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Subspecific variability of Tunisian wild populations of *Capparis spinosa* L.

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Fifteen Tunisian wild populations of caper (*Capparis spinosa* L.) from different geographical regions, including inerm and thorny morphotypes were assessed for their phenotypical variation using eight morphological traits. The thorny type is restricted to the North of the country, while the inerm is widely distributed from the North to the South. The data underwent an analysis of variance and a multivariate analysis. Significant differences among populations and among morphotypes for the eight descriptors were observed. The level of variation was high among populations belonging to the inerm type. The PCA and HAC groupings performed on all measured characters showed a clear discrimination between thorny and inerm morphotypes. The subclusters are concordant with the recent botanical subdivision of *C. spinosa* subsp. *spinosa* and *C. spinosa* subsp. *rupestris* (Sm.) Nyman. These two wild subspecies showed different ecological characteristics. These differences concerned the bioclimate and the soil properties, which the electrical conductivity (EC), the chemical composition (Na⁺, Ca⁺⁺, Mg⁺⁺, SO₄⁻, Cl⁻ and HCO₃⁻) and the soil texture. In addition, the ecological location seems to a factor structuring the variability of the inerm populations.

Key words: *Capparis spinosa* L., phenotypical variation, subspecies, Tunisia.

INTRODUCTION

The genus *Capparis* belonging to the Capparaceae family includes more than 250 species (Jacobs, 1965; Fici, 1993). Caper (*Capparis* L.) is a perennial shrub with a large worldwide distribution. It grows from the shores of Atlantic and Canary Islands to the Middle East in Iran-Turanian biogeographic zone (Zohary, 1960; Jacobs, 1965; Inocencio et al., 2006). The Mediterranean distribution of the genus covers the Atlantic costs from the Canary Islands and Morocco to the Black Sea and Armenia (Inocencio et al., 2006). In the Mediterranean region and Asia, six species and fifteen varieties have been reported by Zohary (1960). While Jacobs (1965)

classified these six species in a single species (*Capparis spinosa* L.). Thus, for many other authors, all species are congregated in one species (*C. spinosa* L.), with two subspecies: *C. spinosa* subsp. *spinosa* and *C. spinosa* subsp. *rupestris*. (Higton and Akeroyd, 1991; Heywood, 1993; Tutin et al., 1993; Fici and Gianguzzi, 1997). The distinction is based on the thorns presence and the leaf morphology. The first subspecies (subsp. *spinosa*) extends from the Mediterranean region to central Asia and Sahara; but the second (subsp. *rupestris*) is limited to the Mediterranean region (Fici, 2004).

Recent molecular data (Inocencio et al., 2005, 2006) subdivided the genus into 10 species in Central and Western Asia, North Africa and Europe. Five species are recorded in the Mediterranean region (*C. spinosa* L., *Capparis sicula* Veill., *Capparis aegyptia* (Lam.) Boiss., *Capparis orientalis* Veill. and *Capparis ovata* Desf.).

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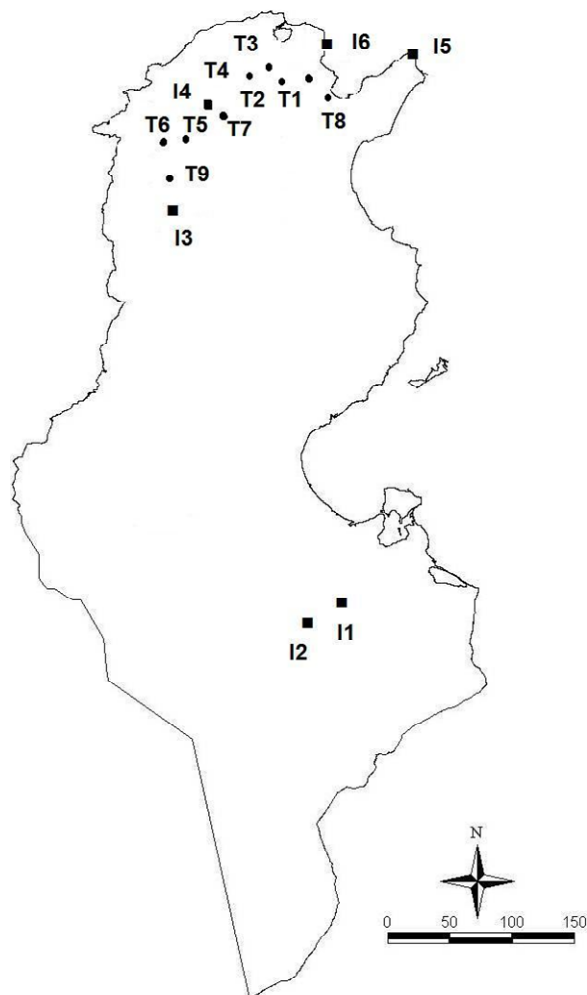


Figure 1. Repartition map of studied populations (●: thorny caper and ■: inerm caper).

Inocencio et al. (2005) mentioned five species in North Africa (*Capparis atlantica* Inocencio, *Capparis zoharyi* Inocencio, *Capparis rupestris* S. and Sm., *Capparis sicula* Veill. and *Capparis ovata* Desf.). *C. spinosa*, in the Mediterranean region, is described to be polymorphic (Tutin et al., 1993; Fici, 2001). The botanical revisions are mainly performed on the morphological descriptors, the anatomical traits, and the molecular analysis (Zohary, 1960; Jacobs, 1965; Fici, 2004; Inocencio et al., 2005 and 2006). In Tunisia, a high variability has been reported for populations in their originating sites (Ghorbel et al., 2001) or cultivated in a collection (Saadaoui et al., 2009) and the systemic revisions remain unclear; the confusion between species, subspecies and varieties is frequent. Zohary (1960) mentioned two species in Tunisia: *C. spinosa* L. and *C. ovata* Desf. However, Pottier-Alapetite (1979) reported only *C. spinosa* L. and four varieties: var. *aegyptica* (Lamk.) Boiss., var. *genuina* Boiss., var. *coriacea* Coss. and var. *rupestris* (S. & Sm.) Viv. The caper (*C. spinosa*) is the most common crop of the genus

especially in the Mediterranean region. This species is known with different vernacular name “kabbar” in North Africa (Arab vernacular name), “Alcaparro” in Spain and Gollaro in Turkey. Caper is shrub with 50 to 200 cm in height; the stems are trailing or ascending. The leaves (2 to 5 cm long) are petiolate, ovate to sub-orbicular, obtuse or emarginated, mucronate sometimes obscurely. The stipules are setaceous, often recurved, but sometimes weakly. Flowers (5 to 7 cm in diameter) are solitary, showy, zygomorphic, the petals are white or pink and stamens numerous. The fruit (3 to 10 cm) is a berry with a long gynophore, it's oblong to somewhat pyriform. The seeds (2 to 4 mm) are reniform (Tutin et al., 1993). *C. spinosa* is the most important commercial crop, the main producing countries are from the Mediterranean Basin, mainly Morocco and Spain (Sozzi, 2001).

In Tunisia, the species is with high socioeconomic value especially for the rural human populations in the Northern part of the country, the immature flower buds are pickled in vinegar or preserved in salt and used in the kitchen as an appetizer with olives, cheese and nuts, or as a complement to meat, salads, pasta and other foods.

This species is used in traditional medicine for its expectorant properties, against rheumatism and to treat headache. Recently, the pharmacology properties and the chemical compositions of this plant have been extensively studied. Chemical studies of the different parts of caper, both fermented and non-fermented, showed the presence of many beneficial compounds (Sher and Alyemeni, 2010; Tlili et al., 2011). Biological studies have revealed significant anti-diabetic (Eddouks et al., 2004; Lemhadri et al., 2007), antisclerosis (Yue-lan et al., 2010), antimicrobial (Ali-Shtayeh and AbuGhdeib, 1999), anti-oxidative (Germano et al., 2002; Hamed et al., 2007), anti-inflammatory (Ageel et al., 1985), immunomodulatory and antiviral (Arena et al., 2008) activities providing a support to the ancient uses.

In Tunisia, the increasing anthropic pressures (overexploitation, clearing) have led to the degradation of the majority of wild populations. The species is represented by scattered populations with only few individuals in several localities. The aim of this study is to assess the phenotypical variations of fifteen wild populations of caper from different regions, including inerm and thorny morphotypes, and to determine physicochemical characteristics of soil for these populations.

MATERIALS AND METHODS

Plant material

The planting material studied is composed of fifteen wild populations of *C. spinosa* L. They belong to four bioclimatic zones as defined by Emberger's pluiothermic coefficient (Emberger, 1966). The studied populations are divided into thorny and inerm morphotypes, the first morphotype includes nine populations and the second contains six populations (Figure 1). In each population, five individuals were collected in areas ranging from 0.5 and 1 ha,

Table 1. Essential ecological characteristics of studied populations

Population	Label	Types	Bioclimatic zone	Latitude (N)	Longitude (E)	Altitude (m)
Ghomrassen	I2	Inerm and pubescent	Arid	33°06'	10°18'	326
Tataouine	I3		Saharian	33°42'	9°23'	211
Dahmani	I5	Inerm and glabrous	Semi-arid	35°57'	8°48'	664
Houmana	I6		Sub-humid	36°40'	9°08'	371
Haouaria	I4		Sub-humid	37°02'	10°59'	33
Ghar El Melh	I1		Sub-humid	37°10'	10°11'	5
Jbel Ammar	T1	Thorny and glabrous	Semi-arid	36°52'	10°00'	53
Chouigui	T2		Semi-arid	36°53'	9°46'	158
Mateur	T3		Sub-humid	37°00'	9°38'	33
Joumine	T4		Sub-humid	36°57'	9°31'	106
Bullaregia	T5		Sub-humid	36°33'	8°44'	204
Chemtou	T6		Sub-humid	36°29'	8°44'	189
Lafareg	T7		Sub-humid	36°28'	8°33'	171
Rommana	T8		Semi-arid	36°52'	10°43'	53
Kef	T9		Sub-humid	36°16'	8°44'	385

according to plant frequencies. The altitude of sites varied from 5 to 664 m (Table 1).

Morphological parameters analyzed

Three qualitative and eight quantitative parameters have been analyzed. The qualitative traits are related to the plant architecture (creeping or erect plant), the thorny stipules development (thin, developed, and curved) and the presence or absence of epidermic hair. The quantitative parameters are the blade length (LL), the blade width (LW) the blade surface (LS), the internodes length (INL) the stamens number per flower (SNF), the seed length and width (SL and SW) and the weight of 1000 seeds (SW_{1000 g}).

Physicochemical analysis of soil

Physicochemical analysis of soil was concerned with thirteen populations, except Tataouine (I3) and Lafareg (T7). For each site, fifteen samples from five locations and three deep intervals (0 to 30 cm, 30 to 60 cm and 60 to 90 cm) were analyzed. The analysis has concerned the pH, the electrical conductivity (EC) and the percentage of total limestone, active limestone and total organic matter (MO), the chemical composition (Na⁺, Cl⁻, Ca⁺⁺, Mg⁺⁺, K⁺, SO₄⁻, HCO₃⁻ and P₂O₅) and soil texture. The techniques used are those cited by Naanaa and Susini (1988). Soil texture was determined by pipette analysis method (Krumbein and Pettijohn, 1938).

Statistical analysis

To compare the heterogeneity of morphological parameters among populations, a variance analysis was made for each character using procedure ANOVA. Averages among parameters were compared using Student Newman Keuls test (P = 0.05).

To estimate the divergence among populations, a principal

component analysis (PCA) and the hierarchical ascending classification (HAC) based on all measured parameters in all populations, have been made by XLSTAT 2.02 statistical software (Xlstat 2010).

RESULTS

Qualitative morphological parameters

The preliminary comparison in the basis of three qualitative descriptors shows that the two morphotypes can be distinguished morphologically.

However, the thorny morphotype is characterized by an erect shoots and non ramified root system (Figure 2). Moreover, in winter, the thorny caper desiccates their branches and a total fall of foliage is observed. Nevertheless, the inerm morphotype is found to be with fine or small thorns. It is creeping and characterized by a ramified root system (Figure 2). The two populations (I2 and I3), belonging to this morphotype and originated from the South of Tunisia, are densely pubescent (Figure 2). The fall of foliage is absent for the two pubescent inerm populations, but it is partial for the inerm glabrous populations, existing in the North and the South of the country.

Quantitative morphological parameters

The analysis of variance showed a high and significant variation for each parameter among populations (Table 2). The high average of blade length (43 mm) was observed for the population I2 (Ghomrassen). The six

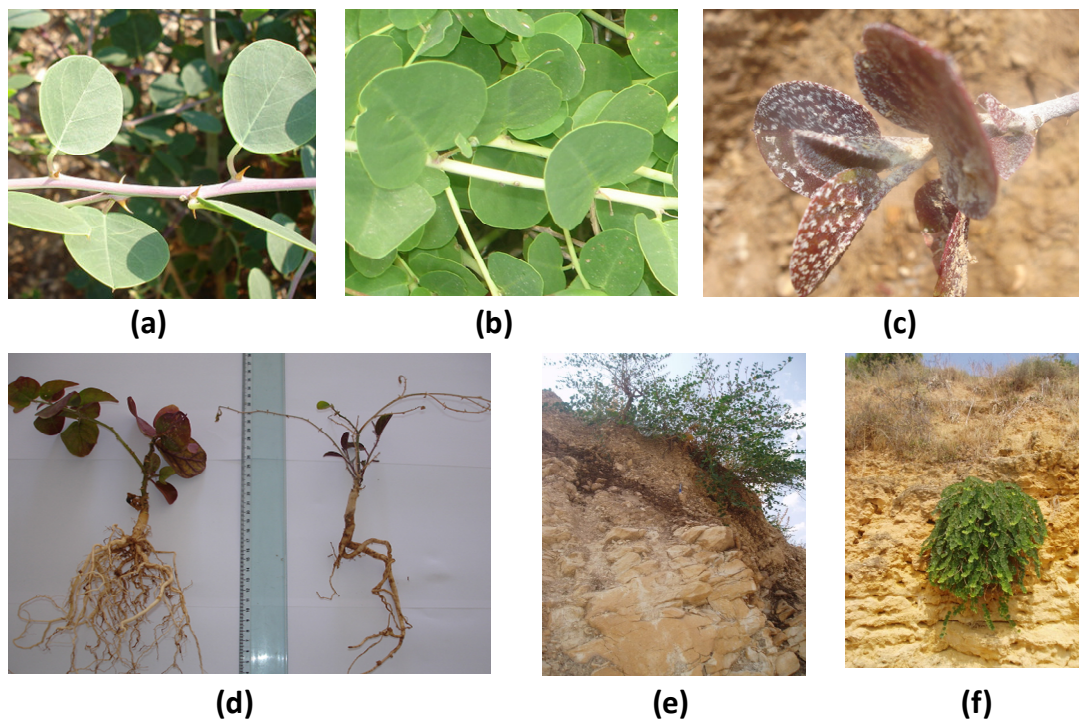


Figure 2. (a) *C. spinosa* subsp. *spinosa*, (b) and (c) *C. spinosa* subsp. *rupestris* respectively glabrous and pubescent, (d) *C. spinosa* subsp. *rupestris* and *C. spinosa* subsp. *spinosa* root system, (e) and (f) architecture and habitat of *C. spinosa* subsp. *spinosa* and *C. spinosa* subsp. *rupestris* respectively.

populations from the inerm morphotype showed higher value for this parameter, it ranged between 28.5 and 43 mm. For the thorny morphotype, this parameter showed lower values (22.6 to 25.2 mm) except for the population T5 (Bullaregia) which presents with a long blade leaves (32 mm).

The Student-Newman-Keuls test (at 5%) revealed 2 to 7 population grouping according to the descriptor. On the basis of the following descriptors: blade length (LL), blade surface (LS) and stamens number per flower (SNF), it was found that populations belonging to the thorny morphotype (nine populations) always appeared in the same group, whereas the six populations belonging to inerm morphotype (I1, I2, I3, I4, I5 and I6) figured in more than one group (Table 2).

Significant correlation coefficients were shown between the majorities of morphological characteristics (Table 3). It should be emphasized that the correlation between the internodes length (INL) and the parameters related to seeds (length, width and weight) and leaves was very low. The parameter internodes length (INL) shows also low correlations with stamens number per flower (SNF), and leaf characteristics (blade length, width and surface). The highest positive correlation coefficient (0.981) was observed between blade length (LL) and blade surface (L). The correlation between descriptors related to leaf between each other and those related to seed between each other are positive and showed high values. In

addition, the correlation values between parameters related to leaf and those related to seed are negative. The highest negative correlations (-0.774) were observed between stamens number per flower (SNF) and seed length (SL) (Table 3).

Multivariate analysis of morphological parameters

The plot of principal component analysis (PCA) identified three principal components (PC) that explained 95% of the total variance. The first axis accounted for 66.73% of the total variation. The highest loading parameters were blade length (LL), blade width (LW), and blade surface (LS) (Figure 3). It also signaled that this axis is negatively correlated to three descriptors related to seeds (LL, LW and $SW_{1000\text{ g}}$). The second axis explained 22.40% of total variance and is related to internodes length (INL), this component is also loaded with negative signs to stamens number per flower (SNF). The third component, instead, explained only 4.42% of total variance and show low value of correlation for all the parameters with positive sign for the stamens number per flower (SNF) descriptor.

The plot of the first two principal components showed a high dispersion of populations without correlation with bioclimate. Two major groups of populations were differentiated. The first group (G1), identified on the left of axes 1 and 2, comprised nine populations from the thorny

Table 2. Average of the morphological parameters measured for all analyzed populations.

Populations		LL (mm)	LW (mm)	LS (mm ²)	SL (mm)	SW (mm)	SW _{1000g} (g)	INL (mm)	SNF
I1	Ghomrassen	43 ± 3.2a	37.3 ± 3.9a	1270 ± 322.4a	3.1 ± 0.2d,e	2.6 ± 0.2c,d,e	7.2 ± 0.4e	31 ± 0.5 a	77.8 ± 1.4 b
I2	Tataouine	28 ± 1.3c,d	27.1 ± 1.6b,c,d,e	710 ± 123b,c,d	3.2 ± 0.2c,d,e	2.5 ± 0.2d,e	7.5 ± 0.7 d,e	11.7 ± 1.4 F	105.6 ± 6.2a
I3	Dahmani	29.1 ± 0.5c,d	27.3 ± 0.6b,c,d,e	783 ± 43.8b,c,d	3 ± 0.1 e	2.5 ± 0.1E	7.1 ± 0.3e	11.6 ± 0.1F	107.4 ± 6.3a
I4	Houmana	35.1 ± 3.6b	32.1 ± 2.5a,b,c	907.7 ± 33.5b,c	3.1 ± 0.3 d,e	2.5 ± 0.3 d,e	8.2 ± 2.5 d,e	23.3 ± 2b	98.6 ± 3.2 a
I5	Haouaria	29.3 ± 1.6c,d	25.2 ± 1.9c,d,e	602.8 ± 92.7c,d	2.9 ± 0.2 e	2.5 ± 0.2E	7 ± 0.7 e	5.5 ± 0.7 g	83.5 ± 7.9 b
I6	Ghar El Melh	28.5 ± 4.3c,d	25.7 ± 0.4 c,d,e	608 ± 58c,d	3.5 ± 0.2b,c	2.8 ± 0.1b,c,d,e	10.4 ± 0.4b,c,d	18.2 ± 2.4c,d,e	78.7 ± 1b
T1	Jbel Ammar	23.1 ± 6d	22 ± 4.2 d,e	428.5 ± 183.7 d	3.4 ± 0.2b,c,d	2.8 ± 0.1b,c,d,e	10.2 ± 2.2b,c,d,e	17.7 ± 0.6c,d,e	73.9 ± 2.2b
T2	Chouigui	21.6 ± 1.1d	23.1 ± 4.1c,d,e	416.3 ± 85d	3.8 ± 0.3a,b	3.1 ± 0.2a,b	13 ± 1.1a,b	19.4 ± 1.2c	65.4 ± 6.9b
T3	Mateur	22 ± 3.2d	22.1 ± 3.8 d,e	364 ± 159.6d	3.5 ± 0.3a,b	2.8 ± 0.3b,c,d,e	11.7 ± 2a,b,c	17.9 ± 0.8c,d,e	70.8 ± 12.1b
T4	Joumine	22.8 ± 2.7d	22.9 ± 3.6c,d,e	430.8 ± 146.7 d	3.5 ± 0.2a,b	2.9 ± 0.3b,c,d	11.4 ± 2.2 a,b,c	18.9 ± 1.6 c,d	65.5 ± 10.5b
T5	Bullaregia	32.2 ± 2.4d	21 ± 2.4e	414 ± 228.1d	3.7 ± 0.1a,b	3 ± 0.1a,b	12 ± 0.7a,b,c	14.7 ± 1.6d,e,f	72.3 ± 10.1b
T6	Chemtou	23.4 ± 1.8d	22.4 ± 2.3d,e	444.3 ± 171.4 d	3.5 ± 0.1 b,c	2.8 ± 0.2 b,c,d,e	9.6 ± 1.5 c,d,e	17.5 ± 1.4 c,d,e	87.9 ± 5.4 b
T7	Lafareg	23.3 ± 1.8 d	23.8 ± 3.1 c,d,e	447.8 ± 64.7 d	3.9 ± 0.1 a	3.3 ± 0.1 A	12.9 ± 1.3 a,b	18.6 ± 0.8 c,d	65.7 ± 7.4 b
T8	Rommana City	24.5 ± 1.4 d	23.3 ± 0.4 c,d,e	459.3 ± 33.9 d	3.7 ± 0.2 a,b	2.9 ± 0.1 b,c	9.6 ± 2.4 c,d,e	18.9 ± 0.4 c,d	74.4 ± 1.5 b
T9	Kef	25.2 ± 2.5 d	24 ± 2.8c,d,e	489 ± 132.5 d	3.6 ± 0.4 a,b	3 ± 0.2 a,b	13.8 ± 2.4 a	19.5 ± 0.9 c	82.4 ± 3.8 b
Mean		26.807	25.220	585.033	80.660	17.627	2.800	3.427	10.107

Means with the same letters are not significantly different at 1% (Student-Newman-Keuls). Limb length (LL), limb width (LW), limb surface (LS), internodes length (INL), stamens number per flower (SNF), seed length (SL), seed width (SW), and weight of 1000 seeds (SW_{1000g}).

morphotype (populations T1, T2, T3, T4, T5, T6, T7, T8 and T9). This group consists of populations from the North of Tunisia and belonging, to semi-arid, subhumid and humid bioclimate zones (Table 1). The nine populations are characterized by small leaves, low stamens number and big seeds (Table 2). The second group (G2) recognized on the right part of the bisector 1-2 included six populations from the inerm morphotype (I1, I2, I3, I4, I5 and I6). Four bioclimatic zones are represented in this group; they are saharian, arid, semi-arid and subhumid. The second group is subdivided into two subgroups. The first subgroup (G2.1) contains the populations of Ghar El Meleh (I1), Haouaria (I4) and Houmana (I6), projected on the positive side

of axes 1 and 2 seems to be isolated from the other populations of inerm morphotype. These populations are characterized by big leaves, small seeds and low internodes (INT). This subgroup is formed by the inerm populations from the subhumid bioclimate. The second subgroup (G2.2) projected on the right part of the plan 1 to 2 and on the negative part of the principal component 2 and the negative side of the axis 1, is made up of populations Chenini Tataouine (I2), Dahmani (I3) and Haouaria (I5). The populations belonging to this group are from the inerm morphotype. This subgroup characterized by big leaves, small seeds, high stamens number, and reduced internodes length. Three bioclimatic zones are represented in this subgroup; they are

saharian, arid and semi-arid bioclimates respectively for I3, I2 and I5 populations. The figure obtained from the first and the third axes, confirmed the clear segregation between the inerm and thorny morphotypes (Figure 4).

The cluster analysis was shown as a dendrogram indicating the estimated relations between studied populations (Figure 5). The dendrogram showed two distinct groups. The regrouped populations could have similar values for each studied descriptor. The first group (G1) consists of the inerm population of Ghar El Melhed (I1). The second group (G2) includes the other populations. This group is subdivided in two subgroups; the five inerm populations (I2, I3, I4, I5 and I6) formed the first subgroup (G2.1) and the

Table 3. Correlation coefficients between morphological parameters.

Variables	LL	LW	LS	SNF	INL	SL	SW	SW _{1000g}
LL	1							
LW	0.977	1						
LS	0.981	0.986	1					
SNF	0.427	0.439	0.493	1				
INL	0.433	0.505	0.427	-0.298	1			
SL	-0.629	-0.601	-0.636	-0.774	0.201	1		
SW	-0.679	-0.635	-0.678	-0.702	0.217	0.951	1	
SW _{1000g}	-0.677	-0.634	-0.693	-0.694	0.176	0.906	0.880	1

Limb length (LL), limb width (LW), limb surface (LS), internodes length (INL), stamens number per flower (SNF), seed length (SL), seed width (SW), and weight of 1000 seeds (SW_{1000g}).

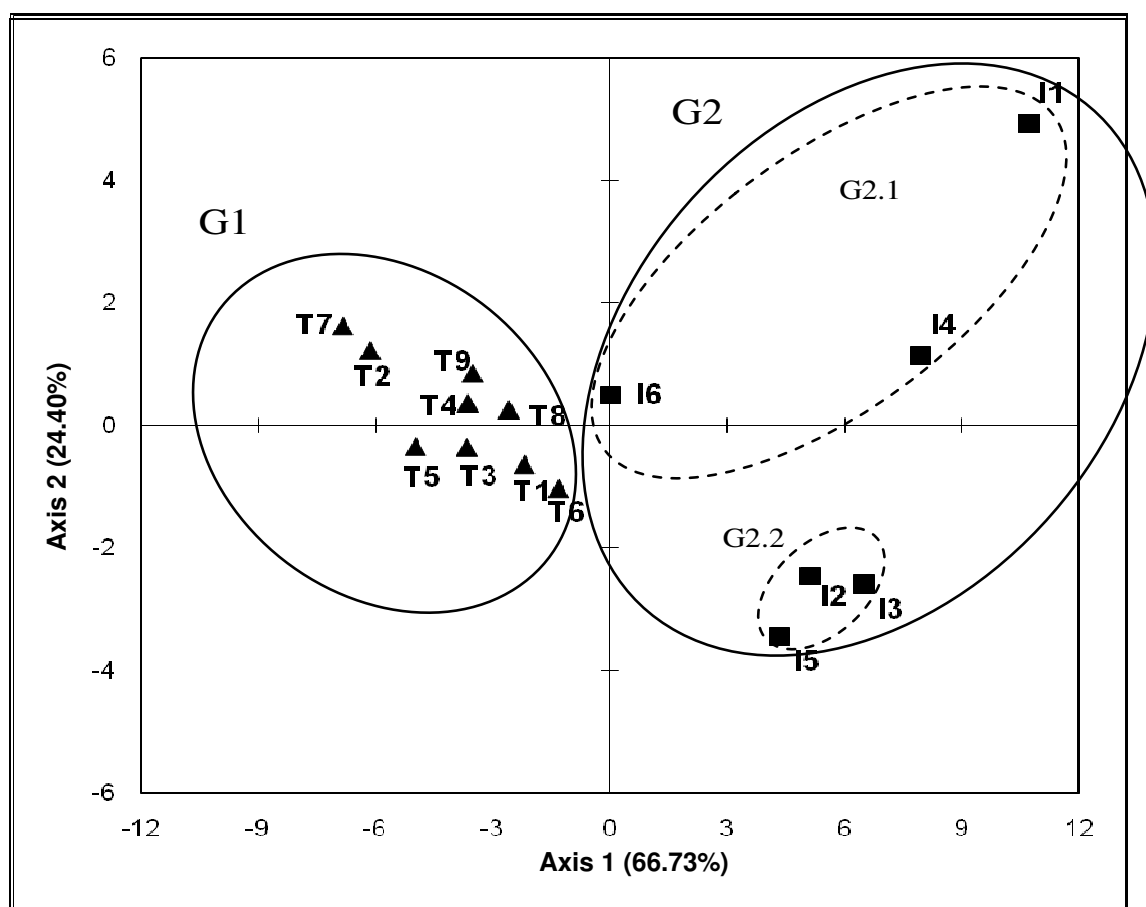


Figure 3. Principal component analysis (ACP) on the morphological parameters performed on populations: Projection of populations on the plan defined by axes 1 to 2 (■: inerm populations; ▲: thorny populations).

all thorny populations constituted the second subgroup (G2.2).

Characteristics of soil and effect of subspecies

The caper grows on alkaline soils, the pH varies from 7.12 to 8.63. The soil caper is characterized by a low EC,

except for the I2 population, and the total percentage of limestone is generally high, the average is 39.68%. The ionic composition varies depending on the site and the subspecies (Tables 4 and 5). *C. spinosa* subsp. *spinosa* occupies the soil characterized by low electrical conductivity, the Na⁺, Ca⁺⁺, Mg⁺⁺, SO₄⁻, Cl⁻, HCO₃⁻ rates are low relative to those of *C. spinosa* subsp. *rupestris*.

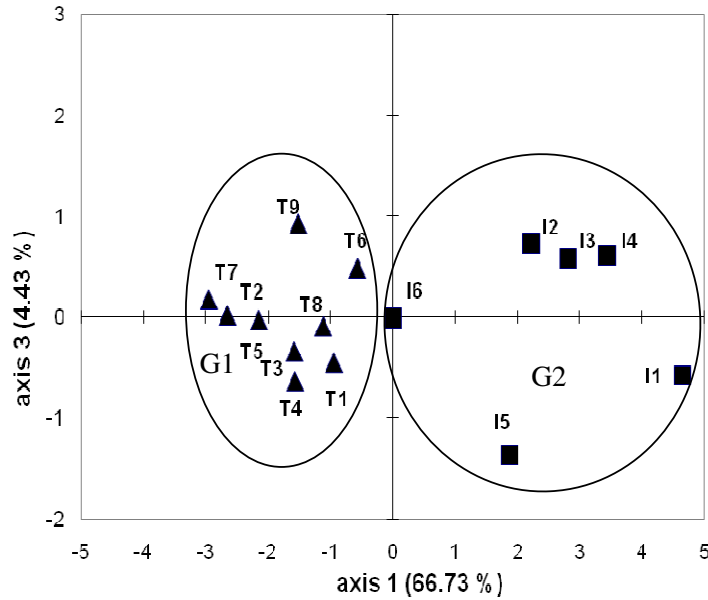


Figure 4. Principal component analysis (ACP) on the morphological parameters performed on populations: Projection of populations on the plan defined by axes 1-3 (■: inerm populations; ▲: thorny populations).

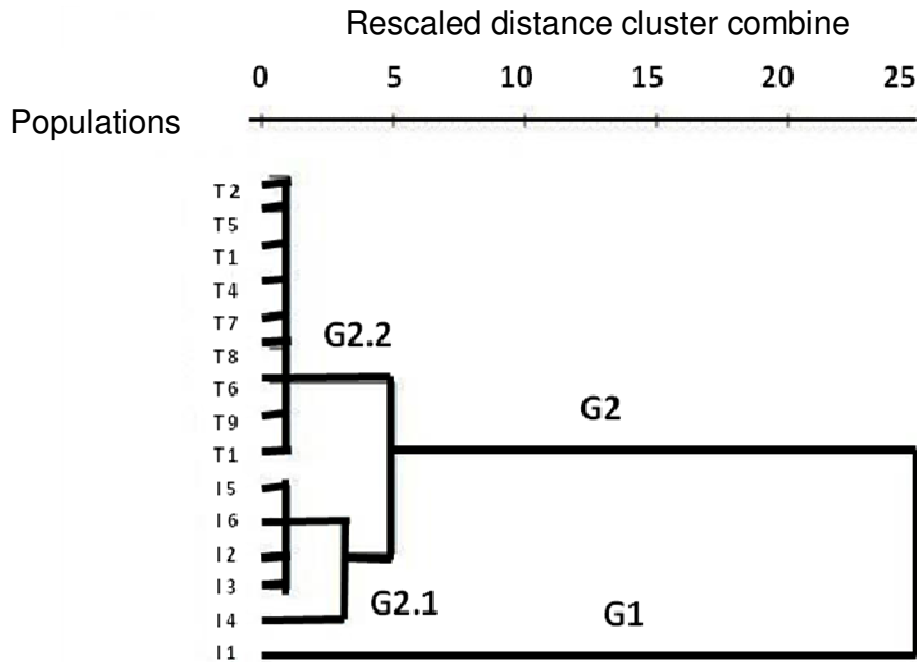


Figure 5. Hierarchical ascendant classification (HAC) of studied caper populations.

The latter subspecies exists on organic and ion-rich soil (Table 5). Thus, the soil texture is different between the two subspecies, the soil of subsp. *spinosa* sites is silty to silt-sandy, but that of subsp. *rupestris* is silt-sandy to sand-silty (Table 5).

DISCUSSION

Despite a number of studies in Tunisia focusing on *C. spinosa* including biochemical (Tlili et al., 2009, 2010), physiological (Ben, 2000) and genetic diversity (Ghorbel

Table 4. Physicochemical characteristics of soils for the studied populations.

Populations	pH	EC (dS.m ⁻¹)	Total limestone (%)	Active limestone (%)	Mg ⁺⁺ (meq.l ⁻¹)	Ca ⁺⁺ (meq.l ⁻¹)	Na ⁺ (meq.l ⁻¹)	K ⁺ (meq.l ⁻¹)	SO ₄ ⁻ (meq.l ⁻¹)	HCO ₃ ⁻ (meq.l ⁻¹)	Cl ⁻ (meq.l ⁻¹)	MO (%)	Soil texture
I2 (n=5)	8.63	12.12	22.8	5	26.34	122.312	6.742	2.294	30.2	63.86	94.06	2.38	sand-silty
I6 (n=15)	7.12	4.28	11.2	0.4	29.88	45.556	0.83	0.744	29.696	22.6	13.404	13.52	silt-sandy
I1 (n=5)	7.90	1.3	71	16.2	7.12	20.914	0.948	0.54	0.5	13.6	8.638	4.06	silt-sandy
I5 (n=5)	7.47	2.46	69.93	21.53	4	24.22	0.58	0.38	0.69	16	3.14	4.99	silt-sandy
I4 (n=5)	8.17	2.58	20.73	4.4	3.68	8.89	0.89	0.25	0.35	8.53	8.99	4.82	sand-silty
T8 (n=15)	7.86	2.66	18.8	0.6	2.36	20.604	0.792	1.19	8.45	15.33	4.14	1.17	silty
T2 (n=15)	7.73	1.19	37.93	13.33	3.15	18.17	0.91	0.25	0.58	24.06	3.21	4.69	silt-sandy
T4 (n=15)	7.86	0.79	38.8	7.46	1.25	16.41	0.73	0.11	0.41	29.26	3.66	1.74	silty
T3 (n=15)	8.04	1.08	41.86	4.53	3.95	11.81	0.54	0.23	0.29	13.26	2.1	1.98	silty
T1 (n=15)	8.15	0.71	43.2	4.86	2.44	5.168	0.484	0.228	0.44	8.86	2.55	2.38	silty
T6 (n=15)	7.92	1.04	31	7.06	2.74	11.43	0.65	0.91	0.53	13.33	2.436	4.28	silt-sandy
T9(n=15)	8.16	2	47.4	8	4.16	38.05	1.64	0.44	15.39	21.3	4.21	1.91	silty
T5(n=15)	8.25	1.52	61.2	9.86	3.51	11.92	0.65	1.48	0.31	14.86	3.71	3.48	silt-sandy

Table 5. Chemical characteristics of soil for *C. spinosa*, subsp. *spinosa* and subsp. *rupestris*.

	pH	EC (dS.m ⁻¹)	Total limestone (%)	Active limestone (%)	Mg ⁺⁺ (meq.l ⁻¹)	Ca ⁺⁺ (meq.l ⁻¹)	Na ⁺ (meq.l ⁻¹)	K ⁺ (meq.l ⁻¹)	SO ₄ ⁻ (meq.l ⁻¹)	HCO ₃ ⁻ (meq.l ⁻¹)	Cl ⁻ (meq.l ⁻¹)	MO (%)
<i>Capparis spinosa</i> (n=195)	7.98	1.91	40.70	7.80	4.56	19.94	0.96	0.59	4.74	16.57	5.84	3.31
<i>C. spinosa</i> subsp. <i>spinosa</i> (n=75)	8.03	1.34	40.31	6.72	2.89	15.91	0.80	0.584	2.99	16.91	3.26	2.58
<i>C. spinosa</i> subsp. <i>rupestris</i> (n=120)	7.84	3.64	41.88	11.04	9.6	32.01	1.44	0.60	9.98	15.55	13.58	5.49

et al., 2001), the phenotypical variability differentiation between the morphotypes of the species are rare (Saadaoui et al., 2009). However, previous study reports the utility of morphologic parameter for taxonomic purposes of *Capparis* ssp. from Mediterranean regions (Eisikowitch et al., 1986; Fici, 2001; Sozzi, 2001).

In the present study, significant variations between populations for all analyzed traits were observed and a wide spectrum of morphological

variation between Tunisian wild populations of *C. spinosa* was shown. These results confirm those obtained for populations grown in collection (Saadaoui et al., 2009). The PCA partitioned the populations studied into two distinct groups, and on the basis of these groupings, subdivision were made according the morphotype of studied populations which was shown to be significantly distinct between inerm and thorny forms.

Two major groups were defined, the first one

comprised all thorny populations and the second group contains all inerm population. Moreover, the last group is subdivided into two subgroups. The first one comprised three populations (I1, I4 and I6). The second subgroup contains three populations (I3, I2 and I5). The same subdivision is obtained for other Tunisian populations by molecular analysis (Ghorbel et al., 2001).

This division confirmed the contrast already seen between populations belonging to thorny

morphotype and inerm one for certain morpho-logical descriptors. The two caper morphotypes showed some architectural and morphological differences. The inerm type is characterized by creeping shoots, but the thorny caper shows an erect shoots. The ANOVA analysis showed that the inerm group is heterogeneous essentially for the leaf parameters (LL, LW and LS), the internodes length (INL) and the number of stamens (SNF), but the thorny group is more heterogeneous for seed parameters (SL, SW and SW_{1000 g}).

This division confirms the results obtained for caper populations grown in collection (Saadaoui et al., 2009) and joins those of recent botanic revisions in Mediterranean basin, which showed the presence of *C. spinosa* subsp. *spinosa* and *C. spinosa* subsp. *rupestris* (Higton and Akeroyd, 1991; Heywood, 1993; Tutin et al., 1993; Fici and Gianguzzi, 1997). Ghorbel et al., (2001) have studied twelve Tunisian populations on the basis of RAPDs and isoenzymatic tools and subdivide the analyzed genotypes into two groups belonging to inerm and thorny morphotypes. In Tunisia, *C. spinosa* showed a high morphological variability, but subsp. *rupestris* is the more heterogeneous with large geographical distribution, it exists from the North to the South. For this reason the populations belonging to thorny morphotype could be closed to *spinosa* subspecies.

The two morphotypes were found in different bioclimatic zones; the thorny caper belonging to three bioclimatic zones (subhumid, upper semi-arid and lower semi-arid), while, the inerm caper subsist in all bioclimates, since subhumid to saharian. The inerm morphotype subdivided in two group, the first (I1, I4, I6) exist exclusively in subhumid bioclimate. However, the second (I2, I3 and I5) exist respectively in saharian, semi-arid and arid bioclimates. So, the geographical remoteness could still explain the phenotypical divergence of subsp. *rupestris*. Indeed, Fici (2001) suggested that the additional effects of climatic and geographical conditions are distinctive speciation factors of *C. spinosa* in the Mediterranean; he reported that ecotypization processes within this group were verified through adaptive autecological, phenological and morphological diversification.

Also, the phenotypical difference between subsp. *spinosa* and subsp. *rupestris*, is related to edaphic parameters. However, soil texture and chemical composition differ between the two subspecies. These results suggest different ecological requirements and physiological behavior.

The population of Houmana (I6) is considered, in this investigation, belonging to the inerm morphotype, this population seems to be localized on an intermediate position between the two morphotypes, because, the morphological parameters of this population are in the middle position between the two morphotypes. This position is explained probably by the presence of some thorny individuals in this population and the possibility of hybridizations between the two subspecies, indeed, this

phenomenon is possible for the caper (Barbera, 1991). This hybridization phenomenon is possible for the I6 population, characterized by the existence of some thorny individuals.

The two Southern populations (I2 and I3), are characterized by the presence of hair. This variable was qualified to be discriminative between the different subgenus of Capparaceae family (Cornejo and Iltis, 2008). Moreover, these two populations (I2 and I3), are characterized by stipules relatively developed, numerous stamens, and reduced internodes. This last parameter allows the plant to have a condensed shape. This shape appears an adaptation with the extreme conditions of the environment (heat, wind). These two populations (I2 and I3) seem to be a variety adapted to the extreme conditions in the Southern Tunisian. The presence of hair and high number of stamens are disadvantageous parameters for selection of good quality buds (Sozzi, 2001). This study showed a wide spectrum of morphological variation between Tunisian wild populations from two different morphotypes of *C. spinosa*. The characterization, classification and the analysis of these morphological forms have become inevitable activities for assessing their genetic diversity (Tiwarei et al., 2005). These results suggest the importance of preserving the genetic resources of caper and could be a starting point for further studies, with the aim of the clonalselection. Thus, evaluation of the biodiversity in wild *C. spinosa* morphotypes dispersed in Tunisia is a fundamental step for the implementation of a conservation strategy.

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