) b,c,d	6.0(±0.54) d,e	57.0(±44.35) b	57.0 (±44.35) c,d,e,f,g	4.4 (±3.38) d,e	5.8(±5.38)f,g	1.6(±0.80) a,b	11.8(±8.18) d,e,f	1.2(±0.63) c,d,e,f,g
4	2.7(±1.28) a,b	19.7(±4.06) c,d	6.7(±1.62) a	7.4(±0.59) a,b,c,d	6.3 (±3.30)c,d	26.7(±24.41)f,g	5.7 (±3.24) c,d	22.1(±10.29) b,c	1.9(±1.55) a,b	29.7(±10.24) b,c	2.4(±1.12) b,c
5	2.0(±0.71) b,c,d,e	23.2(±2.55) b,c,d	2.9(±0.31) b,c	7.5(±0.82) a,b,c	17.6(±12.82) c,d	32.9 (±22.89)e,f,g	8.6 (±4.87) b,c	27.9(±9.27) b	1.4(±1.58) a,b	37.9(±11.20) b	2.5(±1.07) b,c
6	1.0(±0.00) e	26.7(±3.97) a,b	2.1(±0.57) d	5.7(±1.15) e	56.9(±40.33) b	56.9(±40.33)c,d,e,f,g	11.3(±3.80) b	17.2 (±8.11) c,d	1.2(±1.17) b	29.7 (±9.69) b,c	2.1(±0.67) c,d
7	3.3(±1.03) a	21.1(±6.57) b,c,d	3.1(±0.32) b	8.3(±0.77) a	0.0 (±0.00)D	0.0(±0.00)g	15.8(±6.23) a	37.3(±12.27) a	3.2(±1.77) a	56.3(±17.62) a	5.6(±2.09) a
8	1.5(±0.50) b,c,d	21.6(±4.85) b,c,d	2.2(±0.21) c,d	6.1(±0.56) d,e	34.7(±15.04) b,c	59.6(±33.56)c,d,e,f,g	1.3(±1.41) d,e	9.0 (±4.82)d,e,f,g	1.0(±0.87) b	11.3 (±5.83) d,e,f	1.1(±0.79) c,d,e,f,g
9	1.8(±0.75) b,c,d	25.1(±3.98) a,b,c	2.2(±0.19) c,d	5.9(±0.72) e	65.9(±14.09) a,b	115.6 (±66.01) b,c	1.9 (±1.97) d,e	4.0 (±2.37)g	0.7(±0.90) b	6.6 (±2.84) e,f	0.7(±0.33) e,f,g
10	2.7(±1.43) a,b,c	17.5(±3.33) d	2.5(±0.34) b,c,d	6.8(±0.76) b,c,d,e	11.5 (±5.39) c,d	29.1(±16.54)f,g	2.8(±3.29) d,e	14.4(±8.88)c,d,e,f	1.3(±1.55) a,b	18.5(±12.15)c,d,e	1.9(±1.32) c,d,e,f
11	1.1(±0.35) d,e	20.5(±4.10) b,c,d	2.1(±0.33) d	6.2(±0.93) c,d,e	37.6(±21.67) b,c	48.3(±44.27)d,e,f,g	0.9(±2.10) e	5.0 (±4.38)f,g	1.3(±1.48) a,b	7.1(±6.22) e,f	0.9(±0.44)
12	2.0(±1.00) b,c,d,e	20.9(±2.52) b,c,d	2.0(±0.49) d	6.3(±0.70) c,d,e	82.3(±50.02) a	207.3(±114.46) a	3.8(±1.21) d,e	27.7 (±7.85) b	1.8(±0.69) a,b	33.3(±7.52) b	3.5(±1.38) b
13	1.7(±0.82) b,c,d,e	24.0(±3.64) b,c,d	2.4(±0.56) b,c,d	6.8(±1.28) b,c	42.8(±18.29) b	85.4 (±61.78) b,c,d,e,f	0.8 (±0.92) e	3.6 (±3.06) g	1.2(±1.03) b	5.6 (±2.31)f	0.6(±0.19) f,g
14	1.5(±0.50) b,c,d,e	18.3(±3.88) d	2.1(±0.31) d	5.5(±0.94) e	54.6(±22.47) a,b	97.4(±56.08)b,c,d,e	3.2 (±2.55) d,e	7.4(±4.77)e,f,g	0.9(±1.98) b	11.5(±5.58) d,e,f	1.1(±0.63) c,d,e,f,g

Means with the same letters are not significantly different at 5% level of probability (Duncan's multiple comparisons test), for each of the studied parameters.

weight (positively); and negatively with unfolding of last leaf (V2), vegetative zone display (V4) and unfolding of first floral bud (V6) (Table 3).

The third axis, explaining 9.06 % of the variance was associated positively with the beginning of reproductive zone (V4), unfolding of last floral bud (V7), reproductive zone display (V5), leaf average width (V10), Scape length (V13) and seeds produced per plant (V17). However this third factor was associated negatively with the unfolding of first leaf (V1) and number of small bulbs produced per plant (V18) (Table 3).

Plotting the populations on the first two axes (Figure 3A) as well as on the first and third factor (Figure 3B) graphically demonstrated that populations of *A. roseum* from different bioclimatic zones cover the factorial space unequally.

Globally, the fourteen studied populations are not structured according to their bioclimatic originality. Though, some populations from Upper Arid bioclimatic zone could constitute a small group on the first three factors (Figure3, A, B). On the other hand, the four populations originating from Lower Arid bioclimatic zone showed, relative-

Table 5. Correlation coefficients among various quantitative characters (on the basis of combined data from Seventeen locations) of *Allium roseum* accessions collected from various parts of Tunisia (*: significant at 5%, **: significant at 1%).

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21	V22
V1	1																					
V2	-0.63**	1																				
V3	0.64**	-0.06	1																			
V4	0.84**	-0.53*	0.88**	1																		
V5	-0.55*	0.17	-0.53*	-0.53*	1																	
V6	0.45	0.02	0.89**	0.75**	-0.09	1																
V7	0.62**	-0.33	0.67**	0.72**	-0.16	0.70**	1															
V8	0.29	-0.47	-0.17	0.08	-0.10	-0.26	0.51*	1														
V9	0.69**	-0.54*	0.26	0.48	-0.09	0.25	0.29	0.10	1													
V10	0.40	-0.52*	0.18	0.40	-0.20	0.10	0.56*	0.63**	-0.03	1												
V11	0.75**	-0.55*	0.44	0.64**	-0.50*	0.25	0.62**	0.55*	0.33	0.70**	1											
V12	0.50*	-0.42	0.15	0.33	-0.43	-0.05	0.62**	0.90**	0.11	0.68**	0.72**	1										
V13	-0.33	-0.04	-0.52*	-0.42	0.45	-0.36	-0.38	-0.08	0.24	-0.19	-0.28	-0.35	1									
V14	0.51*	-0.11	0.60*	0.56*	-0.54*	0.42	0.53*	0.21	0.27	0.35	0.51*	0.48	-0.17	1								
V15	0.29	-0.39	0.17	0.33	-0.12	0.14	0.53*	0.54*	-0.04	0.78**	0.65**	0.62**	0.00	0.39	1							
V16	-0.54*	0.34	-0.58*	-0.66**	0.48	-0.43	-0.53*	-0.21	-0.18	-0.49*	-0.81**	-0.42	0.20	-0.48	-0.69**	1						
V17	-0.36	0.10	-0.49*	-0.46	0.41	-0.35	-0.24	0.11	-0.10	-0.20	-0.60*	-0.13	0.13	-0.36	-0.46	0.89**	1					
V18	0.25	-0.30	-0.16	0.01	-0.38	-0.39	-0.11	0.32	-0.05	0.42	0.51*	0.42	-0.15	0.22	0.23	-0.25	-0.32	1				
V19	0.50*	-0.54*	0.05	0.30	-0.53*	-0.23	0.20	0.54*	0.08	0.67**	0.66**	0.64**	-0.34	0.33	0.37	-0.30	-0.13	0.82**	1			
V20	0.14	-0.30	-0.15	0.01	-0.12	-0.25	0.29	0.69**	-0.20	0.66**	0.42	0.72**	-0.32	0.30	0.54*	-0.17	-0.04	0.62**	0.67**	1		
V21	0.44	-0.49*	-0.02	0.22	-0.49*	-0.29	0.12	0.51*	0.03	0.63**	0.63**	0.61**	-0.30	0.31	0.36	-0.29	-0.19	0.91**	0.98**	0.70**	1	
V22	0.33	-0.47	-0.09	0.14	-0.42	-0.34	0.18	0.65**	-0.08	0.69**	0.60*	0.71**	-0.34	0.25	0.41	-0.25	-0.10	0.84**	0.95**	0.82**	0.96**	1

ly, a compact distribution according to the first two axes plotting (Figure 3A).

The quantitative phenogram (dendrogram) obtained from the cluster analysis is presented in (Figure 4). Cluster analysis showed three cluster-ing of populations forming three morphotypes (clusters) out of the 14 populations studied. As signaled previously, bioclimatic originality is not a determinant criteria for grouping *A. roseum* ger-maplasm. However, the dendrogram gene-rated by UPGMA method of cluster analysis (Figure 4) showed 3 mainly groups reflecting a mixture of popu-lations from various bioclimatic zones: the second group for example includes populations Sidi Lefi (8), Haddej (11) and El Baten (14) from upper Arid; El Fjèe (6), Samaeillette (9) and Elfrid (13) from Lower Arid and Bir Amir (3) from Upper Saharian bioclimatic zone.

DISCUSSION

This study showed a wide spectrum of morphological variation between the investigated populations of *A. roseum*. The emergency rate of bulbs of the species was low; it can not exceed 13%. This finding agrees with the results des-cribed previously by Zammouri et al., 2008. Problems and difficulties of bulbs germination in

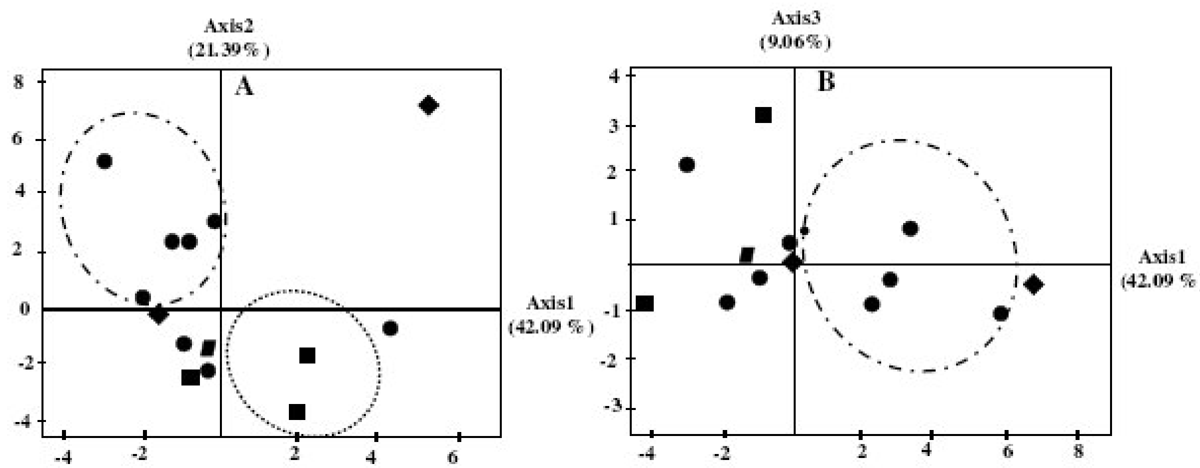

Figure 3 (A, B). Plot of the three first principal components from analysis of *Allium roseum* morphological data. First, second and third principal components (Prin1, Prin2 and Prin3) accounted for 42, 21 and 9% of the total variation.

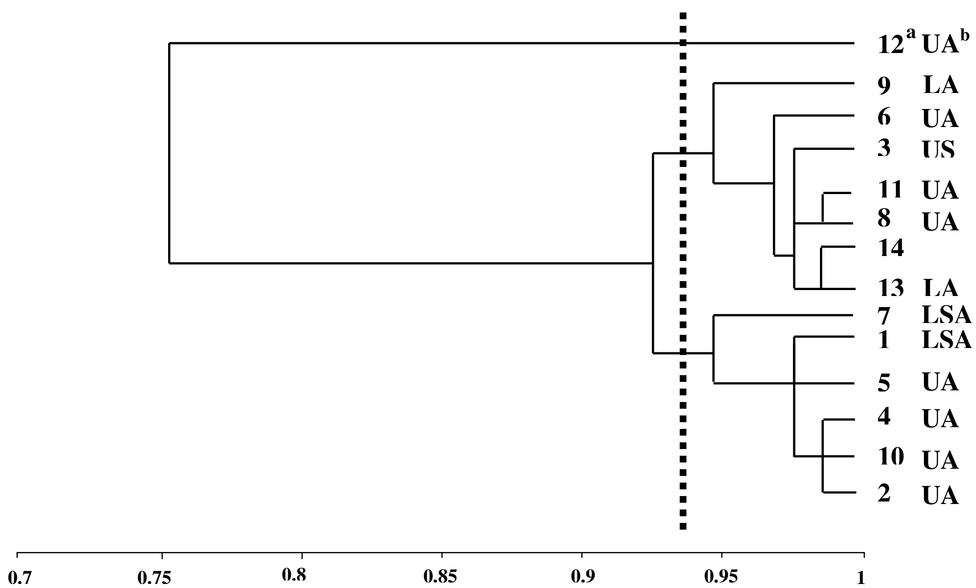

Figure 4. Dendrogram generated by UPGMA method of cluster analysis using SPSS software showing four major clusters on the basis of morphological characters of *Allium roseum* germaplasm in Tunisia.

genus *Allium* has been illustrated by numerous studies (Fritsch and Friesen, 2002; Hanelt et al., 1992; Jendoubi et al., 2001; Figliuolo et al., 2001). This low capacity can be probably due to particular dormancy characterizing the extrinsic (storage conditions: temperature, humidity etc.) and intrinsic factors (bulbs dormancy, maturity etc.) (Yamazaki et al., 1999a; Yamazaki et al., 1999b; Kamenetsky and Gutterman, 2000). Indeed, a close relationship was observed between the ABA content and bulb dormancy in *Allium wakegi* (Yamazaki et al., 1999a). This relationship was consistent with the results of previous studies (Yamazaki et al., 1995; Yamazaki et al., 1999b).

The analysis of the variability indicators *Allium roseum* populations, originating form different bioclimatic zones of Tunisia, showed a large variation in morphological traits. This large variation in morphological characters was reported for the garlic (Baghalian et al., 2006), for other species of the genus *Allium* (Ozodbek et al., 2008), and other plants such banana (Uma et al., 2004) and pomegranate (Zamani et al., bulbs of *A. roseum*. This dormancy can be attributed to The present study could facilitate evaluation and improvement of Tunisian *A. roseum* germaplasm in selection programs. Some of the populations were found to maintain their vegetative cycle more than three months (Nasrallah population), which is regarded as long time in this species, for the development of 'domesticated varieties' for fresh consumption because fresh *A. roseum* leaves are with great demand in Southern Tunisian 2007). territories. In the some way, others populations were found to produce an important quantity of bulbs and/or seeds (Bouali and Dahar populations respectively) was a good potential for developing a high yielding There 'domesticated variety' of *A. roseum* based on range and variation for these important traits.

However, leaves number (V8), Unfolding of last leaf (V2), unfolding of last floral bud (V7), umbel diameter (V9), basis stem diameter (V11), number of Umbels per plant (V12), umbel width (V13), floral stem diameter (V14) and leaf average width (V15); could constitute a useful descriptors to characterize some population of *A. roseum* with high morphologic importance. Furthermore, the parameters described in the study could make the local population good candidates to act as parent materiel in a future breeding programme, favouring rocket germaplasm conservation and management. Therefore, we concur with (Baghalian et al., 2006) who reported that morphological descriptors in garlic (*A. sativum* L.) could not facilitate evaluation and improvement of this species in selection programs.

However, it is necessary, in our opinion, to investigate flavonols, polyphenols and organosulfur compounds in *A. roseum* before initiating any domestication program.

Our results obtained throughout the present study suggest that distribution of *Allium roseum* germaplasm doesn't reveal classification of the populations according to their bioclimatic originality as observed by numerous authors interesting to the genus *Allium* (Brewster and Barnes, 1981; Baghalian et al., 2006).

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