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Genotypic variation effect on quality determination of caper products collected in North-Central Morocco

[Efecto de la variación genotípica sobre la determinación de la calidad de los productos de alcaparras recolectados en el centro-norte de Marruecos]

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Abstract: The caper plant (*Capparis spinosa* L., Capparaceae) from Morocco is described differently, and shows a very variable morphology. In this work, two provenances of caper plant, spontaneous and cultivated, from the North-Central Morocco, are characterized on the basis of morphological and productive criteria. Quantitative and qualitative parameters reveal significant differences between the two origins. The cultivated provenance corresponds to *C. spinosa* subsp. *spinosa*, whereas the spontaneous origin is mainly composed of this subspecies and secondarily *C. orientalis*. Small capers are abundant in the two origins, but their aesthetic quality is more observed in the cultivated one. Caper berries of spontaneous provenance display a longer peduncle and gynophore and those of cultivated provenance are more numerous and thicker. The spontaneous caper genotypes produce capers and caper berries over a longer period and generate less income for the local population.

Keywords: *Capparis* spp.; Characterization; Production; Quality; Morocco.

Resumen: La alcaparra (*Capparis spinosa* L., Capparaceae) de Marruecos se describe de manera diferente y presenta una morfología muy variable. En este trabajo se caracterizan dos procedencias de alcaparras, espontáneas y cultivadas, del centro-norte de Marruecos, en base a criterios morfológicos y productivos. Los parámetros cuantitativos y cualitativos revelan diferencias significativas entre los dos orígenes. La procedencia cultivada corresponde a *C. spinosa* subsp. *spinosa*, mientras que el origen espontáneo está compuesto principalmente por esta subespecie y secundariamente *C. orientalis*. Las alcaparras pequeñas son abundantes en los dos orígenes, pero su calidad estética se observa más en el cultivado. Las alcaparras de procedencia espontánea presentan un pedúnculo y un ginóforo más largos y las de procedencia cultivada son más numerosas y más gruesas. Los genotipos de alcaparras espontáneas producen alcaparras y bayas de alcaparras durante un período más largo y generan menos ingresos para la población local.

Palabras clave: *Capparis* spp.; Caracterización; Producción; Calidad; Marruecos.

INTRODUCTION

Spontaneous and grown species of "*Capparis* L." genus (Capparaceae) from Morocco as well as their infra-specific taxa are differently described by authors, ranging from a single species with two categories to eight species and four subspecies (Quezel & Santa, 1962; Fennane *et al.*, 1999; Valdés *et al.*, 2002; Ozenda, 2004; Inocencio *et al*., 2006; A.P.D., 2020). Common or spiny caper is the typical species of spontaneous and grown caper (*Capparis spinosa* L.), showing a great morphological variability. It is a nanophanerophyte locally named “amsilikh”, “afsas”, “charanek”, “chefleh”, “kebbar”, “l’kebbar”, “kemeb”, “lessfat”, “taylulut” and “tylilout”, and is wide spread from the Mediterranean region to Kashmir, in addition to Crimea (Quezel & Santa, 1962; Tutin *et al*., 1993; Inocencio *et al*., 2002; Valdés *et al*., 2002; Ozenda, 2004; D.F.P., 2011; El Mansouri *et al.*, 2011; Montanari, 2013).

Caper plant is a perennial deciduous shrub in winter, growing throughout the extended dry period (May-October). It grows on rocky and clayey slopes, rocks, walls, and other dry places of plains and mountains up to 2000 m (Quezel & Santa, 1962; Tutin *et al*., 1993; Fennane *et al.*, 1999; Rhizopoulou & Psaras, 2003; Ozenda, 2004; Mishra *et al*., 2009). In addition, the caper plant has a large ecological amplitude and withstands the extreme environmental conditions (drought, poor and degraded soil, and steep slopes), because of its structural and physiological adaptations to drought, such as developing a very powerful root system, and increasing the density of photosynthetic cells and the production of primary metabolites (Rhizopoulou & Psaras, 2003; Benseghir-Boukhari & Seridi, 2007; Sakcali *et al*., 2008; Mishra *et al*. 2009; D.F.P., 2011; Libiad *et al*., 2011; Liu *et al*., 2011; Gull *et al*., 2015; Chedraoui *et al*., 2017).

The common caper was used in ancient Greece, in Andalusia in the 10-15th centuries, and in medieval Morocco during the Almohad period. Its ancient use and planting in the Mediterranean and in Western Asia as food and/or as a condiment is well documented (Bermejo & Sánchez, 1998; Chevallier, 2001; Rivera *et al*., 2002; Van Staëvel *et al*., 2016). This plant is a potential source of valuable nutrients, and is included in many culinary and/or medical recipes (Özcan, 1999; Saadaoui *et al*., 2011; Chedraoui *et al*., 2017).

This species is spontaneous throughout Morocco under Saharan, arid, semi-arid (minimum temperature above 0°C) and subhumid bioclimates. It is widely grown in the regions of Taza, Fez, Meknes, Safi and Marrakech (Bellakhdar, 1997; Fennane *et al*., 1999; Benseghir-Boukhari & Seridi; 2007). It is grazed despite its thorns, and is a real panacea. Almost the whole plant (leaf, flower, fruit, seed and root) is used in several regions, such as Fez, Taza, Taounate, Tissint, Sahara, Rissani, and Dra. It is sometimes mixed with other plants, honey or olive oil. The capers (caper flower buds) preserved in salted and alum water and/or in vinegar, are used as a luxury condiment (Bellakhdar, 1997; Rivera *et al*., 2003; El Mansouri *et al*., 2011; Libiad *et al.*, 2011; Khabbach *et al.*, 2012a).

Among around sixty countries that trade in capers, the US is considered the most important consumer where the price reaches \$25 kg^{-1} of capers ready for consumption, and China makes an annual profit of \$3 M from caper industry (Saadaoui *et al*., 2011; Chedraoui *et al*., 2017). Morocco is a major world exporter of canned capers, harvested from wild or grown plants during the flowering period, overlapping over at least a part of spring and summer, i.e. a harvest period of approximately 5 months. It is also the second world producer after Spain, with a national production of capers and caper berries (caper fruits) of around 21,560 $t.y^{-1}$ (Bellakhdar, 1997; Fennane *et al*., 1999; Valdés *et al*., 2002; Benseghir-Boukhari & Seridi, 2007; D.F.P., 2011; Gull *et al*., 2015). In many Moroccan regions, the caper is labeled as a local product. Under a semi-arid mountain climate (Tiznit Province), the production of capers and caper berries was estimated at 60 $t.y^{-1}$, followed successively by those in the Provinces of Zerhoun (4,000 $t.y^{-1}$), Taounate (7,500 $t.y^{-1}$), and Safi, from 8,000 to 10,000 $t.y^{-1}$ (D.F.P., 2011).

The caper-production process begins with gathering capers and caper berries in natural environments and cultivations, followed by manual sorting and size grading, which define the main conditions for the supply of raw materials and for market demands. Upstream traceability of spontaneous plant exploitation entails development and strengthening of the national legal arsenal needed to efficiently protect and control plant by-products. However, it is not currently easy to find sufficient institutional solutions in the international agreements in force in this regard (Ennabili, 2017).

Controlling the caper quality at the local level would improve the additional income of small farmers and also ensure an effective traceability of raw materials for cooperatives and manufacturers. The broad-based variability of the caper plant (*C. spinosa* L.) would therefore be reflected on the quality of capers and caper berries. This work aims at morphological and productive characterization of two provenances of caper plant, one spontaneous, the other cultivated from the Fez-Meknes region, one of the most productive Moroccan-areas of capers.

MATERIAL AND METHODS

Study locations

Two provenances of *Capparis spinosa* L., one spontaneous, the other cultivated, approximately 81 km apart by direct route, were selected following previous surveys, respectively in Taza (Location 1: N34°20.285' - W004°02.644', area of about 1.8 ha, elevations of 351-594 m, with E-NW and N exposures) and Moulay Yaâcoub (Location 2: N34°11.029' - 004°88.636', approximately 3 ha, 204 m, W exposure), Fez-Meknes region, North-Central Morocco. These two provenances are located between the Middle Atlas and the pre-Rif, in Mediterranean climate with semi-arid and sub-humid bioclimates and a succession of dry years and wet ones (El Garouani & Tribak, 2006).

The location 1 located in the Province of Taza, is characterized by a very variable slope ranging from 15 to 100% (cliffs) and by conglomerate and limestone substrates (Figure No. 1). Plant cover (50-60%) mainly consists of herbaceous plants (*Ammoides pissila*, *Scolymus hispanica*, *Carthamus* spp., *Ampelodesmos* spp., *Marrubium vulgare*, *Lavandula multifida*, *Ajuga iva*…) kept in large numbers in bushes caper, and secondarily shrubs and semi-shrubs (*Nerium oleander*, *Chamaerops humilis*, *Acacia* spp., and *Pistacia* spp.). Anthropogenic activities were observed in this location, namely grazing, trampling, and rocks and soil extraction. The location 2 located in the Province of Moulay Yaâkoub, with an overall slope of about 10% and rather clayey substrate (Figure No. 1). It corresponds to a caper orchard with intercrops of cereals and legumes, and sometimes left fallow or as rangelands.

Figure No. 1
Partial views of the locations studied. Location 1 (Taza) on the left and location 2 (Moulay Yaâkoub) on the right

Plant description and sampling

Field surveys were carried out during the “May-August 2019” period, coinciding with the flowering and fruiting of *C. spinosa*. This season experienced a low activity of picking capers and caper berries by peasants and farmers because of their very low price. Three successive prospecting, measurement and sampling campaigns were carried out at each location in June, July and August. The parameters that were chosen for this study were recorded in Table No. 1.

They concern 10 healthy caper-bushes, 50 plant branches of 1-2 years, 476 mature leaves, 29 flowers, 200 capers and 222 caper berries per location.

Table No. 1
Descriptor parameters studied in caper plant

	Descriptor parameters
Density	Inter-bush distance in four directions. Mean inter-bush distance. Estimated density of caper brush.
Bush	Height. Large diameter, small, and mean diameters. Branch number. Branch length and maximum width. Secondary branch number per branch.
Leaf	Length and larger width of leaf blade. Petiole length. Stipule length and shape.
Caper	Color. Length and width. Length of caper stalk. Number per branch, of various calibers: 1-5 mm, 6-7 mm, 7-8mm, 8-9mm, 9-11mm, 11-12 mm, 12-14 mm, and larger than 14 mm. Number of capers with open calyx. Wet weight.
Flower	Number per caper bush and branch. Diameter and height. Flower-stalk length. Length of calyx carrier. Sepal length, width, and number. Concavity depth of sepal. Petal length, width, and number. Stamen number. Style length.
Caper berry	Number per branch and bush. Length. Thickness. Stalk and gynophores lengths. Wet weight.

The density of caper bushes was estimated indirectly using the formula "$\text{Caper bush density (ha}^{-1}) = \frac{10^4}{\pi\left[\frac{MD+MIT}{2}\right]^2}$", where: MD, mean bush diameter (m), and MIT, mean inter-bush distance (m). Caper and caper berry productions were assessed on the basis of the bush density and the production per bush. To this end, 10 bushes per location were randomly chosen, and only a proportionate part of each was cut.

Data processing

Data are presented depending on location, Sampling campaign, and caper-plant bush. The one-way analysis of variance (ANOVA) of normal distribution data was performed using the STATISTICA software, V.5, otherwise only averages and percentages were calculated.

RESULTS

Plant bushes

Comparison of morphological parameters and bush density showed significant to very highly significant differences between the two locations, except for the large diameter of the bush and one of the four inter-bush distances (Table No. 2). In spontaneous provenance, bushes are higher (0.63 ± 0.25 m), with more branches (101.1 ± 58.98 branches.bush^{-1}) and are irregularly distributed (inter-bush distance of 14.4 ± 12.6 m). Under cultivation conditions, caper bushes are wider (mean diameter of 2.47 ± 0.49 m) and are regularly and densely distributed (355.2 ± 76.58 bushes.ha^{-1}). This estimated density is similar to that measured in the field (350.0 bushes.ha^{-1}).

In addition, the spontaneous caper bushes are characterized by more fragile and older branches in comparison with the cultivated one. All of these morphological and density differences between the two origins are largely related to local conditions, an older aboveground part and poor soil of the spontaneous caper, and annual mowing and fertilizer supplying of the cultivated one.

Plant branches of 1-2 years

The length of one-year branch (117.2 ± 26.53 cm) and the maximum width (64.28 ± 22.19 cm) of the cultivated caper are very highly greater than those of spontaneous provenances, with an older aboveground part (Table No. 3). The difference in bush average-diameter between the two locations is less significant (Table No. 2). Caper-branches are reddish-green in the location 1, and generally green in the location 2.

Table No. 2
Bush characteristics in caper-plants from spontaneous and cultivated areas

Caper bush descriptors*	D1	D2	MD	H	NR	IT1	IT2	IT3	IT4	ITM	ED
Spontaneous (Location 1)	2.20 ± 0.77a	1.67 ± 0.48	1.94 ± 0.60	0.63 ± 0.25	101 ± 59.0	14.0 ± 15.6a	12.1 ± 5.39	11.5 ± 11.0	19.9 ± 25.6	14.4 ± 12.6	113 ± 7.9
Cultivated (Location 2)	2.64 ± 0.54a	2.30 ± 0.46	2.47 ± 0.49	0.43 ± 0.07	24.4 ± 5.21	4.64 ± 0.74a	5.11 ± 0.81	2.39 ± 0.91	2.29 ± 0.30	3.61 ± 0.54	355 ± 76.6
All (N = 20)	2.42 ± 0.68	1.98 ± 0.56	2.20 ± 0.60	0.53 ± 0.21	62.8 ± 56.7	9.34 ± 11.8	8.62 ± 5.20	6.93 ± 8.89	11.1 ± 19.8	8.99 ± 10.3	234 ± 148

***Size and distance are in m, and density in ha^{-1}. For each variable, means followed by the same letter are not significantly different at 5%**
D1, large diameter. D2, small diameter. ED, estimated density. H, height. IT1,2,3,4, inter-bushes distance in four directions. MD, mean diameter. MIT, mean inter-bushes distance. NR, branches number

Table No. 3
Branch characteristics in caper-plants from spontaneous and cultivated areas

Comparison critera	Branch length (cm)	Branch maximum width (cm)	Secondary branch number
Locations (Populations)			
Spontaneous (Location 1)	50.31 ± 21.82	28.68 ± 20.85	5.27 ± 5.19
Cultivated (Location 2)	117.2 ± 26.53	64.28 ± 22.19	24.2 ± 7.17
All (N = 120)	83.77 ± 41.40	46.48 ± 27.91	14.7 ± 11.3
Sampling campaigns			
June - Location 1	48.23 ± 22.32a	25.10 ± 14.76a	5.60 ± 5.47a
July - Location 1	52.40 ± 21.50a	32.27 ± 25.30a	4.93 ± 4.99a
June - Location 2	103.5 ± 28.02	64.93 ± 24.83b	23.5 ± 7.20b
July - Location 2	130.9 ± 16.10	63.63 ± 19.61b	24.8 ± 7.20b
All (N = 120)	83.78 ± 41.40	46.48 ± 27.92	14.7 ± 11.3

For each variable, means followed by the same letter are not significantly different at 5%

Caper bushes are also more branched under cultivation circumstances, reaching 24.2 ± 7.17 vs. only 5.27 ± 5.19 secondary branches.branch-1 in the spontaneous provenance (Table No. 3), probably due to the regular fertilizer supplying and annual mowing for the first case, and the aging of the aboveground part for the second. Considering the first two sampling campaigns (full plant flowering), it turned out that the branch growth in grown caper increased very highly significantly, going from 103.5 ± 28.02 to 130.9 ± 16.10 cm (Table No. 3).

Plant leaf

Conditions in location 2 clearly favor the length and maximum width of the leaf blade, and significantly the length of the petiole in comparison with the location 1 (Table No. 4). The plant leaf showed a lengthwise growth of blade and petiole in spontaneous provenance, while the maximum width of the blade decreased. But the ratio of the blade length to its maximum width highlighted an overall general lengthwise growth for the two locations (1.34 - 1.39 in spontaneous provenance, vs. 1.17-1.27 in cultivated one), i.e. a more rounded leaf form in the location 2 (Table No. 4). The caper leaves were all mucronate in the location 2, and partly non-mucronate in the location 1, probably due to the mucron loss after the first growing season.

Table No. 4
Leaf characteristics in caper-plants from spontaneous and cultivated areas

Comparison critera	Leaf-blade length (cm)	Leaf-blade larger width (cm)	Petiole length (cm)
Locations (Populations)			
Spontaneous (Location 1)	3.60 ± 0.52	2.64 ± 0.45	0.64 ± 0.23
Cultivated (Location 2)	3.83 ± 0.48	3.15 ± 0.44	0.68 ± 0.13
All (N = 480)	3.72 ± 0.51	2.90 ± 0.51	0.66 ± 0.19
Sampling campaigns			
June - Location 1	3.44 ± 0.44	2.57 ± 0.43a	0.59 ± 0.25
July - Location 1	3.77 ± 0.54a	2.72 ± 0.46a	0.69 ± 0.19a
June - Location 2	3.78 ± 0.49a	3.23 ± 0.46	0.67 ± 0.15a
July - Location 2	3.89 ± 0.47a	3.07 ± 0.39	0.70 ± 0.10a
All (N = 480)	3.72 ± 0.51	2.90 ± 0.51	0.66 ± 0.19

For each variable, means followed by the same letter are not significantly different at 5%

Caper bush comparison according to the leaf-blade length independently of the location and the sampling campaign allowed a very highly significant distinction between a bush from the location 1 (LL2; Figure No. 2) from all other bushes (LL1), with 3.02 ± 0.35 and 3.32 ± 0.42-4.13 ± 0.47 cm in the same order (F=10.84, *p*=6.701E-27). For the maximum leaf-blade width, two bush groups unrelated to locations were very highly significantly identified (LW1 and LW2; Figure No. 2), with respective value classes of 2.90 ± 0.46-3.42 ± 0.31 and 2.2 ± 0.25 - 2.79 ± 0.31 cm (F=22.25, *p*=0).

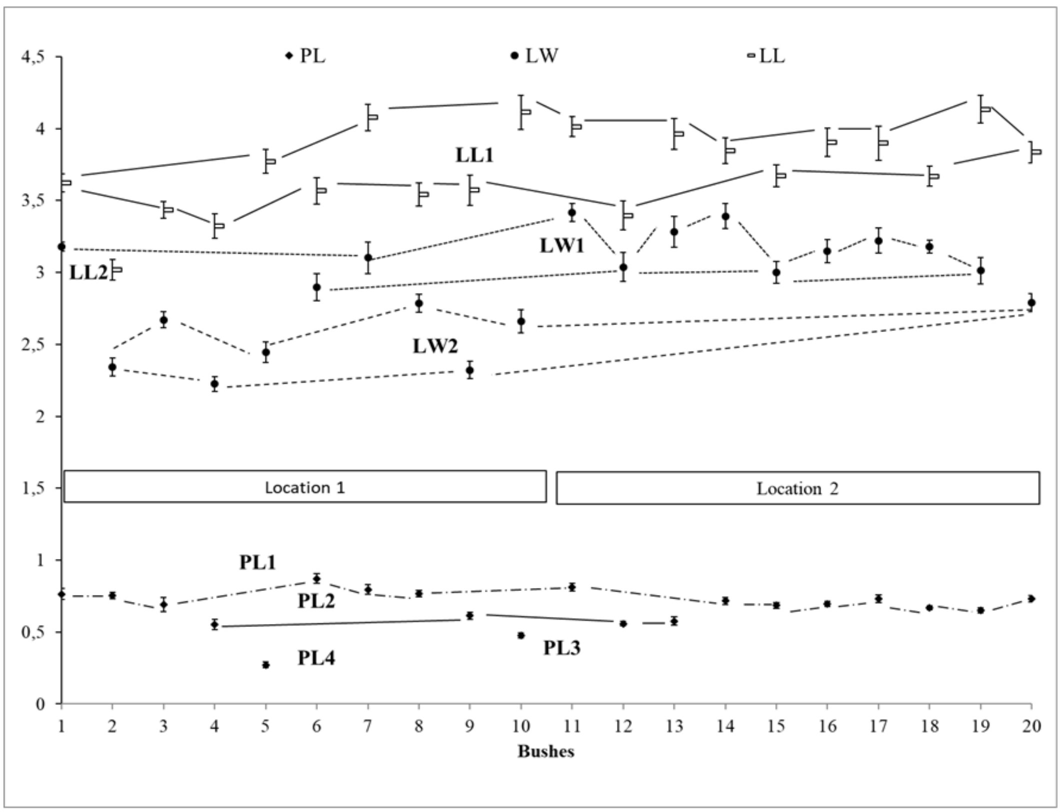

Figure No. 2
Leaf characteristics (cm) in caper-plants according to caper bushes. LL, leaf-blade length. LW, leaf-blade maximal width. LP, petiole length

The petiole length revealed more variation by classifying the bushes very highly significantly in four groups, two of which are common between the two locations (PL1: 0.69 ± 0.25 - 0.87 ± 0.16 cm and PL2: 0.55 ± 0.18 - 0.61 ± 0.12 cm), one specific to the location 2 (PL3: 0.47 ± 0.09 cm) and one corresponding to the location 1 (PL4: 0.27 ± 0.10 cm); F=24.54, *p*=0 (Figure No. 2).

Stipules are more robust in the cultivated bushes (100% vs. 64.9% in spontaneous ones), and mostly curved (85% vs. 60%). They are doubly longer in the location 2 (4.36 ± 0.63 mm) when compared to the location 1 (2.01 ± 0.56 mm; F=551.2, *p*=0). Bushes with significantly less developed leaves and shorter stipules in the spontaneous provenance could be related to the conditions of cultivation in the location 2 and the presence of biannual and/or multiannual branches in the location 1. But this would not make a distinction between morphological forms within studied origins.

Caper

Caper length and weight are favored in cultivation, reaching respectively 0.91 ± 0.32 cm (F=37.74, *p*=6.307E-09) and 0.40 ± 0.29 g (F=7.444, *p*=0.007), while the caper width (1.14 ± 0.73 cm) and stalk length (2.57 ± 1.26 cm) caper are similar in the two locations. This showed a possible improvement of caper production under cultivation conditions.

The number of capers per branch, classified by industrial-size, was generally very variable and did not highlight any significant differences between the two locations except for the number of capers with open calyx which was more important in cultivation (Table No. 5). The season of presence of capers more spread out in spontaneous provenance (June-August, vs. June in cultivated one). The good performances in terms of caper size were recorded for capers of classes 1-5 mm, 11-12 mm and 12-14 mm (June-July, Location 1; June - L. 2), 11-12 mm (July - L.1, June - L. 2), 6-7 mm, 7-8 mm, and 8-9 mm (June - L. 2), and with a caliber greater than 14 mm (June - L. 1 and 2), Table No. 5. Caper quality would then depend both on the required size and the type of caper origin.

Table No. 5
Number of capers per branch in cultivated and spontaneous population

Comparison critera	C15	C67	C78	C89	C911	C112	C124	S14	CCO
Locations (Populations)									
Spontaneous (Location 1)	5.78 ±10.3a	2.18 ±3.36a	1.43 ±2.75a	1.18 ±1.90a	2.42 ±3.97a	0.97 ±1.83a	1.28 ±2.06a	0.65 ±1.10a	0.28 ±0.96
Cultivated (Location 2)	4.25 ±6.72a	2.26 ±3.84a	1.53 ±2.95a	1.27 ±2.08a	2.00 ±3.34a	1.27 ±2.16a	1.67 ±2.47a	0.90 ±2.01a	1.27 ±1.67
All (N = 120)	5.02 ±8.69	2.22 ±3.59	1.48 ±2.84	1.22 ±1.99	2.21 ±3.66	1.12 ±2.00	1.47 ±2.27	0.77 ±1.62	0.77 ±1.44
Sampling campaigns									
June - Location 1	5.27 ±7.45a	2.17 ±2.67a	1.27 ±1.74a	1.60 ±2.14a	2.30 ±2.49a	0.90 ±1.52a	1.60 ±1.79a	1.10 ±1.32a	0.13 ±0.35a
July - Location 1	6.30 ±12.6a	2.20 ±3.99	1.60 ±3.51a	0.77 ±1.55	2.53 ±5.08a	1.03 ±2.13a	0.97 ±2.28a	0.20 ±0.55b	0.43 ±1.30a
June - Location 2	8.50 ±7.39a	4.53 ±4.39	3.07 ±3.58	2.53 ±2.34	4.00 ±3.80a	2.53 ±2.49a	3.33 ±2.58a	1.80 ±2.55a	2.53 ±1.53
July - Location 2	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00a	0.00 ±0.00a	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00b	0.00 ±0.00a
All (N = 120)	5.02 ±8.69	2.22 ±3.59	1.48 ±2.84	1.22 ±1.99	2.21 ±3.66	1.12 ±2.00	1.48 ±2.27	0.77 ±1.62	0.77 ±1.44

For each variable, means followed by the same letter are not significantly different at 5%
C15, 1-5 mm capers. C67, 6-7 mm. C78, 7-8 mm. C89, 8-9 mm. C911, 9-11 mm. C112, 11-12 mm. C124, 12-14 mm. S14, more than 14 mm. CCO, number of capers with open calyx

In the location 1, capers are dark green (42%), dark green to slightly pink (35%) and reddish green (23%). These color differences can be attributed to the diversification of micro-habitats (variable exposure, shade, caper bush growing on the cliff…) and to physiological adaptations to different environmental stresses. In addition, a pooled insertion of three capers in the leaf axil was particularly noted in this location. In the location 2, capers are dark green or dark green to slightly pink, in similar proportions. This color homogeneity can be attributed in the same way to the homogeneity of the relief, the absence of shaded micro-habitats, and growing conditions. Consequently, cultivated caper plants would be advisable in terms of aesthetic quality, since they present generally capers of unified color in comparison with those in spontaneous caper plants.

Flower

The full flowering of the caper bush spreads over the months of June and July in the two locations, with a partial revival beyond this period in the spontaneous provenance. Caper flowers in the two locations are predominantly with white petals (87.5%), and only 12.5% are white-pink. Moreover, the same bush sometimes displays both flower types. All flowers also have a dilated helmet-like sepal with varying depth. In the spontaneous provenance, flowers have longer peduncles (5.03 ± 0.56 cm), wider sepals (1.95 ± 0.40 cm) and more dilated dissimilar sepals (1.07 ± 0.20 cm). The stamen number per flower in the cultivated caper is rather higher (101.6 ± 11.61 stamens.flower^{-1}), Table No. 6.

Table No. 6
Flower characteristics (cm) in caper plant from spontaneous and cultivated areas

Flower descriptors	FD	FH	S	SL	SW	CD	PL	PW	NE	TL
Spontaneous (Location 1)	3.42 ±0.55a	3.82 ±1.13a	5.03 ±0.56	2.08 ±0.33a	1.95 ±0.40	1.07± 0.20	2.75 ±0.53a	2.20± 0.63a	93.1 ±6.38	3.21 ±0.99a
Cultivated (Location 2)	3.20 ±1.97a	3.43 ±1.26a	4.09 ±0.36	2.19 ±0.19a	1.42 ±0.08	0.75± 0.05	2.72 ±0.37a	2.05± 0.34a	110.1 ±9.120	3.56 ±0.42a
All (N = 20)	3.31 ±1.41	3.62 ±1.18	4.56 ±0.66	2.13 ±0.27	1.68 ±0.39	0.91± 0.22	2.73 ±0.44	2.12± 0.50	101.6 ±11.61	3.38 ±0.76

For each variable, means followed by the same letter are not significantly different at 5%
CD, concavity depth of sepal. FD, diameter. FH, height. NE, stamen number. PL, petal length. PW, petal width. S, stalk length. SL, sepal length. SW, sepal width. TL, style length

Numbers of flowers (1.261 flowers.branch^{-1}, F=3.451, p=0.065) and abortive ones per branch (1.622 abortive flowers.branch^{-1}, F=0.188, p=0.665) showed no significant differences between the two locations; it was the same when considering these parameters per bush (7.5 flowers.bush^{-1}, F=0.932, p=0.347; 9.75 abortive flowers.bush^{-1}, F=0.048, p=0.829). During June and July sampling-campaigns, numbers of flowers (F=24.23, p=3.182E-12) and abortive ones per branch (F=6.977, p=2.356E-04) revealed a very highly significant difference. These two variables increased in July for abortive flowers in spontaneous provenances, while they tended towards zero under cultivation conditions (Figure No. 3), ostensibly following the abundant fructification stage and/or attack of capers by insects. This reveals a supposed resistance of the spontaneous provenance to insects, sometimes

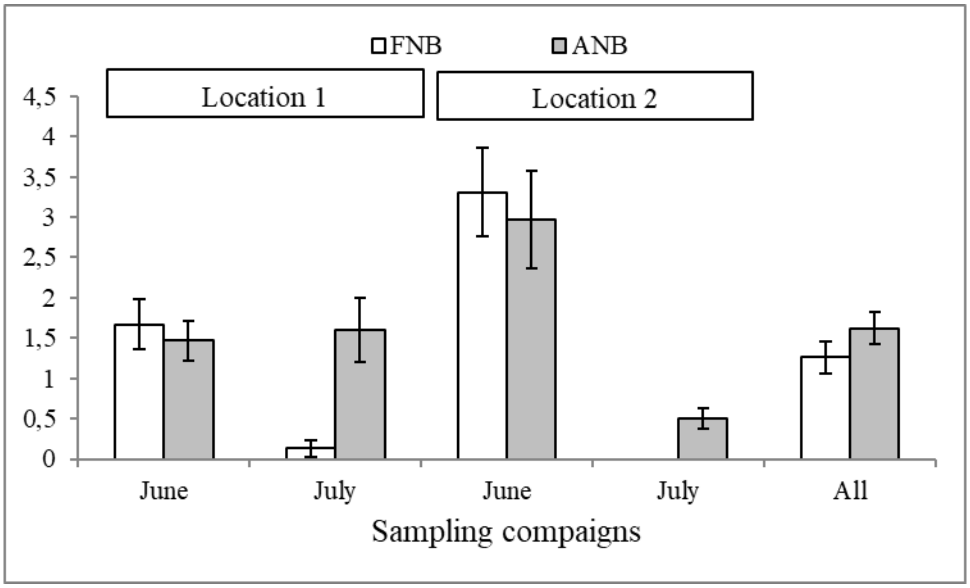

Figure No. 3
Flower number (FNB) and abortive flower one (ANB) per branch of caper-plants (N = 120)

Caper berry
Caper branches from the location 2 are very highly richer in caper berries, when compared to those from the location 1 (10.05 ± 11.35 vs. 1.16 ± 1.54 caper berries.branch^{-1}; F=36.05, *p*=2.171). While, numbers of open (0.1, F=1.913, *p*=0.169) and burst caper-berries per branch (0.041, F=1.876, *p*=0.173) displayed no significant differences between the two locations, correlated supposedly to the late maturing stage of caper berries.

While caper berries of cultivated caper are thicker (1.77 ± 0.48 cm; F=16.216, *p*=1.301E-04), those of spontaneous caper have longer peduncle (4.66 ± 0.54 cm; F=30.77, *p*=3.836E-07) and gynophore (5.20 ± 0.99 cm; F=4.378, *p*=396.5E-04). Nevertheless, caper-berry length (3.10 ± 1.50 cm; F=3.222, *p*=0.077) and weight (4.94 ± 4.47 g; F=2.626E-04, *p*=0.987) are similar regardless of their origins.

The caper-berry number per branch increased in July, especially in the location 2 (12.5 ± 13.81 caper berries.branch^{-1}; F=14.460, *p*=4.581), concurring with its abundant fruiting phase. The number of open caper berries per branch was almost similar in the two locations during all campaigns (0.1 open caper berry.branch^{-1}; F=1.868, *p*=0.138), and that of burst ones was chiefly recorded in July in spontaneous provenance (0.13 ± 0.34 burst caper berry.branch^{-1}; F=3.1253, *p*=0.0285). Caper-berry length, thickness, stalk length, and fresh weight very highly depend on the sampling period, and reached higher values in July, i.e. 4.725 ± 1.554 cm (F=23.289, *p*=8.570, Location 1), 2.04 ± 0.25 cm (F=42.318, *p*=3.449, L. 2), 4.74 ± 0.367 cm (F=12.512, *p*=9.830, L. 1), and 8.977 ± 5.171 g (F=23.569, *p*=6.912, L. 1) in the same order. The gynophore length did not vary significantly according to the sampling period for the two locations (5.158 cm; F=1.855, *p*=0.144).

It turns out then that bushes of the spontaneous caper are green-reddish, larger, more spaced, and with more numerous and older branches. Flowers have a longer peduncle, wider sepals and a more concave dissimilar sepal. Caper berries have a longer peduncle and gynophore. One the other hand, bushes of the cultivated caper are green, taller, and less spaced. They have a larger average diameter, and longer, wider and more branched branches. Leaves are longer, and wider, with longer petioles and longer, robust, and mostly curved stipules. Flowers have more stamens, and capers are heavier, longer, and wider, with longer peduncles and more open calyx prevalence. Caper berries are more numerous and thicker.

Based on sampling campaigns, the caper production varied considerably but was similar for both locations (52.49 ± 37.32 in location 1 and 52.00 ± 37.86 $kg.ha^{-1}.campaign^{-1}$ in L 2). The caper-berry production was also very fluctuating, but markedly high in the cultivated provenance (429.4 ± 274.2) than in the spontaneous one (65.78 ± 73.53 $kg.ha^{-1}.campaign^{-1}$). This would generate for the local population a modest and random financial product of \$43 and \$193 $.ha^{-1}.campagn^{-1}$ respectively for locations 1 and 2, i.e. from \$85 to \$214 and from \$380 to \$951 $.ha^{-1}.year^{-1}$ in the same order, according to the farm year and caper offer/demand. The spontaneous provenance would produce capers and caper berries over a longer period, and would generate less income for the local population, in comparison with the cultivated caper, displaying more intensive production and generating more income. Cropping factors of the caper plant associated to its exploitation, mainly the annual mowing, the cereal and legume intercrops, and the organization of caper and caper-berry picking would undoubtedly be more substantial than genotypic factors, in comparison with the spontaneous provenance.

DISCUSSION

Taxonomic variation

Among the descriptive parameters of the caper plant chosen for this study, more than 25 quantitative descriptors, relating to bush, branches, leaves, capers, flowers and caper berries, presented significant differences between the two origins, spontaneous and cultivated. The dissimilar sepal, dilated in helmet-shape, characterizes all caper bushes in both locations, and has only been highlighted to our knowledge by Ozenda (2004) in *C. galeata* Fresn. [syn. *C. spinosa* subsp. *cartilaginea* (Decne.) Maire & Weiller] from the Sahara, but the petal color in this taxon does not agree with the two case studies.

Based on criteria of the leaf (blade length and width, and petiole length), stipules (length, shape and robustness), and flower (sepal length and stamen number), the cultivated caper would correspond to *C. spinosa* var. *canescens* Coss. [syn. *C. sicula* Veill. subsp. *sicula*]. According to the same leaf and stipule criteria, and the floral peduncle length, the spontaneous caper plant would be equivalent to *C. ovata* Desf. subsp. *ovata* (Inocencio *et al*., 2006). However, this correspondence is not obvious in view of other correspondences, particularly of floral characters such as sepal width and/or length, the concavity of the dissimilar sepal, the floral peduncle and/or the number of stamens.

Saifi *et al*. (2009) and Saifi *et al*. (2010) reported the existence of three species of caper bush in the "Fez-Taounate- My Idriss Zerhoune" area, overlapping on the cultivated provenance considered in this study, *C. cartilaginea* Decne. [Syn. *C. spinosa* subsp. *cartilaginea* (Decne.) Maire & Weiller], often spontaneous, three varieties of *C. ovata* Desf., and four varieties of *C. spinosa* L., mainly on the basis of leaf (width, petiole length, and stipule length), and flower (caper number per branch, and caper width and weight) criteria. However, the results of the present study allow no correspondence with these taxa. In fact, these authors claimed that, on the basis of a genetic study, all of these *Capparis* spp. groups are very close to one another even when they are morphologically distinct (Saifi *et al*., 2011).

Only leaf-blade length and width and the petiole length allowed a significant difference between different plant groups regardless of origin, with common characteristics with the following taxa, *C. atlantica* Inocencio, D. Rivera & al., *C. ovata* Desf. subsp. *ovata*, *C. sicula* Veill. subsp. *sicula*, *C. spinosa* L., and *C. zoharyi* Inocencio, D. Rivera & al. Whereas the spontaneous provenance encompasses a genotype with very short petiole. Caper leaves are pubescent and variable in shape in the two locations studied, not allowing a morphological distinction between caper species. Quezel & Santa (1962), Fennane *et al*. (1999) and Valdés *et al*. (2002) reported a great morphological variability of leaves in *C. spinosa* L. from Morocco. These morphological changes could be a response to different ecological factors, and could mislead the perception of genetic differences between caper species (Inocencio *et al*., 2005).

Stipules are mostly robust in the spontaneous provenance (around 65%) and totally robust in the cultivated one; they are also 60 and 85% curved in the same order, and doubly longer in the cultivated caper. According to Tutin *et al.* (1993) and Valdés *et al*. (2002), the location 2 corresponds to a homogeneous population of *C. spinosa* L. subsp. *spinosa*, while the location 1 could be equivalent to a population of this subspecies, dotted with bushes of *C. spinosa* subsp. *rupestris* [Syn. *C. orientalis* Veill.]. With regard to the habitat of each subspecies, *C. spinosa* L. subsp. *spinosa* grows on coastal rocks and cliffs, generally on limestone (Tutin *et al*., 1993), which further proves the correlation between the heterogeneity of the caper population and that of the soil and substrate in the location 1.

In addition, molecular study and morphological analysis of caper populations located in Sicily and the surrounding area underlined that the wild populations include two different subspecies, *C. spinosa* subsp. *spinosa* and *C. spinosa* subsp. *rupestris*. These results suggest a clear genetic distinction between the subspecies at regional level, with different ecological preferences and distinct morphological characters (Gristina *et al*., 2014).

Other taxonomic and molecular studies on *Capparis* spp. did not make it possible to decide on its specific diversity in Morocco, and reported the presence of only one species in Southern Europe, North Africa, and Western and Central Asia: *C. spinosa* L., comprising these two sub- species and their variants, i.e. *C. spinosa* subsp. *spinosa* var. *aegyptia* (Lam.) Boissier, *C. spinosa* subsp. *spinosa* var. *atlantica* (Inocencio, D. Rivera, Obón & Alcaraz) Fici, *C. spinosa* subsp. *spinosa* var. *canescens* Cosson, *C. spinosa* subsp. *rupestris* (Sm.) Nyman, and *C. spinosa* subsp. *rupestris* var. *ovata* (Desf.) Fici, comb. (Musallam *et al*., 2010; Ózbek & Kara, 2013; Fici, 2014; Ahmadi & Saeidi, 2018).

Caper production

The caper size is the main quantitative quality-criterion and varies according to the following classes: Lilliput (1-5), Non-pareilles (6-7), Surfines (7-8), Capucines (8-9), Capotes (9-11), Fines (11-12), Gruesas (12-14) and Out-of-calibers (>14 mm). Small-capers are the best-selling on the market and are the most expensive (E.A.C.C.E., 1987; Inocencio *et al*., 2002; D.F.P., 2011; Ramdani, 2017). The results showed that small-capers were abundant in both plant types. Tutin *et al.* (1993) associated large capers with the subspecies *C. spinosa* subsp. *spinosa*, corresponding to the cultivated population in our case, while Gristina *et al.* (2014) underlined a genetic affinity of the cultivated caper with *C. spinosa* subsp. *rupestris*. During the first sampling campaign, the cultivated bushes produced more capers in comparison with the spontaneous ones, possibly due to the disharmony of flowering and fruiting periods under the wild and cultivation conditions.

To meet consumer requirements, capers must be picked fresh, before the flower blooms, and they must have a color varying from light green to dark green and possibly a slightly pinkish hue. These aesthetic quality standards are more observed in the cultivated population (100%) compared to the spontaneous one (77%), provided that the harvesting frequency is increased to avoid the appearance of capers with an open calyx in the first case.

In northern Morocco, *C. spinosa* is among other spontaneous plants whose fruit is picked for local use and/or marketing, namely *Ceratonia siliqua*, *Opuncia ficus-indica*, *Arbutus unedo, Ziziphus lotus*, *Quercus ilex, Chamaerops humilis, Myrtus communis*, *Rubus ulmifolius*… (Ennabili *et al*., 2000; Libiad *et al*., 2011; Khabbach *et al*., 2012a; Khabbach *et al*., 2012b; Gharnit & Ennabili, 2016). The exploitation of this plant generates significant income by providing important seasonal jobs, especially during harvesting of caper and caper berries, ranging from 3 to 5 months depending on the region (D.F.P., 2011; Khabbach *et al*., 2012a; Libiad *et al*., 2011; Libiad *et al*., 2014).

The production of capers in the study area is more than twice as high as that recorded in the Safi province (Ramdani, 2017). The financial product due to the sale of capers and caper berries estimated in this study is approximately 6 and 12 times less than those estimated respectively by Kenny (1997) and Libiad *et al*. (2011). The unit price of capers recorded is around 5 times less than that reported by El Mansouri *et al.* (2011) and Khabbach *et al*. (2012a). This regression is obviously related to the speculation of intermediary traders on the one hand and to the intensive development of the caper cultivation in a more controlled manner in recent years on the other hand.

The cultivation of the caper plant must therefore consider the taxonomic identity to better standardize caper exploitation and quality. Moreover, Inocencio *et al*. (2002) reported heterogeneity of marketed capers from more than one plant species (*C. spinosa*, *C. sicula*, *C. orientalis*, and *C. aegyptia*). Additionally, the caper plant has a great regenerative capacity, without specific soil and/or climatic requirements and also contributes to soil-fixing (Fennane *et al*., 1999; Benseghir-Boukhari & Seridi, 2007; Ould El Hadj *et al*., 2009; D.F.P., 2011; Libiad *et al*., 2011; Fennane & Rejdali, 2016; Licata *et al*., 2016).

CONCLUSION

The caper species shows a great genetic variability, resists well the dryness and, consequently, should be considered a valuable resource for regions with poor soils and suffering from climatic hazards, more specifically under arid and semi-arid bioclimates of Morocco. The spontaneous caper includes more than one taxonomic rank, generates less income for the local population and produces capers over a longer period when compared to the cultivated caper.

Caper production especially in cultivated population, remarkably higher compared to other regions of Morocco, invokes the development of the caper plant cultivation as well as its promotion on a regional basis by opting for clones producing high quality capers. Other cropping factors of this plant in terms of exploitation, such as annual mowing, intercrop types, organization and upstream traceability of capers and caper berries... remain to be controlled.

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