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Effect of Provenance on Morphological Variability within and between Natural Populations of Moroccan *Myrtus communis* L.

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ABSTRACT

Myrtle (*Myrtus communis* L.) is a typical Mediterranean shrub of significant ecological and social importance. It is grown for its ornamental value and aromatic properties, and its usage has great importance even nowadays. The objective of this work was to evaluate the intra- and inter-population genetic variability of *Myrtus communis* L. from Morocco. Twelve populations belonging to three different biogeographical zones (Western Rif, Pre-Rif and Central Plateau) were studied. Twenty-six morphological traits were measured, in different parts of the plant (leaf, fruit and seed), of which sixteen were quantitative. Analysis of variance (ANOVA) showed intra- and inter-population variations for most of the traits studied. The result showed that there is a strong positive correlation between the different morphological traits of the leaf, fruit, seed and the shrub of whole plant traits (height, canopy). These correlations could be exploited as bio-indicators for *ex-situ* planting tests for myrtle breeding programs in Morocco. Multivariate analysis (hierarchical classification) grouped the populations studied into two distinct groups. Principal component analysis (PCA) as well the correlation between morphological traits and geographic factors suggested that the variance between populations is due to the effect of provenance. The study suggested that the structure of the genetic variability of the species is linked to geographical distribution.

Key words: Genetic variability, Geographic distribution, Morphological traits, *Myrtus communis* L., Phenotypic correlation

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Introduction

Myrtle (*Myrtus communis* L.) is a typical Mediterranean shrub of significant ecological and social importance (Wahid, 2013; Melito et al., 2016). It is distributed throughout the Mediterranean basin as far as the Middle East and Asia (Prada & Arizpe, 2008; Migliore et al., 2012; Zilkah & Goldschdmidt, 2014). It is a medicinal, decorative and aromatic plant that is traditionally well-known for its diverse uses (Agrimonti et al., 2007). Myrtle has increasingly become one of the leading plants in food, pharmaceutical and cosmetic industry due to its medicinal virtues and food value (Flamini et al., 2004; Barboni et al., 2010; Wahid, 2013; Aabdousse et al., 2020). The pharmacological properties of essential oils of *Myrtus communis* have been explored and the medicinal role of bioactive molecules demonstrated (Onal et al., 2005; Gündüz et al., 2009; Serce et al., 2010; Cannas et al., 2013).

Given the importance and economic value of this species, the demand for myrtle biomass has become increasingly accentuated (Wahid, 2013). However, the harvesting of its raw material is carried out in an irrational and uncontrollable manner from natural populations. This creates a strong pressure on its resources and as a consequence, the extent of the natural populations is gradually decreasing (Messaoud et al., 2006; Wahid et al., 2018). Conservation and genetic improvement programs for this species have therefore become indispensable in order to rationalize its exploitation, and control the balance between supply and demand of its resources. The implementation of these programs is based on studies of intra- and inter-population genetic diversity. The domestication and genetic improvement of this species is dependent on knowledge of genetic variation to select individuals that perform not only well under the present environment, but are also likely to perform well under future climatic conditions.

In the Mediterranean basin, several studies have assessed the genetic diversity of *M. communis* using different morphological, allozymic and molecular markers (cases of RAPD, ISSR, SSR, AFLP and microsatellite) (Messaoud et al., 2006; 2011; Agrimonti et al., 2007; Albaladejo et al., 2008; Melito et al., 2013a; 2014; 2016; Nora et al., 2015). Most of these studies confirm genetic differentiation between populations and a high rate of intra-population homozygosity.

However, morphological traits are essential to make an initial inventory of the description of genetic variability (Wahid et al., 2016; Chatti et al., 2017). In Morocco, one study of myrtle, based on limited sampling, indicated that populations differ in morphology (Wahid et al., 2016).

The objective of the present study was to study the genetic variability between and within natural populations in Morocco, and to evaluate correlations among morphological traits and between morphological traits and environmental variables.

Materials and Methods

Plant Material

In order to cover all the biogeographically distinct areas from an ecological and climatic point of view, we carried out sampling in natural forests dominated by oak forests and sometimes by Aleppo pine reforestation stands, and in ravines characterized by soils of a clayey, clayey-silt, clayey-marl, clayey-limestone and marl nature. These sampling sites are characterized by three types of bioclimates: sub-humid, humid and per-humid, also, by different phytosociological systems. The collection of samples for this study was carried out systematically between November 2016 and January 2017 during the myrtle fruit maturation period. Twelve natural populations were selected in different biogeographical regions, in the northern Rif mountains, and central (plains) parts of Morocco (the eastern pre-Rif, the western Rif and the Central Plateau) (Fig. 1; Table 1).

For each population, between nine and nineteen trees were selected at random for leaf and fruit collection (Table 1). The difference in the number of trees collected is due to variation in the size and number of individuals in each population (Wahid et al., 2018). The collected samples (leaves and fruits) were stored in paper bags in the laboratory at –20°C until their use in various analyses. Size measurements were carried out of the same shrubs where leaves and fruits were sampled.

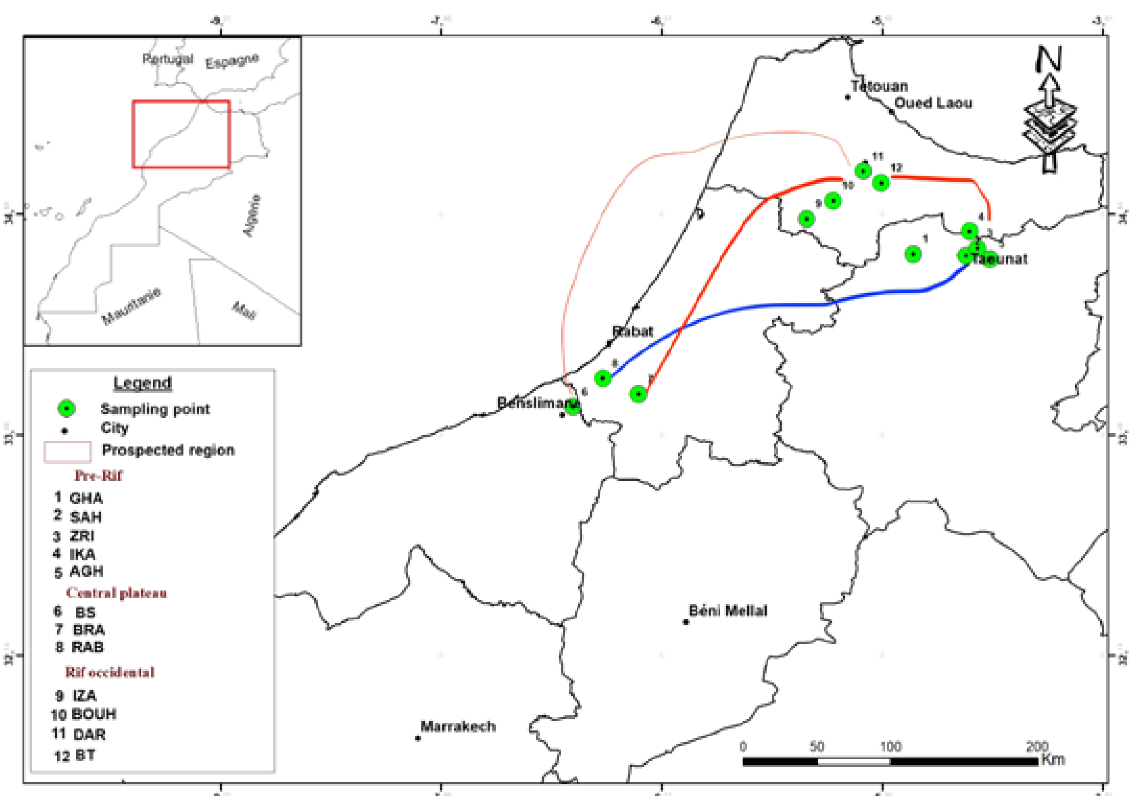

Figure 1. Sampling sites of the natural myrtle populations studied.

Table 1. Geographic and climatic characteristics of sampling sites and number of samples per population (N).

	Population	Code	N	Ecological Zones	Longitude	Latitude	Altitude (m)	Pr (mm)	T (°C)	Bioclimatic stage
1.	Ghafsai	GHA	11	Pre-Rif	34°35′ 39.8″N	04°57′ 59.5″W	441	772	18.1	Sub-humid
2.	Barrage sahla	SAH	11		34°35′ 02.1″N	04°38′ 37.7″W	460	653	17.7	Sub-humid
3.	Chettaba	ZRI	11		34°37′ 46.8″N	04°34′ 17.4″W	380	608	18	Sub-humid
4.	Douar zitouna	IKA	11		34°43′ 53.4″N	04°37′ 19.8″W	475	654	17.2	Sub-humid
5.	Aghbalou	AGH	9		34°33′ 47.6″N	04°29′ 47.1″W	439	595	17.5	Sub-humid
6.	Bâaidnat	BS	11	Central plateau	33°39′ 28.4″N	07°02′ 59.7″W	275	470	16.7	Sub-humid
7.	Kourifla	BRA	19		33°49′ 57.7″N	06°51′ 57.2″W	220	469	17	Sub-humid
8.	El Menzeh	RAB	11		33°44′ 10.8″N	06°38′ 52.9″W	332	484	17.2	Sub-humid
9.	Forêt Izaran	IZA	13	Occidental Rif / North	34°48′ 29.0″N	05°37′ 06″W	411	742	18.5	Humid
10.	Parc Bouhachem	BOUH	15		34°55′25.6″N	05°27′27.9″W	285	871	17.7	Humid
11.	Centre Ikejioun	DAR	10		35°06′11″N	05°16′23″W	450	805	16.9	Humid
12.	Aabaïd	BT	11		35°01′48″N	05°09′43″W	745	984	15.9	Humid

Morphological Study

The sampling was carried out at the middle level of the shrubs, from which we selected three to five branches at random in order to collect leaves and fruits. Twenty leaves were taken from these branches and stored in plastic bags clearly identified by their harvest cards (date, collection place and number of individuals per population) at -20°C. Twenty fruits were also collected from different levels of the plant and stored. These leaves and fruits samples are used for the measurement of different morphological traits. A total of 26 traits were measured for the shrub, leaves and fruits for each individual sampled. Sixteen quantitative traits and ten qualitative traits studied with the measurement methods and units are described in Table 2. The choice of morphological traits measured was made based on *Pistacia vera* L. descriptors published by IPGRI (1997).

Data Analysis

The data obtained were subjected to statistical analyses in order to characterize the intra- and inter-population variability existing in the natural myrtle populations studied. Descriptive statistics including the coefficient of variation (CV) and relative frequencies (F), for both quantitative and qualitative characteristics, allowed the levels of variation of the means for each characteristic to be assessed. The comparison of the means for the quantitative characteristics studied was carried out by the unidirectional analysis of variance (ANOVA). Correlations among the quantitative characteristics were estimated using Pearson's correlation coefficient (r). A principal component analysis (PCA) was conducted on the individual-tree mean for each trait. The first three principal components were used for further analyses. Spearman's non-parametric rank correlation was used to study the correlation between population means for each morphological trait and principal components, with environmental factors (climatic and geographic) such as altitude, latitude, longitude, precipitation and precipitation. A hierarchical cluster analysis was performed based on the matrix of the means of measured traits. All of these analyses were performed by the software IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., 2011).

Results

Quantitative Characteristics

Descriptive statistics for all quantitative characteristics measured are presented in Tables 3 and 4. The mean values show high levels of variation for the traits studied. The analysis of variance shows a highly significant difference among the *M. communis* populations studied for most quantitative traits ($P<0.001$).

The extent of variability differed among traits. Total seed weight per fruit (PTG/F), total number of seeds per

Table 2. Morphological and pomological features measured for myrtle populations in Morocco.

Part of the plant	Quantitative character	Code	Unit of measure	Measuring method	Qualitative character	Code	Value assigned
Plant	Height of principal branch plant	LGP	m	Metre	Plant vigor	VP	3 : Weak ; 5 : Medium ; 7 : Strong
	Width of principal branch plant	LRP	m	Metre	Plant ramification	RAM	3 : Light ; 5 : Medium ; 7 : Dense
	Diameter of branches	DIA	cm	Ribbon Meter	Apical dominance	AD	3 : Weak ; 5 : Medium ; 7 : Strong
Leaf	Leaf length	LGFe	cm	Electronic calliper	Leaf border	BFe	1 : flat; 2 : undulated.
	Leaf width	LRFe	cm	Electronic calliper	Leaf Form	FFe	1 : Wide lanceolate, 2 : Elliptical, 3 : Oval.
	Ratio between LRFe & LGFe	LRFe/ LGFe	-		Leaf color	CFe	1 : light green, 2 : green, 3 : dark green.
					Leaf base form	FBFe	1 : Attenuated, 2 : Obtuse, 3 : Truncated, 4 : Oblique
					Leaf apex form	FAFe	1 : Acuminate, 2 : Mucronate, 3 : Mucronulate.
Fruit	Weight of 20 fruits	PF	g	Precision balance	Fruit form	FF	1 : Rounded ; 2 : Ovoid; 3 : Elongated
	Fruit length	LGF	mm	Electronic calliper	Fruit color	CF	1: Green; 2: Light purple; 3: Dark purple; 4: Black
	Fruit width	LRF	mm	Electronic calliper			
	Ratio between LGF & LRF	LGF/ LRF	-				
	Seed length	LGG	mm	Electronic calliper			
	Seed width	LRG	mm	Electronic calliper			
	Ratio between LGG & LRG	LGG/ LRG	-				
	Average seed weight	PG	mg	Precision balance			
	Number of seeds/fruit	NTG/F	-	Counting			
	Total weight of seeds/ fruit	PTG/F	mg	Precision balance			

fruit (NTG/F), 20-fruit weight (PF), height of principal branch plant (LGP), mean seed weight and plant branches showed high variation (CV>41%). On the other hand, the ratio of seed length to seed width [R(LGG/LRG)], seed length (LGG), fruit length (LGF), fruit width (LRF), R(LGF/LRF) and twig diameter (DIA) showed relatively low variation in comparison with the other traits (CV<20%).

Total seed weight per fruit (PTG/F) ranged from 34.83 ± 21.68 mg for the BT population to 76.15 ± 50.10 mg for the RAB population, with an overall mean of 52.44 ± 34.49 mg. The total number of seeds per fruit (NTG/F) varies from 4.24± 1.92 for the BRA population to 9.41 ± 4.34 for the SAH population, with a CV of 64.05%. However, the weight of 20 fruits (PF) varies from 3.60 ± 0.89 g for the BT population to 8.38 ± 2.63 g for the BRA population, with an overall average of 5.42 ± 3.11 g. The characteristics of the shrub vary: plant length (LGP) from 2 m for the ZRI population to 6.36 ± 0.67 m for the IKA population with an average of 2.69 ± 1.54 m (CV=57.18%), for plant width (PLW) from 1.84 ± 1.07 m for the BRA population to 4.18 ± 0.40 m for the IKA population (CV=41.0%) and for twig diameter (DIA) from 2.06 ± 0.13 cm for the BS population to 2.89 ± 0.33 cm for the AGH population, with a mean of 2.70 ± 0.49 cm (CV=18.15%). Leaf length (LGFe) varies from 3.67 ± 0.64 cm and 3.67 ± 0.85 cm for the AGH and

Table 3. Quantitative characteristics measured for the plant and leaves.

Trait Pop	LGP	LRP	DIA	LGFe	LRFe	LRFe/LGFe
Pre-Rif	3,36±1,89 1,00-8,00 (56,34)	2,96±0,98 2,00-5,00 (33,08)	2,85±0,30 1,97-3,20 (10,39)	3,73±0,69 2,00-8,00 18,41)	1,28±0,46 1,00-4,00 36,03)	0,36±0,07 0,16-1,20 (19,95)
1. GHA	2.27±0.47 2.00-3.00 (20.55)	2.09±0.30 2.00-3.00 (14.42)	2.85±0.29 2.10-3.20 (10.06)	3.69±0.61 2.00-5.00 (16.48)	1.30±0.48 1.00-3.00 (36.83)	0.38±0.06 0.26-0.61 (15.35)
2. SAH	1.82±0.40 1.00-2.00 (22.25)	2.27±0.47 2.00-3.00 (20.55)	2.97±0.17 2.67-3.20 (5.71)	3.67±0.85 2.00-8.00 (23.21)	1.22±0.42 1.00-2.00 (34.11)	0.34±0.07 0.16-0.75 (20.37)
3. ZRI	2.00±0.00 2.00-2.00 (0.00)	2.64±0.50 2.00-3.00 (19.14)	2.54±0.33 1.97-3.20 (12.91)	3.81±0.55 2.00-5.00 (14.32)	1.20±0.40 1.00-2.00 (33.56)	0.36±0.05 0.27-0.58 (13.34)
4. IKA	6.36±0.67 6.00-8.00 (10.60)	4.18±0.40 4.00-5.00 (9.69)	2.88±0.21 3.00-3.00 (0.00)	3.82±0.73 2.00-6.00 (19.06)	1.39±0.51 1.00-4.00 (37.05)	0.52±2.12 0.25-1.20 (22.80)
5. AGH	4.56±0.88 4.00-6.00 (19.34)	3.78±0.83 2.00-5.00 (22.04)	2.89±0.33 2.00-3.00 (11.52)	3.67±0.64 2.00-5.00 (17.52)	1.27±0.45 1.00-3.00 (35.83)	0.86±4.81 1.00-3.00 (24.08)
Central Plateau	2,59±1,14 1,00-4,00 (44,08)	2,27±1,03 1,00-4,00 (45,20)	2,50±0,49 1,93-3,00 (19,75)	4,35±0,77 1,42-9,20 (17,68	1,50±0,48 0,92-5,90 (31,86)	0,35±0,12 0,14-1,48 (34,54)
6. BS	2.64±0.67 2.00-4.00 (25.57)	2.00±0.00 2.00-2.00 (0.00)	2.06±0.13 1.93-2.23 (6.22)	4.53±0.92 2.00-9.20 (20.34)	1.54±0.53 1.00-5.90 (34.57)	0.35±0.14 0.14-1.48 (39.57)
7. BRA	2.05±1.27 1.00-4.00 (61.78)	1.84±1.07 1.00-4.00 (57.97)	2.59±0.37 1.90-3.07 (14.25)	4.31±0.58 3.10-8.50 (13.50)	1.50±0.48 0.92-5.90 (31.75)	0.35±0.12 0.15-1.48 (34.06)
8. RAB	3.45±0.69 2.00-4.00 (19.94)	3.27±0.79 2.00-4.00 (24.04)	2.64±0.50 2.00-3.00 (19.13)	4.26±0.86 1.42-6.77 (20.17)	1.45±0.41 1.00-2.00 (28.43)	0.35±0.11 0.17-1.39 (29.90)
Western Rif	2,04±1,04 1,00-6,00 (50,96)	2,29±0,98 1,00-5,00 (42,83)	2,69±0,46 1,60-3,77 (17,08)	4,58±0,84 1,00-15,00 (18,36)	1,49±0,38 0,80-5,00 (25,54)	0,33±0,11 0,12-1,40 (32,15)
9. IZA	1.62±0.65 1.00-3.00 (40.27)	2.08±0.86 1.00-4.00 (41.52)	2.82±0.37 2.33-3.77 (13.30)	4.59±1.08 1.00-15.00 (23.46)	1.53±0.52 0.80-5.00 (33.93)	0.34±0.14 0.12-1.40 (39.89)
10 BOUH	2.06±0.13 1.93-2.23 (6.22)	2.53±1.36 1.00-6.00 (53.52)	2.47±1.19 1.00-5.00 (48.13)	4.57±0.67 3.00-6.90 (14.59)	1.48±0.35 0.80-4.20 (23.47)	0.33±0.09 0.16-0.78 (26.12)
11. DAR	1.60±0.84 1.00-3.00 (52.70)	2.30±0.95 1.00-4.00 (41.25)	2.19±0.34 1.60-2.63 (15.46)	4.55±0.73 1.42-6.36 (16.10)	1.49±0.32 0.91-2.45 (21.33)	0.34±0.12 0.17-1.39 (34.38)
12. BT	2.27±0.79 1.00-4.00 (34.59)	2.27±0.90 1.00-4.00 (39.80)	2.74±0.50 2.07-3.75 (18.18)	4.60±0.83 1.94-7.63 (18.06)	1.47±0.27 0.91-1.98 (18.27)	0.33±0.08 0.16-0.74 (25.84)
Mean	2.69±1.54 1.00-8.00 (57.18)	2.53±1.04 1.00-5.00 (41.09)	2.70±0.49 2.00-4.00 (18.15)	4.20±0.85 1.00-15.00 (20.23)	1.48±3.52 0.80-5.90 (31.99)	0.37±0.86 0.12-1.48 (28.99)
F-value	29.543***	9.746***	6.863***	62.934***	1.201	1.440

Mean ± standard deviation; minimum-maximum; coefficient of variation (CV%) and F-values (***p<0.001).

Table 4. Quantitative characteristics measured for fruit and seeds.

Trait Pop	LGF	LRF	PF	R (LGF/ LRF)	NTG/F	PTG/F	PG	LRG	LGG	R (LGG/ LRG)
Pre-Rif	9.93±1.91 3.15-21.91 (19.19)	7.24±1.36 3.85-13.67 (18.72)	5.80±4.36 1.20-30.55 (75.22)	1.38±0.22 0.31-3.68 (16.00)	6.41±4.18 1.00-32.00 (65.21)	66.02±33.24 0.20-232.50 (50.36)	12.91±5.65 3.62-43.30 (43.79)	3.04±1.83 1.79-45.49 (60.10)	3.78±0.55 2.50-14.10 (14.53)	1.29±0.15 0.89-4.41 (11.74)
1. GHA	10.52±1.66 4.17-13.81 (15.74)	7.64±1.20 4.74-10.67 (15.72)	5.75±1.83 2.37-8.31 (31.87)	1.39±0.15 0.46-1.78 (11.04)	7.99±4.15 2.00-24.00 (51.98)	66.52±31.14 14.50-182.00 (46.82)	9.43±3.22 3.62-20.43 (34.13)	2.73±0.33 1.79-3.93 (12.13)	3.46±0.37 2.50-4.60 (10.81)	1.28±0.09 0.89-1.53 (6.96)
2. SAH	10.87±1.79 3.15-14.74 (16.45)	7.91±1.20 5.71-13.67 (15.22)	5.86±1.46 3.34-7.56 (24.96)	1.39±0.19 0.31-1.83 (13.89)	9.41±4.34 2.00-32.00 (46.17)	76.09±29.84 6.60-232.50 (39.22)	9.63±3.25 3.94-19.60 (33.72)	3.21±3.94 2.06-45.49 (122.95)	3.69±0.49 2.73-4.87 (13.37)	1.31±0.08 1.06-1.57 (6.46)
3. ZRI	10.71±1.64 3.33-21.91 (15.28)	7.73±1.22 5.11-12.56 (15.73)	6.15±2.29 3.78-13.00 (37.20)	1.37±0.28 0.47-3.11 (20.49)	4.35±3.68 1.00-22.00 (84.69)	55.15±29.50 13.50-213.70 (53.49)	16.81±7.57 6.78-43.30 (45.01)	3.08±0.44 2.17-4.32 (14.33)	3.84±0.49 2.90-5.50 (12.80)	1.26±0.11 1.00-1.85 (9.12)
4. IKA	8.57±1.60 5.35-19.12 (18.62)	6.13±1.06 3.85-9.09 (17.23)	7.08±8.67 1.20-30.55 (122.35)	1.41±0.26 0.89-3.68 (18.05)	4.63±2.63 1.00-14.00 (56.77)	64.83±40.71 0.20-223.00 (62.80)	15.01±4.32 7.44-27.60 (28.77)	3.08±0.29 2.40-3.81 (9.35)	3.99±0.76 3.29-14.10 (18.94)	1.32±0.27 1.06-4.41 (20.16)
5. AGH	8.78±1.41 3.51-12.46 (16.00)	6.69±1.14 4.10-10.36 (17.03)	3.76±1.01 2.55-6.08 (26.85)	1.33±0.18 0.56-2.00 (13.73)	5.48±3.14 1.00-28.00 (57.25)	67.83±29.90 1.92-199.30 (44.09)	13.86±4.20 7.28-28.77 (30.28)	3.12±0.31 2.51-3.99 (9.98)	3.97±0.31 3.25-5.71 (7.83)	1.29±0.11 1.01-1.60 (8.58)
Central Plateau	10.89±1.61 3.72-19.77 (14.77)	8.01±1.38 2.25-13.50 (17.26)	5.96±2.45 2.52-11.42 (41.01)	1.38±0.24 0.65-4.23 (17.05)	4.90±3.04 1.00-19.00 (61.93)	50.07±37.17 3.00-401.00 (74.24)	13.17±5.38 1.65-39.50 (40.87)	3.07±0.36 2.05-4.42 (11.60)	3.90±0.42 2.39-6.12 (10.74)	1.28±0.10 0.96-1.96 (8.16)
6. BS	10.98±1.40 7.24-14.07 (12.72)	7.82±1.09 2.25-10.04 (13.99)	4.36±1.32 2.52-6.94 (30.31)	1.43±0.29 1.06-4.23 (20.28)	4.90±2.74 1.00-19.00 (55.88)	40.92±27.54 8.47-128.00 (67.29)	12.99±5.68 1.65-34.20 (43.76)	3.22±0.42 2.05-4.42 (13.19)	4.13±0.46 2.39-6.06 (11.11)	1.29±0.10 0.96-1.69 (7.37)
7. BRA	10.63±1.65 7.24-19.77 (15.55)	7.66±1.24 3.21-11.03 (16.15)	5.49±1.68 3.86-10.10 (30.59)	1.41±0.22 0.87-3.64 (15.96)	4.24±1.92 1.00-14.00 (45.32)	40.27±23.62 9.80-150.00 (58.64)	12.32±5.32 1.74-38.00 (43.23)	2.99±0.28 2.26-4.12 (9.48)	3.78±0.33 2.89-4.67 (8.76)	1.28±0.10 1.07-1.71 (7.64)
8. RAB	11.24±1.66 3.72-15.09 (14.75)	8.80±1.55 5.30-13.50 (17.63)	8.38±2.63 3.91-11.42 (31.40)	2.00±10.61 0.65-1.95 (12.18)	6.05±4.30 1.00-19.00 (71.09)	76.15±50.10 3.00-401.00 (65.80)	14.83±4.79 7.22-39.50 (32.32)	3.05±0.35 2.15-4.12 (11.36)	3.88±0.42 2.90-6.12 (10.91)	1.28±0.12 0.99-1.96 (9.61)
Western Rif	10.83±1.44 1.37-14.07 (13.33)	7.86±1.10 2.25-11.01 (14.00)	4.55±1.23 2.36-6.94 (27.04)	1.40±0.24 0.17-4.23 (17.22)	4.65±2.47 1.00-19.00 (53.24)	39.73±27.49 8.47-154.10 (69.20)	13.37±6.12 1.65-37.00 (45.79)	3.24±0.46 2.05-4.55 (14.31)	4.13±0.52 2.39-6.12 (12.68)	1.29±0.10 0.96-2.10 (7.78)
9. IZA	11.23±1.34 5.58-14.07 (11.92)	8.26±1.01 2.25-11.01 (12.27)	5.29±0.92 3.99-6.94 (17.38)	1.38±0.28 0.88-4.23 (20.23)	4.46±2.58 1.00-19.00 (57.74)	43.11±31.27 9.05-154.10 (72.55)	16.28±6.44 5.96-37.00 (39.57)	3.47±0.43 2.51-4.55 (12.34)	4.38±0.49 3.39-6.12 (11.10)	1.27±0.11 0.96-1.71 (8.43)

Trait Pop	LGF	LRF	PF	R (LGF/ LRF)	NTG/F	PTG/F	PG	LRG	LGG	R (LGG/ LRG)
10. BOUH	10.77± 1.52 1.37-14.07 (14.16)	1.65± 1.09 2.25-10.4 (14.25)	4.18 ± 1.29 2.36-6.94 (30.86)	1.43 ± 0.26 0.17-4.23 (18.49)	4.78 ± 2.52 1.00-19.00 (52.73)	38.37 ±25.47 8.47-128.00 (25.47)	12.00 ±5.40 1.65-34.20 (44.98)	3.13 ±0.43 2.05-4.42 (13.63)	4.01 ±0.48 2.39-6.06 (11.95)	1.29 ± 0.09 0.96-1.69 (6.94)
11. DAR	10.91±1.31 5.58-13.92 (11.98)	8.17±1.04 4.40-11.01 (12.67)	5.19±0.81 3.99-6.23 (15.55)	1.35±0.19 0.88-2.80 (13.95)	4.53±2.37 1.00-12.00 (52.28)	42.76±30.00 9.05-154.10 (70.16)	15.37±6.28 5.96-37.00 (40.88)	3.40±0.46 2.33-4.55 (13.55)	4.30±0.53 3.14-6.12 (12.32)	1.28±0.12 0.97-2.10 (9.26)
12. BT	10.38±1.44 1.37-13.08 (13.86)	7.40±1.03 4.34-9.43 (13.87)	3.60±0.89 2.36-4.93 (24.65)	1.42±0.19 0.17-2.69 (13.22)	4.79±2.38 1.00-15.00 (49.59)	34.83±21.68 8.47-113.40 (62.24)	9.96±3.84 1.65-21.45 (38.55)	2.99±0.37 2.05-4.13 (12.43)	3.86±0.44 2.39-4.82 (11.29)	1.30±0.08 1.09-1.52 (6.33)
Mean	10.52±1.73 1.37-21.91 (16.48)	7.67±1.33 2.25-13.67 (17.27)	5.42±3.11 1.20-30.55 (57.41)	1.39±0.23 0.17-4.23 (16.74)	5.37±3.44 1.00-32.00 (64.05)	52.44±34.49 0.20-401.00 (65.77)	13.14±5.74 1.65-43.30 (43.72)	3.12±1.16 1.79-45.49 (37.34)	3.94±0.53 2.39-14.10 (13.40)	1.29±0.12 0.89-4.41 (9.54)
F-value	67.055***	77.115***	52.655***	7.542***	63.035***	58.053***	55.355***	6.689***	66.481***	4.589***

Mean ± standard deviation; minimum-maximum; coefficient of variation (CV%) and F-values (***p<0.001).

SAH populations respectively, and up to 4.60 ± 0.83 cm for the BT population with a mean of 4.20 ± 0.85 cm. The leaf length width (LRFe) ranges from 1.20 ± 0.40 cm for the ZRI population to 1.54 ± 0.53 cm for the BS population with a mean of 1.48 ± 3.52 cm and a CV of 31.99%.

Qualitative Characteristics

The comparison of qualitative characteristics for the natural populations of *Myrtus communis* studied are presented in Table 5. These results show that the leaf border (BFe) of most of the populations are characterized by individuals with flat leaf border, with the exception of the IKA population which has 9.1% of individuals with wavy leaves. For the leaf form (FFe), it can be observed that most populations record high values for the oval form (>80%), but lower in the AGH population (65%) and higher in the BOUH population (100%). The shape of the base of the leaf (FBFe) is mostly attenuated (60.57%), obtuse in fewer (27.50%), while the oblique form is infrequent (0.05%). The GHA, SAH, ZRI and IKA populations are characterized by individuals with attenuated leaf base form (100%), while the obtuse form is present in the IZA population (76.9%). The leaf apex (FAFe) is mostly acuminate (58.01%), but both mucronate and mucronulate forms were observed with percentages of 22.47% and 19.53% respectively. The GHA, SAH and ZRI populations are characterized by shrubs with acuminate leaf apex form (100%), whereas the mucronulate form is present in the BOUH population (66.7%) and the mucronulate form characterizes individuals in the IZA population (84.6%).

Plant vigor (VP) is dominated by the strong form (67.89%), while medium vigor presents 31.28% and low vigor is almost absent (0.83%). The RAB population is characterized by individuals with high plant vigor (100%), while average vigor has been observed in most populations with percentages ranging from 15.8% (BRA population) to 46.7% in the BOUH population. While branching (RAM) is mostly dense (56.38%), medium branching was also observed frequently (42.98%), while the sparse form is almost absent (0.64%). The BRA and GHA populations are characterized by densely branched individuals with percentages of 84.2% and 81.8% respectively. The GHA and BS populations are characterized by medium-branched shrubs with percentages of 77.8% and 72.7% respectively. In addition, apical dominance (AD) is rather strong (72.62%), but the average form of AD was also observed (26.09%).

Table 5. Frequencies of qualitative traits categorized into 3-7 classes.

Trait	Level	BOUH	BRA	BT	DAR	IZA	GHA	SAH	ZRI	IKA	AGH	RAB	BS	Mean
VP	3	0.0	0.0	0	10	0	0	0	0	0	0	0	0	0.83
	5	46.7	15.8	36.4	50	38.5	27.3	27.3	36.4	18.2	33.3	0	45.5	31.28
	7	53.3	84.2	63.6	40	61.5	72.7	72.7	63.6	81.8	66.7	100	54.5	67.89
RAM	3	0	0	0	0	7.7	0	0	0	0	0	0	0	0.64
	5	40.0	15.8	54.5	50	23.1	18.2	27.3	27.3	63.6	77.8	45.5	72.7	42.98
	7	60.0	84.2	45.5	50	69.2	81.8	72.7	72.7	36.4	22.2	54.5	27.3	56.38
DA	3	0	0	0	0	15.4	0	0	0	0	0	0	0	1.28
	5	46.7	21.1	54.5	30	15.4	9.1	27.3	18.2	27.3	0	0	63.6	26.09
	7	53.3	78.9	45.5	70	69.2	90.9	72.7	81.8	72.7	100	100	36.4	72.62
BFe	**1**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**90.9**	**100**	**100**	**100**	**99.24**
	2	0	0	0	0	0	0	0	0	9.1	0	0	0	0.76
FFe	1	0	14.2	9.1	10	7.7	0	0.5	0	9.1	1.1	0.5	14.1	5.53
	2	0	0	9.1	0	0	18.2	0	81.8	10.5	33.9	18.2	0	14.31
	3	100	85.8	81.8	90	92.3	81.8	99.5	18.2	80.5	65	81.4	85.9	80.18
CFe	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	100	100	100	100	100	100	100	100	100	100	100	100	100
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
FBFe	1	46.7	42.9	36.1	20	0	100	100	100	100	99.4	59.1	22.7	60.57
	2	33.3	41.3	54.8	60	76.9	0	0	0	0	0	22.7	40.9	27.50
	3	20.0	15.8	9.1	20	23.1	0	0	0	0	0	18.2	36.4	11.88
	4	0.0	0.0	0	0	0	0	0	0	0	0.6	0	0	0.05
FAFe	1	20.0	67.6	18.2	20	0	100	100	100	96.8	88.9	69.1	15.5	58.01
	2	66.7	32.4	45.5	40	15.4	0	0	0	0	11.1	15	43.6	22.47
	3	13.3	0.0	36.4	40	84.6	0	0	0	3.2	0	15.9	40.9	19.53
CF	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	18.2	0	0	68.2	88.9	0	0	14.61
	3	0	5.3	0	0	0	72.7	0	0	27.3	11.1	0	0	9.70
	4	**100**	**94.7**	**100**	**100**	**100**	**9.1**	**27.3**	**100**	**4.5**	0	81.8	100	68.12
FF	1	99.3	57.4	100	94	94.6	85	56.4	95.9	56.8	41.7	19.1	99.1	74.94
	2	0.7	21.6	0	6	5.4	15	43.6	4.1	43.2	58.3	71.8	0.9	22.55
	3	0	21.1	0	0	0	0	0	0	0	0	9.1	0	2.51

The GHA and RAB populations are characterized by individuals with strong apical dominance (100%), while other populations (BS, BT and BOUH) have shrubs with medium AD with percentages of 63.6%, 54.5% and 46.7% respectively.

Fruit color (FC) is mostly black (68.12%), but dark purple and violet fruits were encountered with percentages of 9.70% and 14.61% respectively. The BOUH, BT, DAR, IZA, ZRI and BS populations are characterized by individuals with black fruit (100%), dark purple is present in the GHA population (72.7%) and purple is found in individuals from the AGH and IKA populations with percentages of 88.9% and 68.2% respectively. In addition, the fruit shape (FF) is mostly rounded (74.94%), but ovoid and elongated forms were observed in 22.55% and 2.51% of all individuals respectively. The BT population has shrubs with only the rounded fruit shape (100%), while the

RAB population has the ovoid form in 71.8% of the individuals.

Phenotypic Correlations Among Morphological Traits

The phenotypic correlations among the quantitative morphological traits measured for natural populations of *M. communis* from Morocco are presented in Table 6. These results show several correlations between the morphological traits, however, not all were significant. Following are the significant correlations. A positive correlation was noted between fruit width (LRF) and fruit length (LGF) with a correlation coefficient of r= 0.94. Total seed weight per fruit (PTG/F) was significant and positively correlated with the weight of 20 fruits (PF, r= 0.62) and with the total number of seeds per fruit (NTG/F, r = 0.68), and is negatively correlated with the ratio between fruit length and width [R(LGF/LRF), r =-0.59]. Mean seed weight (PG) is negatively correlated with the total number of seeds per fruit (NTG/F, r= -0.63). A positive correlation was noted between seed length (LGG) and mean seed weight (PG, r = 0.66) and seed width (LRG, r = 0.88). Seed length (LGG) is negatively correlated with the total number of seeds per fruit (NTG/F, r= 0.63). Leaf length (LGFe) is negatively correlated with total seed weight per fruit (PTG/F, r= 0.80) and positively correlated with seed length (LGG, r= 0.63). The ratio between leaf width and leaf length (LRFe/LGFe) is negatively correlated with fruit length (LGF, r = -0.69) and positively correlated with leaf width (LRFe, r = 0.91). Height of the principal branch of the plant (LGP; see Table 2) is negatively correlated with fruit length (LGF, r = –0.85) and width (LRF, r = –0.73). However, width of principal branch plant (LRP) is negatively correlated with fruit length and width (r = –0.78 and r = –0.62 respectively), while it is positively correlated with the ratio of leaf width to length (LRFe/LGFe) and with shrub length (r = 0.57 and r = 0.90 respectively).

Morphological Variability

The phenotypic variability between populations for almost all traits measured (except for a few traits related to fruit and seeds) was highly significant as shown in the one-way ANOVA tests (Tables 3, 4). The principal component analysis (PCA)

Table 6. Correlation between measured quantitative traits for shrub, leaf, fruit and seeds (Pearson's r).

	LGF	LRF	P F	R (LGF/ LRF)	NTG/F	PTG/F	PG	LRG	LGG	R (LGG/ LRG)	LGFe	LRFe	LRFe/ LGFe	LGP	LRP	DIA
LGF	1															
LRF	0.940**	1														
P F	0.101	0.256	1													
R (LGF/ LRF)	-0.038	-0.367	-0.447	1												
NTG/F	0.105	0.145	0.202	-0.165	1											
PTG/F	-0.283	-0.071	0.617*	-0.587*	0.689*	1										
PG	-0.043	0.084	0.335	-0.380	-0.633*	-0.044	1									
LRG	0.251	0.281	-0.129	-0.087	-0.299	-0.274	0.552	1								
LGG	0.100	0.131	-0.204	-0.020	-0.631*	-0.480	0.660*	0.883**	1							
R(LGG/LRG)	-0.450	-0.494	-0.053	0.352	0.384	0.242	-0.527	-0.135	-0.176	1						
LGFe	0.525	0.440	-0.319	0.257	-0.563	-0.809**	0.119	0.451	0.633*	-0.155	1					
LRFe	-0.564	-0.400	-0.435	-0.355	-0.215	0.078	0.157	0.041	0.200	-0.041	-0.155	1				
LRFe/LGFe	-0.696*	-0.523	-0.247	-0.406	0.054	0.399	0.079	-0.149	-0.091	0.032	-0.544	0.913**	1			
LGP	-0.852**	-0.734**	0.243	-0.081	-0.137	0.402	0.197	-0.215	-0.005	0.514	-0.390	0.422	0.515	1		
LRP	-0.789**	-0.625*	0.279	-0.293	-0.034	0.554	0.307	-0.068	0.018	0.428	-0.510	0.433	0.576*	0.908**	1	
DIA	-0.411	-0.356	0.149	-0.089	0.458	.518	-0.295	-0.313	-0.439	0.349	-0.544	0.087	0.306	0.295	0.305	1

*, significant at p<0.05; **, significant at p<0.01.

shows that 74.33 % of the total variation between the natural populations of myrtle in Morocco was explained by the first three components (Fig. 2, Table 7). The first component (PC 1), which explains 35.27 % of the total variation, had high factor loads of variables related to the total weight of seeds per fruit (PTG/F), the ratio between leaf width and leaf length (LRFe/LGFe), height of principal branch plant (LGP), width of principal branch plant (LRP) and twig diameter (DIA) (Table 8). The second component (PC 2), which explains 22.41% of the total variation, was correlated with variables associated with the seed -- average seed weight (PG), seed length (LGG), seed width (LRG) -- and leaf width (LRFe). The third component (PC 3) which explains 16.64 % of total variation was correlated with fruit and seed traits -- width of fruit (LRF), weight of 20 fruits (PF), Total weight of seeds/fruit (PTG/F) and Average seed weight (PG). These results show the sources of phenotypic variability within and among populations.

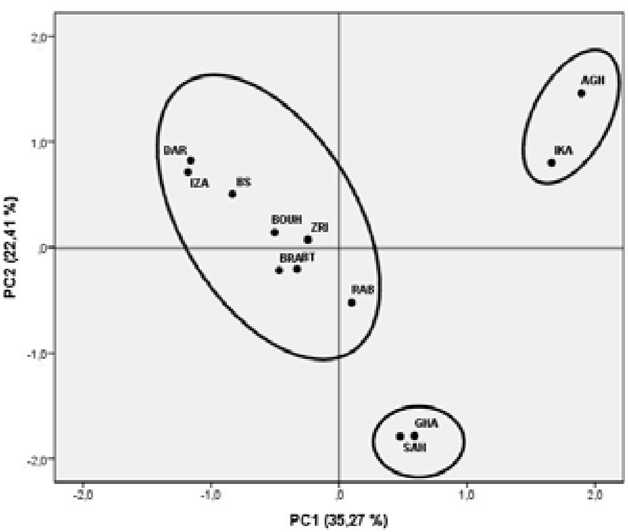

Figure 2. Principal components analysis of morphological traits measured for 12 natural myrtle populations in Morocco.

Table 7. Total variance of the measured morphological trait explained by the principal components.

Component	Extraction Totals of squares of selected factors		
	Total	% of variance	% cumulated
PC 1	5.644	35.272	35.272
PC 2	3.586	22.411	57.682
PC 3	2.664	16.649	74.332
PC 4	1.655	10.345	84.676
PC 5	1.109	6.929	91.605

The analysis of the averages of the measured morphological characteristics leads to a hierarchical classification by the method of aggregation of the studied populations (Fig. 3), resulting in the identification of two main groups (A/B) (Fig. 3). The first subgroup (A) consists of six accessions, four from Rif (DAR, IZA, BT, BOUH) and two from Central Plateau (BRA and BS) with a slight differentiation of the BT population. These accessions are characterized by a similarity in the values of most morphological traits, especially by low values of twig diameter (DIA), which is significantly correlated with altitude. The ZRI population (from pre-Rif) is the least similar to the rest of the populations in this group.

The second group (B) consists of five populations, four populations from pre-Rif (SAH, IKA, AGH and GHA) and one population from central plateau (RAB). These accessions are distinguished from the other populations by identical and high values of total seed weight per fruit (PTG/F) and lower values of leaf length (LGFe) (Fig. 2, Table 7)). Considering the fruit characteristics (length and width), it seems that they do not influence the variability and clustering of the studied populations.

Differences among the western Rif populations are due to the traits PTG/F and LGP, which are highly correlated with PC1 (0.71 and 0.79 respectively) (Fig. 2, Table 7), with the PG, LRG and LGG traits significantly correlated with PC2, and the LRF and PF traits positively correlated with PC3. Variability among pre-Rif populations (Fig. 2) is due to the values of traits related to fruit (LGF, LRF and PF), grain (NTG/F, PTG/F and PG), and shrub size (LGP and LRP). Also, the central plateau populations are different due to fruit (LGF, LRF and PF), seed (NTG/F, PTG/F, PG, LRG, LGG) and shrub traits (LGP, LRP and DIA) (Fig. 2, Table 7).

The correlations of morphological features and PC1-PC3, with altitude, latitude, longitude, temperature and precipitation are shown in Table 9. Fruit traits (LGF and LRF) and leaf length (LGFe) are negatively correlated with longitude (-0.70, -0.58 and -0.601, respectively), i.e., the biggest fruit and widest leaves characterize populations located in the western most populations (Central Plateau) of the natural myrtle distribution in Morocco. Twig diameter (DIA) was positively correlated with altitude (0.59). Positive correlation between weight of 20 fruit (PF) and Tmax was observed (0.63), which may explain the presence

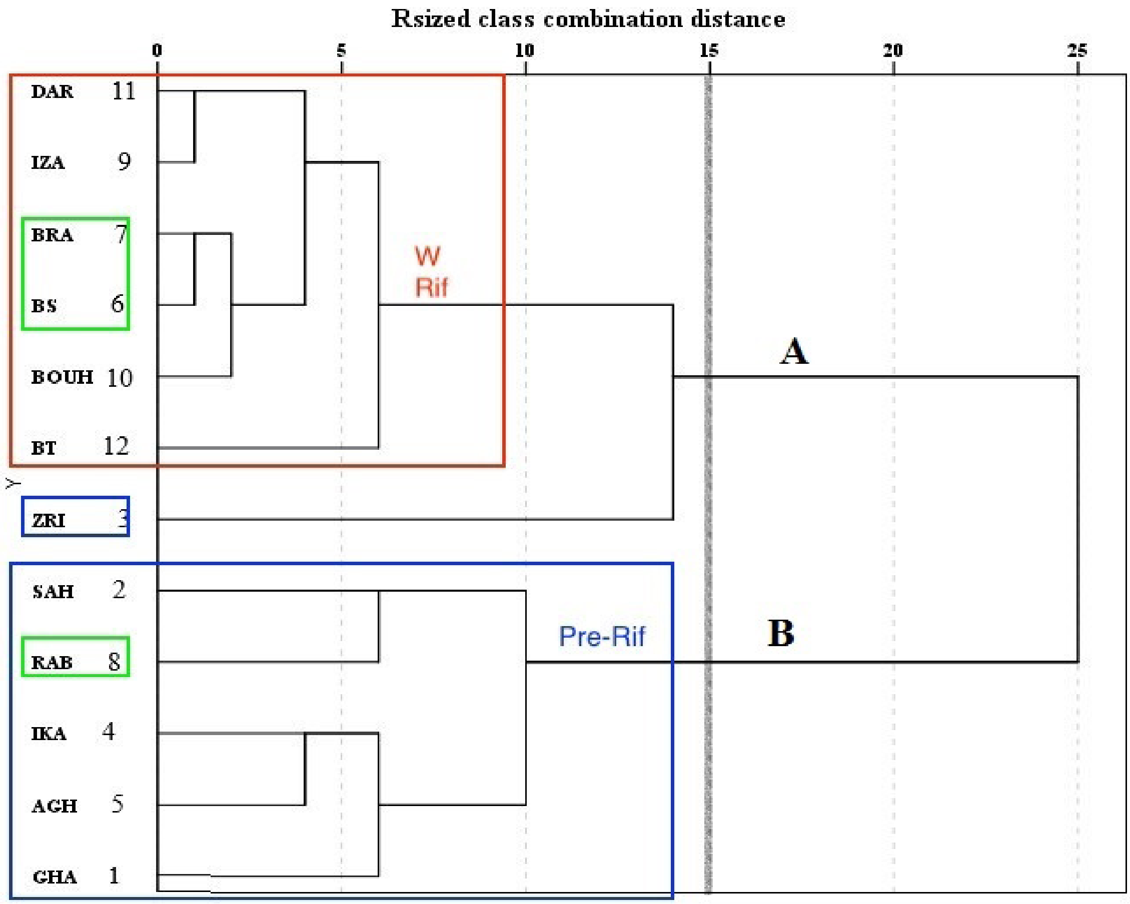

Figure 3. Hierarchical classification of natural myrtle populations using Euclidean distance based on measured quantitative traits.

Table 8. Loadings of Morphological traits on the first three PCs (The highest one (>0.5 threshold) are in bold.

	PC1	PC2	PC3
LGF	-0.846	-0.415	0.259
LRF	-0.717	-0.347	**0.520**
P F	0.173	-0.301	**0.709**
R (LGF/ LRF)	-0.214	-0.067	-0.856
NTG/F	0.349	-0.790	0.107
PTG/F	**0.709**	-0.371	**0.559**
PG	-0.151	**0.688**	**0.604**
LRG	-0.461	**0.526**	0.238
LGG	-0.455	**0.782**	0.114
R(LGG/LRG)	0.490	-0.157	-0.489
LGFe	-0.807	0.306	-0.227
LRFe	0.454	**0.615**	-0.009
LRFe/LGFe	**0.718**	0.394	0.080
LGP	**0.788**	0.406	-0.029
LRP	**0.802**	0.399	0.187
DIA	**0.627**	-0.316	-0.029

of relatively heavy fruit in the pre-Rif and Central Plateau populations distinguished by high Tmax values. Leaf width is positively correlated with Tmin (0.66) and negatively with Tmax (-0.85). Several traits are not correlated to geographical parameters, but they are correlated to climatic conditions, but this correlation is not statistically significant, this is the case of the maximum temperature of the warmest month (Tmax) with LGF, LRF and NTG/F traits (0.21, 0.30, 0.24 respectively) and the mean annual rainfall (Pr) with LGFe and LGG (0.45 and 0.17 respectively). PC1 (significantly correlated with PTG/F, LRP and DIA) was marginally correlated with longitude, which was also positively correlated with those traits (0.43, 0.46 and 0.57 respectively).

Discussion

The results showed a high level of variation between natural populations of Moroccan *Myrtus communis* in morphological characters. The analysis of variance (ANOVA) and comparison of the means of the studied traits by calculating coefficients of variation (CV),

Table 9. Spearman non-parametric coefficient of correlation between morphological traits and principal components and environmental features.

	Longitude	Latitude	Altitude (m)	Pr (mm)	T (°C)	Tmin	Tmax
LGF	**-0.699***	-0.105	-0.441	-0.182	0.039	0.195	0.214
LRF	**-0.580***	-0.070	-0.336	-0.210	0.039	0.105	0.305
P F	0.049	-0.266	-0.021	-0.364	0.086	-0.075	**0.632***
R (LGF/ LRF)	-0.266	0.028	-0.084	0.203	-0.253	-0.105	-0.189
NTG/F	0.105	-0.266	0.294	0.042	0.160	0.240	0.239
PTG/F	0.343	-0.364	0.182	-0.350	0.385	0.255	0.460
PG	0.049	0.182	-0.126	-0.182	-0.004	-0.060	-0.070
LRG	-0.133	0.287	-0.042	0.091	0.253	0.090	-0.042
LGG	-0.336	0.343	-0.119	0.168	-0.136	0.180	-0.379
R(LGG/LRG)	0.154	-0.028	0.434	0.147	-0.253	0.075	-0.091
LGFe	**-0.601***	0.497	-0.091	0.448	-0.471	-0.270	-0.225
LRFe	-0.392	-0.231	-0.448	-0.280	-0.202	**0.661***	**-0.846****
LRFe/LGFe	0.469	-0.566	-0.091	-0.510	0.257	0.375	-0.049
LGP	0.077	-0.385	-0.056	-0.252	-0.226	0.436	-0.393
LRP	0.462	-0.049	0.161	-0.140	0.101	0.120	-0.049
DIA	0.573	0.112	**0.594***	0.231	0.373	-0.120	0.407
PC 1	0.322	-0.077	0.056	-0.056	-0.187	0.120	-0.467
PC 2	0.420	-0.280	0.105	-0.399	0.342	0.075	0.453
PC 3	-0.343	0.343	0.000	0.189	0.016	0.120	-0.056
PC 4	0.315	0.056	0.538	0.378	0.175	-0.045	0.239
PC 5	0.182	0.259	0.091	0.322	0.222	0.015	-0.298

Longitude, latitude, altitude, precipitation, and temperature. Significant values are represented by P<0.05: *; P<0.01: **

showed most important variations, and this is in accordance with the results of previous studies (Mulas et al., 2002; Ruffoni et al., 2003; Messaoud et al., 2007). This variance between populations could be explained by the provenance effect (Pre-Rif, Western Rif and Central Plateau). Provenance is characterized by extreme variations in terms of environmental conditions, especially climatic conditions, which act on the phenotype of myrtle (Wahid et al., 2016). Western Rif populations (IZA, BOUH, DAR and BT) show high values for leaf size (LGFe and LRFe), whereas Central Plateau populations (RAB, BRA and BS) show moderate values for these traits, while pre-Rif populations (GHA, SAH, ZRI, IKA, and AGH) had the lowest values.

The results of correlation tests reveal a relation between the morphological traits and climatic parameters of the populations studied. This comparison shows that populations in the western Rif Mountains that have long, broad leaves tolerate higher levels of humidity (precipitation) and relatively low mean annual temperature, compared to pre-Rif populations that are characterized by shorter, narrower leaves and can tolerate high temperature levels and moderate humidity, which was found in the study by Wahid et al. (2016). As well, the other quantitative traits measured are closely related to the environmental conditions of the provenances of the sampled individuals, since they show variations along the geographic and ecological gradient such as those noted in leaf size (LGFe and LRFe). With the exception of some fruit pomological traits (PF, NTG/F, PTG/F and PG), most quantitative traits record high values for West Rif populations, followed by Central Plateau populations and then Pre-Rif populations. These variations could be explained by the fact that these traits are controlled by environmental climatic conditions (Wahid et al., 2012). Indeed, the important role of the biogeographic zone in determining the genetic diversity of this species has been demonstrated by previous studies using molecular markers (Messaoud et al., 2007; Melito et al., 2014).

A strong positive correlation was observed between different morphological traits. These are the same results obtained by Wahid et al. (2016). In addition, negative correlations were also observed between the different morphological traits of different parts of the plant (leaf, fruit and seed). These relationships established between certain morphological traits could help to have clear ideas and to set objectives for the selection and production of better-performing varieties.

Finally, the PCA results showed that the first three components explain 74.33% of the total variation between populations. Among the traits with high factor loadings, traits that contribute to the formation of the main components are: total seed weight per fruit, average seed weight, seed length and width, fruit width, fruit weight, twig diameter, and main branch height and width. These results and correlations between morphological traits and geographical factors of provenances, as well as the hierarchical classification allowed to classify the studied populations into two main groups irrespective of their geographical origin. These results show that there are other factors or environmental conditions behind this grouping, and we could suggest the hypothesis of inbreeding between the populations studied, which can be verified by assessing the genetic diversity of this species using molecular markers.

In conclusion, there is significant variation between individuals (intra-population) and between populations (inter-population) for most of the morphological traits studied. The variance between populations is due to provenance (Pre-Rif, Western Rif and Central Plateau). With the exception of some morphological traits (e.g. PF, NTG/F, PTG/F and PG), most quantitative traits record high values for Western Rif populations, followed by Central Plateau populations and subsequently Pre-Rif populations. Our results also show that there is a strong positive correlation between the different morphological traits of the leaf, fruit, seed and height of the principal branch. These correlations could be exploited as bio-indicators for ex-situ planting tests for myrtle breeding programs in Morocco. On the basis of the hierarchical classification, it can be concluded that the natural populations of myrtle in Morocco can be divided into two groups. The Central Plateau populations (BS and BRA) formed the same group with ZRI population from pre-Rif and the Western Rif populations (IZA, BOUH, DAR, BT), and the Pre-Rif populations (IKA, AGH, SAH, GHA) formed a group with the Central Plateau RAB population. Principal component analysis (PCA) as well the correlation between morphological traits and geographic factors suggested that the variance between populations is due to the effect of provenance. The study suggested that any genetic variability within the species may be linked to geographical distribution.

References

Aabdousse, J., Faida, R., Boulli, A., Hasib, A. & Wahid, N. 2020. Ethnobotanical study of commercialized medicinal plants in the Beni Mellal Khenifra region (Morocco), with special reference to *Myrtus communis* L. Ethnobotany Research & Applications, 19: 1-13. http://dx.doi.org/10.32859/era.19.27.

Agrimonti, C., Bianchi, R., Bianchi, A., Ballero, M., Poli, F. & Marmiroli, N. 2007. Understanding biological conservation strategies: a molecular- genetic approach to the case of myrtle (*Myrtus communis* L.) in two Italian Regions: Sardinia and Calabria. Conservation Genetics, 8: 385-396.

Albaladejo, R.G., Carrillo, L.F., Aparicio, A., Fernández-Manjarrés, J.F. & González-Varo, J.P. 2008. Population genetic structure in *Myrtus communis* L. in a chronically fragmented landscape in the Mediterranean: can gene flow counteract habitat perturbation? Plant Biology, 11: 442-453.

Barboni, T., Venturini, N., Paolini, J., Desjobert, J.M., Chiaramonti, N. & Costa, J. 2010. Characterisation of volatiles and polyphenols for quality assessment of alcoholic beverages prepared from Corsican *Myrtus communis* berries. Food Chemistry, 122: 1304-1312.

Cannas, S., Molicotti, P., Ruggeri, M., Cubeddu, M., Sanguinetti, M., Marongiu, B. & Zanetti, S. 2013. Antimycotic activity of *Myrtus communis* L. towards *Candida* spp. from clinical isolates. Journal of Infection in Developing Countries, 7: 295-298.

Chatti, K., Choulak, S., Guenni, K., Hannach, AS. 2017. Genetic diversity analysis using morphological parameters in Tunisian Pistachio (*Pistacia vera* L.). Journal of Research in Biological Sciences, 2: 29-34.

Flamini, G., Cioni, P.L., Morelli, I., Maccioni, S. & Baldini, R. 2004. Phytochemical typologies in some populations of *Myrtus communis* L. on Caprione Promontory (East Liguria, Italy). Food Chemistry, 85: 599-604. https://doi.org/10.1016/j.foodchem.2003.08.005.

Gündüz, G.T., Gönül, Ş.A. & Karapinar, M. 2009. Efficacy of myrtle oil against *Salmonella Typhimurium* on fresh produce. International Journal of Food Microbiology , 130: 147-150.

IBM Corp. 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

IPGRI. 1997. Descripteurs du pistachier (*Pistacia vera* L.). Institut International des Ressources Phytogénétiques, Rome, Italie, 54 pp.

Melito, S., Chessa, I., Erre, P., Podani, J. & Mulas, M. 2013a. The genetic diversity of Sardinian myrtle (*Myrtus communis* L.) populations. Electronic Journal of Biotechnology, 16: 1-14.

Melito, S., Fadda, A., Rapposelli, E. & Mulas, M. 2014. Genetic diversity and population structure of Sardinian myrtle (*Myrtus communis* L.) selections as obtained by AFLP markers. HortScience, 49: 531-537.

Melito, S., Bella, S.L.A., Martinelli, F., Cammalleri, I., Tuttolomondo, T., Leto, C. & Mulas, M. 2016. Morphological, chemical, and genetic diversity of wild myrtle (*Myrtus communis* L.) populations in Sicily. Turkish Journal of Agriculture and Forestry, 40: 249-261. https://doi.org/10.3906/tar-1505-118.

Messaoud, C., Khoudja, M. & Boussaid, M. 2006. Genetic diversity and structure of wild Tunisian *Myrtus communis* L. (Myrtaceae) populations. Genetic Resources and Crop Evolution, 53: 407-417.

Messaoud, C., Afif, M., Boulila, A., Mohamed Nejib, R. & Boussaid, M. 2007. Genetic variation of Tunisian *Myrtus communis* L. (Myrtaceae) populations assessed by isozymes and RAPDs. Annals of Forest Science, 64: 845-853.

Messaoud, C., Béjaoui, A. & Boussaid, M. 2011. Fruit color, chemical and genetic diversity and structure of *Myrtus communis* L. var. italica Mill. morph populations. Biochemical Systematics and Ecology, 39: 570-580.

Migliore, J., Baumel, A. & Juin, M. 2012. From Mediterranean shores to central Saharan mountains : key phylogeographical insights from the genus Myrtus. Journal of Biogeography, 39: 942-956. https://doi.org/10.1111/j.1365-2699.2011.02646.x.

Mulas, M., Francesconi, A.H.D. & Perinu, B. 2002. Myrtle (*Myrtus communis* L.) as a new aromatic crop: cultivar selection. Journal of Herbs, Spices & Medicinal Plants, 9: 127-131.

Nora, S., Albaladejo., R.G. & Aparicio, A. 2015. Genetic variation and structure in the Mediterranean shrubs *Myrtus communis* and *Pistacia lentiscus* in different landscape contexts. Plant Biology, 17: 311-319.

Onal, S., Timur, B., Okutucu, S. & Zihnioglu, F. 2005. Inhibition of α-glucosidase by aqueous extracts of some potent antidiabetic medicinal plants. Preparative Biochemistry & Biotechnology, 35: 29-36.

Prada, M.A. & Arizpe, D. 2008. Riparian tree and shrub propagation hand-book. Generalitat Valenciana, Spanish, 203 pp.

Ruffoni, B., Airò, M., Fascelia, G., Mascarello, C., Zizzo, G. & Cervelli, C. 2003. Propagation and acclimatization of ornamental Myrtle genotypes. Acta Horticulturae, 616: 255-258.

Serce, S., Ercisli, S., Sengul, M., Gunduz, K. & Orhan, E. 2010. Antioxidant activities and fatty acid composition of wild grown myrtle (*Myrtus communis* L.) fruits. Pharmacognosy Magazine, 6: 9-12.

Wahid, N., André, R., Lamhamedi, M.S., Beaulieu, J., Margolis, H.A. & DeBlois, J. 2012. Genetic parameters and performance stability of white spruce somatic seedlings in clonal tests. Forest Ecology and Management, 270: 45-53.

Wahid, N. 2013. Ethnobotanique Perspectives de la valorisation de l'usage et de laculture du *Myrtus communis* L.au Maroc. Phytothérapie, 11: 237-243. https://doi.org/10.1007/s10298-013-0800-z.

Wahid, N., Chkichekh, A. & Bakry, M. 2016. Morphological traits and essential oil yield variation of three *Myrtus communis*L. populations : implication for domestication. Direct Research Journal of Agriculture and Food Science, 4: 199-207.

Wahid, N., Aabdousse, J., Chkhichekh, A., EL Aboudi, A., Lamhamedi, M.S. & Bakry, M. 2018. Prospection et modalités d'échantillonnage pour capturer la diversité génétique des populations naturelles : cas du *Myrtus communis* L. au Maroc. Ecologia Mediterranea, 44: 85-96.

Zilkah, S. & Goldschdmidt, E.E. 2014. Myrtle (*Myrtus communis* L.) - A native Mediterranean and cultured crop species. dans: Yaniv, Z. & Dudai, N. ed. Medicinal and Aromatic Plants of the Middle-East, vol 2, Springer, Amsterdam, Netherlands, 253-267 pp.