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Morphological Characterization of Prickly Pears (*Opuntia ficus indica* (L.) Mill.) Cultivated in Lebanon

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Abstract: ***Opuntia ficus indica (L.) Mill. is a long-domesticated cactus crop that is important in agricultural systems throughout arid and semiarid parts of the world. It has been introduced in the Mediterranean basin contributing to the diversification of fruit crops. In the present work, we report on the first assessment of prickly pears cultivated in Lebanon based on a set of descriptors including morphological traits of the tree, cladode and fruit, and chemical traits of the juice. Forty three accessions were characterized in their cultivated habitats of which 12 accessions considered as local and putatively named Baladi and 31 accessions imported and designated as Franji. Principal components analysis showed that fruit, juice and pulp weights, seed number, peel thickness, and plant vigor, habit and shape are the most significant traits. PCA bi-plot showed not a likely spatial differentiation between the accessions. The dendrogram constructed according to Euclidean distance separated the accessions in six main sub-groups based mainly on fruit weight and plant habit. Much variability observed for both Baladi and Franji accessions may be attributed to seed propagation and multiple origin of initial propagating material. These results indicate a significant diversity within the Lebanese germplasm that should be further completed by a DNA analysis to understand the genetic structure of this germplasm.***

Keywords: *Opuntia ficus indica* (L.) Mill, Germplasm, Morphology, Chemical traits, Variability

1. Introduction

Native to Latin America, *Opuntia ficus indica* (L.) Mill. commonly named prickly pear, is a long-domesticated cactus crop that is important in agricultural systems throughout arid and semiarid parts of the world (Anderson, 2001). It has been introduced in the Mediterranean basin in the 15th century (Donkin, 1977). The species is well known for its ability to grow in dry and even desert conditions and its cultivation has been especially important in marginal and subsistence economies (Vigueras and Portillo, 2001; Feugang, 2006). Commercial plantations are concentrated in Spain, Italy, Mexico, Brazil, Chile, Argentina, and USA (Basile, 2001). Prickly pear plants are used in a variety of ways, such as food and beverage, feed, medicinal and dyeing (De Kock, 1980; Pimienta and Muñoz-Urias, 1995). Seed oil of prickly pear is exceptionally valuable because of its high content of essential fatty acids such as linoleic acid (omega-6), Vitamin E (around 1000 mg/kg) and sterols (around 10 g/kg) (Ennouri *et al*, 2006).

A wide range of varieties are cultivated worldwide. They are mainly differentiated by the plant habit and fruit characteristics (Perez, 1993). Diversified germplasm has been reported in Mexico, Chile and USA with spiny and spine-less varieties and various peel and flesh color (Sudzuki, 1995; Pimienta and Muñoz-Urias, 1995). In the Mediterranean basin, Sicilian and Spanish cultivars such as 'Gialla' (yellow flesh),'Bianca' (white flesh) and 'Rossa' (red flesh) are widely cultivated (Barbera *et al*, 1992). Tentative to commercialize seedless varieties have been reported in the Mediterranean but with little success at the commercial level because of the small size of the fruit and its poor quality (Weiss *et al*, 1993).

In Lebanon, prickly pear culture is reported long time ago where it is mainly spread on the littoral and inland zones from South to North, between zero to 900 m of altitude. Prickly pear trees are mostly located at orchards periphery as natural fences or can be found in gardens and in some small commercial cultivations. They are cultivated mainly for fresh fruits consumption and more secondarily for arak production (alcoholic Lebanese beverage) and medicinal uses. Prickly pear has always been underutilized in Lebanon and its cultivation is not yet organized. Unfortunately, in Lebanon, no written data is available regarding neither for the history and distribution nor for the acreage and production of prickly pear. Although export of prickly pear fruits has been reported to Arab neighboring countries, relevant data are not available. Finally, prickly pear varieties grown in Lebanon have never been investigated before.

Due to its high adaptability to the arid and semi-arid conditions, to its extending market and to the low cost of maintenance and agricultural practices needed for this crop, much attention is being directed to develop prickly pear culture in Lebanon. This may contribute to the diversification of agriculture in the region, the development of new typical agricultural products and their increased offer at local markets, the introduction of prickly pear into food processing, feed and medicinal industry, the acquisition of new source of income for local growers and traditional farms, and the preservation of agrobiodiversity.

Traditionally, morphological descriptors are used to evaluate accessions and to assess their genetic diversity. Although expression of these descriptors is strongly influenced by environmental conditions and agricultural practices,

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morphological characterization is highly recommended as a first step prior to attempting advanced assessment through molecular markers (Hoogendijk and Williams, 2001). Additionally, the inventory of accessions based on morphological descriptions is of great importance for planning both genetic resources preservation and diversification strategies.

According to our knowledge there are no available records or any other information about Lebanese prickly pear accessions or varieties. In order to promote underutilized prickly pears as nutritionally rich and functional food and feed and to preserve existing genetic variability of prickly pears grown in Lebanon, the inventory and evaluation of accessions is necessary.

The main objectives of the this study were: (1) to make an inventory of prickly pears accessions growing in different orchards and home gardens in Lebanon, (2) to describe and evaluate collected plant material according to morphological characteristics and to determine the amount of morphological variability and genetic diversity. Expected results of this study will be used for the establishment of the first Lebanese prickly pears resources collection and for enhancing the study of agronomical important traits of varieties under equal growing conditions.

2. Material and Methods

2.1 Plant Material

Field survey and germplasm collecting mission were performed during vegetation (June - October) in 2012 with the aim of collecting a maximum of the in situ prickly pears accessions growing in family gardens and commercial plantations throughout Lebanon. Thirty two locations have been retained for the study spread over four main geographical areas, the North, the South, Mount Lebanon, and the elevated agricultural plateau of Bekaa (Fig. 1). They were located between 21 and 936 m of altitude and receiving rainfalls of 200 to 1050 mm (Table 1). A total of 43 accessions were defined for the study, based on the information given initially by the farmers. For each accession, five trees of 15 to 25 years old and having good canopy were chosen to be submitted to morphological characterization. In order to assure data traceability, information on GPS coordinates and elevations of the sampled trees were collected (Table 1). For each tree, five mature cladodes and 20 fully mature fruits (determined visually) were taken on lateral branches around the tree between first of August and mid-September.

2.2 Morphological and chemical descriptors

Characterization of prickly pear accessions was based on the list of cactus descriptors which were previously developed by the International Cooperation Network on Prickly Pear (Chessa and Nieddu, 1997). For each accession, 12 qualitative and 11 quantitative descriptors were then examined: plant shape (flat, round, elongate), vigor (low, intermediate, high) and habit (upright, medium, spreading, prostrate, shrubby, arborescent); cladode shape (ovate, round, elliptic), spines (absent, few, intermediate, many) and glochids (absent, few, intermediate, many); fruit shape (ovoid, round, elliptic, oblong) and weight (g) and glochids (absent, few, intermediate, many); recepticular scar position (sunken, flat, elevated), diameter (mm) and depth (mm); peel color (greenish orange, purple, greenish yellow, orange, pale orange, pink to orange, purple, yellowish green, yellow with orange), thickness (mm) and weight (g); pulp color (dark yellow, orange, orange-yellow, purple, red, violet, white, yellow, yellow-orange), firmness (firm, medium, soft) and weight (g); seed count; juice weight (g), pH, total soluble sugar (TSS, °Brix), titrable acidity (TA %).

2.3 Data analysis

Qualitative characteristics have been described and scored. For quantitative traits, the mean ± standard deviation and coefficient of variation were calculated. The normality test of Shapiro-Wilk was performed for each variable to check if the sample comes from a normally distributed population (Shapiro and Wilk, 1965). The coefficient of variation was calculated for quantitative characteristics. The estimation of variability for each qualitative and quantitative character was computed using the standardized Shannon-Weaver Diversity Index (H') (Shannon and Weaver, 1949). Diversity indices were compared based on Friedman formula at the level of significance α=0.01. To assess the degree of similarity between the units tested and understand the relationships between them, the data were subjected to a principal component analysis (PCA) in order to condense the quantitative and qualitative traits in a small number of synthetic components. Thus, the degree of contribution of each of the characters to the total variation was calculated in order to indicate the most relevant characters (Saporta, 1990). Hierarchical Cluster Analysis was executed using Euclidean Distance following the ward's method implemented in XLSTAT version 7.5.2 (Addinsoft, 2004).

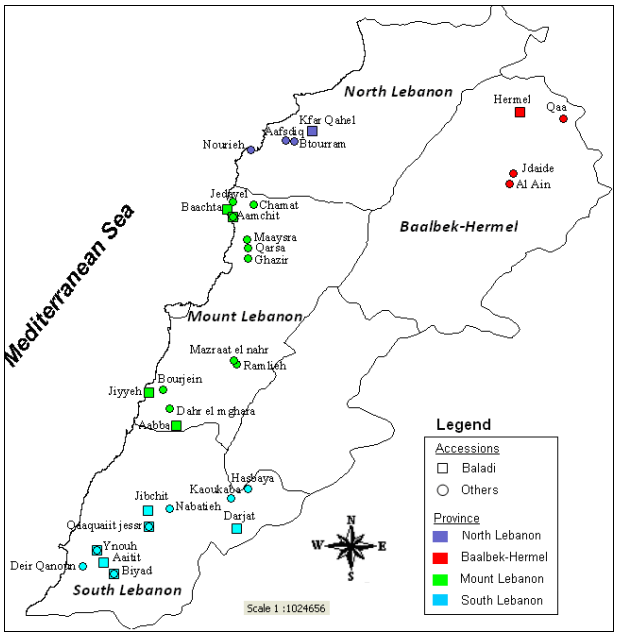


Fig. 1. Geographic distribution of prickly pear accessions sampled in the study as visualized with DIVA-GIS program (Hijmans *et al*, 2001).

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Table 1. Climatic and geographic distribution of the 32 locations surveyed for prickly pear accessions.

Location (caza)	Alt-itude (m)	Rain-fall (mm)	Latitude (°N)	Longitude (°E)	Accessions collected
Aabba (Mount Lebanon)	321	770	33°44'56"	35°39'22"	*Baladi Asfar ML1*
Aamchit (Mount Lebanon)	122	990	33°40'54"	35°26'49"	*Baladi Asfar ML2*
Aamchit - Deyr (Mount Lebanon)	132	990	33°15'45"	35°17'26"	*Franji Asfar ML3; Franji Asfar ML4*
Bourjein (Mount Lebanon)	487	777	33°25'12"	35°41'90"	*Franji Asfar ML5*
Chamat (Mount Lebanon)	454	990	33°23'44"	35°38'30"	*Franji Asfar ML6*
Dahr el mghara (Mount Lebanon)	282	777	34° 09'30"	35°38'20"	*Franji Asfar ML7*
Ghazir (Mount Lebanon)	639	1050	34° 9'53"	35°41'58"	*Franji Asfar ML8*
Jedayel (Mount Lebanon)	136	990	33°21'51"	35°25'21"	*Franji Asfar ML9*
Jiyyeh (Mount Lebanon)	44	770	33°40'34"	35°25'30"	*Baladi Asfar ML10*
Maaysra (Mount Lebanon)	550	1050	34° 4'26"	35°41'01"	*Franji Asfar ML11*
Mazraat el nahr (Mount Lebanon)	523	777	34°21'35"	35°51'12"	*Franji Asfar ML12*
Qarsa (Mount Lebanon)	590	1050	34°13'13"	36°22'12"	*Franji Asfar ML13*
Ramlieh (Mount Lebanon)	659	777	34°23'27"	36°30'43"	*Franji Asfar ML14; Espani Asfar ML15; Franji Violet ML16; Franji Asfar ML17*
Aaitit (South Lebanon)	311	794	33°39'24"	35°29'08"	*Baladi Asfar SL18*
Baachta (South Lebanon)	21	990	33°11'59"	35°20'06"	*Baladi Asfar SL19*
Biyad (South Lebanon)	370	794	33°13'09"	35°15'11"	*Franji Asfar SL20; Franji Asfar chmaii SL21; Baladi Asfar SL22*
Darjat (South Lebanon)	456	800	34° 8'33"	35°38'50"	*Baladi Asfar SL23*
Deir Qanoun (South Lebanon)	144	794	34° 8'38"	35°38'45"	*Franji Asfar SL24*
Hasbaya (South Lebanon)	718	800	34° 9'59"	35°38'20"	*Franji Ahmar SL25*
Jibchit (South Lebanon)	339	770	33°21'47"	35°24'28"	*Baladi Asfar SL26*
Kaoukaba (South Lebanon)	680	800	34° 01'24"	35°41'11"	*Franji Asfar SL27*
Nabatieh (South Lebanon)	440	770	34°20'02"	35°47'09"	*Franji Asfar SL28*
Qaaquaiit jessr (South Lebanon)	238	770	34°14'48"	36°22'50"	*Baladi Asfar SL 29; Franji Ahmar SL30*
Ynouh (South Lebanon)	90	794	34°24'32"	36°24'6"	*Baladi Asfar SL31; Franji Ahmar SL32*
Al Ain (Baalbek-Hermel)	917	250	33°13'42"	35°18'29"	*Baladi Asfar BH33*
Hermel (Baalbek-Hermel)	709	240	33°19'18"	35°25'21"	*Baladi Asfar BH34*
Jdaide (Baalbek-Hermel)	936	250	33°22'12"	35°28'46"	*Franji Ahmar Asfar BH35; Franji Ahmar BH36*
Qaa (Baalbek-Hermel)	583	200	34°19'52"	35°48'29"	*Ourdouni Asfar BH37; Franji Asfar BH38*
Btourram (North Lebanon)	270	819	33°18'58"	35°39'24"	*Franji Asfar NL39*
Aafsdik (North Lebanon)	307	824	34°19'54"	35°47'10"	*Franji Asfar ML40; Brazili Abyad ML41*
Kfar Qahel (North Lebanon)	110	819	34°03'05"	35°41'11"	*Franji Asfar NL42*
Nourieh (North Lebanon)	171	819	34°18'32"	35°41'37"	*Franji Ahmar NL43*

3. Results

3.1 General status of prickly pears plantations

Prickly pear trees were mostly growing in a sporadic way or scattered among other fruit trees in orchards and family gardens. Many of them were rather growing in very harsh conditions and in marginalized and rocky lands. Remarkably, seven commercial plantations of 0.5 to 2 ha were found with one plantation in Qaa (Bekaa North), two others in Chouf (Mount Lebanon), one in Batroun (North Lebanon), two in Hasbaya (South Lebanon) and one in Sour (South Lebanon) (Fig 1; Table 1). Cultural practices such as drop irrigation, fertilization pruning and pest treatments were applied only in commercial plantations.

When asking the farmers about the origin of their planting material, 12 of the 43 accessions studied were said to be local and putatively named "*Baladi*", while the other 31 accessions were imported from European (Spain), Arabic nurseries (Jordan) or others (*Brazili* as to Brazilian origin), and commonly designated by farmers as "*Franji"* (meaning foreigner in Arbic language) thus in association to the fruit skin color *(Abyad* meaning white, *Ahmar* meaning red, *Asfar* meaning yellow) (Table 1). It is worthy noted that both *Baladi* and *Franji* accessions were found in small and commercial plantations and their distribution was not linked to a specific geographic area.

3.2 Tree and cladode characteristics

Most of the accessions had a semi upright habit and a round shape *(e.g. Baladi Asfar ML2, Franji Asfar SL28, Franji Asfar ML5*) (Table 2). Only three accessions had a flat shape *(Franji Asfar ML6, Baladi Asfar ML1, Franji Asfar SL24)* and three other accessions were found with upright habit and elongated shape (*Franji Asfar BH33, Brazili Abyad ML41, Baladi Asfar SL31).* Tree vigor was intermediate for most of prickly pear accessions *(e.g. Baladi Asfar SL 29, Franji Asfar ML13, Franji Asfar ML3*). Only five accessions had low vigor *(e.g. Franji Asfar SL22, Baladi Asfar SL23)* while 11 accessions were highly vigorous (*e.g. Franji Asfar ML9, Baladi Asfar SL18).*

Also variability was noticed for the cladode characteristics among the 43 studied accessions (Table 2). Twenty eight of Franji accessions (on 31 studied) were spineless while all the 13 *Baladi* accessions studied were spiny. Among the spineless accessions, only one had ovoid cladodes *(Franji Ahmar Asfar BH35)* while the remaining 26 accessions had elliptical cladodes *(e.g. Franji Ahmar BH36, Ourdouni Asfar BH37).* Glochids were absent on the cladodes of all *Baladi* accessions while they were few to absent in *Franji* accessions.

3.3 Fruit and juice characteristics

Generally, maturity date started from Mid-July in the sites located in the littoral zone to late September in the sites located in the inland zone (data not shown). No differences were observed among accessions growing in the same area, since fruits of different accessions became mature at the same time.

Four fruit shapes were observed among the accessions studied (Table 3). Nineteen accessions were found with ovoid fruits *(e.g. Franji Asfar ML6, Baladi Asfar SL18)* and 16 accessions with elliptical fruits *(e.g. Ourdouni Asfar BH37, Franji Asfar SL28, Baladi Asfar SL20).* Oblong fruits were found in six accessions (*e.g. Franji Asfar BH33*) and in any of *Baladi* accessions, while only two accessions had round fruits *(Franji Asfar ML9, Franji Asfar BH38).* Fruit shape varied from between round, ovoid, oblong and elliptic for *Franji* accessions where it was mainly elliptic and ovoid for *Baladi* accessions.

Accessions studied had a sunken receptacular position except for two accessions, *Franji Asfar ML9 and Brazili Abyad NL41,* which had flat receptacular scar (Table 3).

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Four major peel colors were found among the 43 accessions studied at maturity stage of the fruit (Table 3). Twenty three accessions had orange peel (*e.g. Baladi Asfar ML1, Franji Asfar ML9*), five accessions had pink to orange peel (*Baladi Asfar BH34, Franji Asfar BH38, Franji Asfar NL39)* and four Franji accessions had purple peel *(e.g. Franji Violet ML16, Franji Ahmar SL25).* Greenish orange peel was found in five accessions *(e.g. Franji Asfar ML5, Baladi Asfar ML12, Franji Ahmar SL30).*

All accessions had glochids on their fruits at an intermediate density (Table 3). Only five accessions had few glochids *(e.g. Baladi Asfar ML12, Franji Asfar BH38)* while *Baladi Asfar SL20, Brazili Abyad NL41* were easily distinguished by the presence of many glochids on their fruits.

Pulp color was found to be orange in most accessions *(e.g. Franji Asfar ML17, Baladi Asfar SL29).* Only three accessions had dark yellow pulp (*Franji Asfar ML9, Franji Asfar NL39, Baladi Asfar NL42)* and one accession had white pulp Brazili Abyad NL41. For the remaining accessions, three *Franji* were found with violet pulp *(Franji Violet ML16, Franji Ahmar SL32, Franji Ahmar SL25),* one with red pulp *(Franji Ahmar NL43)* and one with purple pulp (*Franji Ahmar SL30)* (Table 3).

The majority of the accessions had small sized fruits (80-120 g) *(e.g. Baladi Asfar SL19, Franji Asfar ML4, Ourdouni Asfar BH37),* while six accessions had very small fruit (<80g) *(e.g. Baladi Asfar ML10, Franji Asfar ML17, Franji Ahmar Asfar BH35, Baladi Asfar NL42)* (Table 4). Medium sized fruits (121-150 g) were recorded for only nine accessions *(e.g. Franji Asfar ML6, Franji Asfar ML5, Franji Asfar SL24, Baladi Asfar ML12).*

Most of the "*Baladi"* and "Franji" accessions showed moderate peel weight ranging from 35 to 55 g *(e.g. Baladi Asfar ML1, Franji Asfar ML3)* (Table 4). Five accessions had light peel weight (< 35g) *(e.g. Baladi Asfar ML10, Franji Asfar ML17)* and six Franji accessions had heavy peel weight (> 55 g) *(e.g. Baladi Asfar ML12, Franji Asfar ML6, Franji Violet ML16, Franji Ahmar SL30).* As to the pulp weight, it ranged from 30.88 g (*Baladi Asfar ML10)* to 70.21 g *(Baladi Asfar ML12) for Baladi accessions and from 21.80 g (Franji Asfar ML17)* to 83.14 g (*Franji Asfar ML6).*

Fruits of most accessions contained moderate number of seeds with 208 to 300 seeds per fruit, vs. eight accessions with numerous seeds per fruit (up to 352 seeds per fruit) *(e.g. Ourdouni Asfar BH37, Franji Violet ML16, Franji Asfar ML14*) and four accessions with few seeds per fruit (100-200) (e*.g. Franji asfar ML17, Baladi Asfar ML10) (Table 4*).

Juice weight of mature fruits ranged from 12 to 54 g per fruit (Table 5). Two accessions (Franji Asfar ML5, Franji Ahmar SL25) were highly juicy while four accessions had very low juice content (*Franji Asfar ML17, Baladi Asfar ML10, Franji Ahmar Asfar BH35, Baladi Asfar NL42).*

The pH was slightly similar between accessions, varying between 5.06 (*Baladi* Asfar SL23) and 6.4 *(Franji Asfar ML17).* Sugar content varied between 7.14 *(Franji Asfar ML17)* and 14.24 °*Brix (Franji Ahmar SL32).* Actually twenty of the accessions studied had low sugar content with 10.56 to 11.99 °Brix and 11 accessions had moderate values while only two accessions had high sugar content of 14°Brix and above. Globally fruits are usually harvested few days before full maturity time while fruits still have a rather acid taste back.

Table 2. Plant and cladode characteristics for the 43 prickly pear accessions.

Accession Name	Plant vigor	Plant shape	Plant habit	Cladode shape	Spines density	Glochids density
Baladi Asfar ML1	High	Flat	Spreading	Ovate	Many	Absent
Baladi Asfar ML2	Average	Round	Medium	Ovate	Many	Absent
Franji Asfar ML3	Average	Round	Medium	Elliptic	Few	absent
Franji Asfar ML4	Average	Round	Medium	Elliptic	Few	Few
Franji Asfar ML5	High	Round	Shrubby	Elliptic	Few	Few
Franji Asfar ML6	High	Flat	Medium	Elliptic	Few	Absent
Franji Asfar ML7	Average	Round	Medium	Elliptic	Few	Few
Franji Asfar ML8	Average	Round	Medium	Elliptic	Few	Absent
Franji Asfar ML9	High	Round	Medium	Elliptic	Few	Absent
Baladi Asfar ML10	High	Round	Medium	Ovate	Many	Absent
Franji Asfar ML11	Average	Round	Medium	Elliptic	Few	Absent
Franji Asfar ML12	High	Round	Shrubby	Elliptic	Average	Absent
Franji Asfar ML13	Average	Round	Medium	Elliptic	Few	Absent
Baladi Asfar SL18	High	Round	Medium	Elliptic	Few	Absent
Espani Asfar ML15	Average	Round	Shrubby	Elliptic	Absent	Few
Franji Violet ML16	Average	Round	Shrubby	Elliptic	Absent	Few
Franji Asfar ML17	Average	Round	Medium	Elliptic	Absent	Few
Baladi Asfar SL18	Average	Round	Medium	Elliptic	Many	Absent
Baladi Asfar SL19	Average	Round	Medium	Ovate	Many	Absent
Franji Asfar SL20	High	Round	Medium	Elliptic	Many	Few
Franji Asfar SL21	Average	Round	Medium	Elliptic	Few	Absent
Baladi Asfar SL22	Low	Round	Medium	Ovate	Few	Absent
Baladi Asfar SL23	Low	Round	Medium	Ovate	Many	Absent
Franji Asfar SL24	Average	Flat	Prostrate	Elliptic	Few	Absent
Franji Ahmar SL25	Average	Round	Medium	Elliptic	Few	Few
Baladi Asfar SL26	Average	Round	Medium	Elliptic	Many	Absent
Franji Asfar SL27	High	Round	Medium	Elliptic	few	Absent
Franji Asfar SL28	Average	Round	Medium	Elliptic	Average	Absent
Baladi Asfar SL29	Average	Round	Medium	Ovate	Many	Absent
Franji Ahmar SL30	Low	Round	Medium	Elliptic	Few	Absent
Baladi Asfar SL31	High	Elongate	Upright	Elliptic	Many	Absent
Franji Ahmar SL32	Average	Round	Shrubby	Elliptic	Few	Absent
Baladi Asfar BH33	High	Elongate	Upright	Elliptic	Few	Absent
Baladi Asfar BH34	Average	Round	Medium	Elliptic	Many	Absent
Franji Ahmar BH35	Low	Round	Shrubby	Ovate	Absent	Few
Franji Ahmar BH36	High	Round	Shrubby	Elliptic	Absent	Few
Ourdouni BH37	Average	Round	Medium	Elliptic	Absent	Few
Franji Asfar BH38	Average	Round	Shrubby	Elliptic	Absent	Absent
Franji Asfar NL39	High	Round	Shrubby	Elliptic	Few	Absent
Franji Asfar NL40	High	Round	Arborescent	Elliptic	Few	Absent
Brazili Abyad NL41	High	Elongate	Upright	Elliptic	Many	Few
Franji Asfar NL42	High	Round	Medium	Elliptic	Many	Absent
Franji Ahmar NL43	Average	Round	Medium	Elliptic	Few	Absent
CV%	34.11	18.194	45.974	31.915	42.887	35.329

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Table 3. Qualitative morphological fruit characteristics for the 43 prickly pear accessions.

Accession Name	Fruit Glochids	Fruit Shape	Receptacle Position	Peel Color	Pulp Color	Pulp Firmness
Baladi Asfar ML1	Intermediate	Ovoid	Sunken	Orange	Orange-Yellow	Firm
Baladi Asfar ML2	Intermediate	Elliptic	Sunken	Orange	Orange	Medium
Franji Asfar ML3	Intermediate	Elliptic	Sunken	Pale orange	Yellow	Soft
Franji Asfar ML4	Intermediate	Oblong	Sunken	Orange	Yellow-Orange	Soft
Franji Asfar ML5	Intermediate	Elliptic	Sunken	Greenish orange	Orange	Medium
Franji Asfar ML6	Intermediate	Ovoid	Sunken	Greenish orange	Orange	Medium
Franji Asfar ML7	Intermediate	Ovoid	Sunken	Yellowish with orange	Yellow-Orange	Firm
Franji Asfar ML8	Intermediate	Elliptic	Sunken	Greenish orange	Orange	Soft
Franji Asfar ML9	Intermediate	Round	Flat	Orange	Dark Yellow	Medium
Baladi Asfar ML10	Intermediate	Ovoid	Sunken	Orange	Yellow-Orange	Medium
Franji Asfar ML11	Intermediate	Elliptic	Sunken	Greenish orange	Orange	Soft
Franji Asfar ML12	Few	Ovoid	Sunken	Greenish orange	Orange	Firm
Franji Asfar ML13	Few	Elliptic	Sunken	Orange	Orange	Soft
Franji Asfar ML14	Intermediate	Elliptic	Sunken	Orange	Orange	Medium
Espani Asfar ML15	Intermediate	Oblong	Sunken	Orange	Orange	Medium
Franji Violet ML16	Intermediate	Oblong	Sunken	Purple	Violet	Medium
Franji Asfar ML17	Intermediate	Elliptic	Sunken	Greenish Yellow	Orange	Firm
Baladi Asfar SL18	Intermediate	Ovoid	Sunken	Orange	Orange	Medium
Baladi Asfar SL19	Intermediate	Ovoid	Sunken	Orange	Yellow	Medium
Franji Asfar SL20	Many	Elliptic	Sunken	Orange	Orange	Soft
Franji Asfar Chmaii SL21	Intermediate	Oblong	Sunken	Orange	Orange-Yellow	Soft
Baladi Asfar SL22	Few	Ovoid	Sunken	Greenish Yellow	Orange-Yellow	Firm
Baladi Asfar SL23	Intermediate	Ovoid	Sunken	Orange	Yellow	Soft
Franji Asfar SL24	Intermediate	Elliptic	Sunken	Orange	Yellow	Medium
Franji Ahmar SL25	Intermediate	Ovoid	Sunken	Purple	Violet	Medium
Baladi Asfar SL26	Intermediate	Ovoid	Sunken	Orange	Orange	Soft
Franji Asfar SL27	Intermediate	Ovoid	Sunken	Orange	Orange	Firm
Franji Asfar SL28	Intermediate	Elliptic	Sunken	Orange	Orange	Soft
Baladi Asfar SL29	Intermediate	Ovoid	Sunken	Orange	Orange	Medium
Franji Ahmar SL30	Intermediate	Ovoid	Sunken	Greenish purple	Purple	Soft
Baladi Asfar SL31	Intermediate	Elliptic	Sunken	Orange	Orange	Firm
Franji Ahmar SL32	Intermediate	Ovoid	Sunken	Purple	Violet	Firm
Baladi Asfar BH33	Intermediate	Oblong	Sunken	Orange	Orange	Medium
Baladi Asfar BH34	Intermediate	Ovoid	Sunken	Pink to orange	Yellow	Soft
Franji Ahmar Asfar BH35	Intermediate	Ovoid	Sunken	Pink to orange	Orange-Yellow	Medium
Franji Ahmar BH36	Intermediate	Ovoid	Sunken	Pink to orange	Orange	Medium
Ourdouni Asfar BH37	Intermediate	Elliptic	Sunken	Orange	Orange	Soft
Franji Asfar BH38	Few	Round	Sunken	Pink to orange	Yellow	Soft
Franji Asfar NL39	Intermediate	Ovoid	Sunken	Pink to orange	Dark Yellow	Medium
Franji Asfar NL40	Intermediate	Elliptic	Sunken	Orange	Orange	Medium
Brazili Abyad NL41	Many	Elliptic	Flat	Yellowish green	White	Firm
Franji Asfar NL42	Intermediate	Elliptic	Sunken	Orange	Dark Yellow	Medium
Franji Ahmar NL43	Intermediate	Ovoid	Sunken	Purple	Red	Soft
CV%	16.44	48.99	11.621	42.111	71.398	33.521

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Table 4. Quantitative morphological fruit characteristics for the 43 prickly pear accessions.

Accession Name	Fruit Weight (g)	Receptacle diameter (mm)	Receptacle depth (mm)	Peel Thickness (mm)	Peel weight	Pulp weight	Seed number
Baladi Asfar ML1	91.12±20.61	21.59±2.77	6.03±1.55	4.81±2.53	48.20±14.27	42.64±13.21	220
Baladi Asfar ML2	82.05±11.44	17.23±1.37	6.50±1.24	3.14±0.81	35.57±5.85	43.19±8.63	227
Franji Asfar ML3	102.20±19.94	20.11±1.60	6.95±1.29	3.36±0.46	47.20±7.69	54.30±14.87	213
Franji Asfar ML4	107.82±28.19	18.12±0.85	4.03±0.82	2.25±0.71	37.80±12.68	70.30±16.27	274
Franji Asfar ML5	135.71±30.23	17.77±1.23	4.59±1.28	2.96±0.73	53.92±13.83	80.50±17.21	324
Franji Asfar ML6	141.13±22.43	17.58±1.39	5.80±1.31	3.04±0.57	57.43±5.53	83.14±20.90	255
Franji Asfar ML7	113.80±16.87	17.59±2.77	4.01±2.13	3.66±0.76	46.50±9.80	66.10±8.37	300
Franji Asfar ML8	124.75±34.50	20.57±2.32	5.07±1.48	3.44±0.52	52.65±18.89	72.10±18.37	246
Franji Asfar ML9	121.59±38.86	23.91±3.17	2.93±2.13	5.84±2.55	62.41±21.85	61.06±16.92	281
Baladi Asfar ML10	68.71±22.04	18.92±1.16	7.08±1.39	3.95±1.40	36.79±14.25	30.88±9.43	178
Franji Asfar ML11	80.76±16.31	17.63±2.20	5.09±1.53	3.47±1.21	33.76±6.04	47.00±11.98	195
Franji Asfar ML12	124.04±19.12	17.36±1.55	5.16±1.19	2.90±0.74	51.00±7.27	70.21±14.07	269
Franji Asfar ML13	104.40±31.70	19.84±1.56	4.40±1.14	3.56±0.88	47.40±15.64	53.76±21.98	242
Franji Asfar ML14	112.43±29.09	14.57±2.38	5.05±1.47	2.56±0.78	40.78±12.60	70.09±17.84	316
Espani Asfar ML15	89.90±16.82	17.37±1.57	6.87±1.45	3.14±1.08	42.40±10.04	47.50±12.18	304
Franji Violet ML16	121.40±24.85	19.52±0.48	5.62±1.24	3.90±1.19	57.20±12.36	64.20±13.77	319
Franji Asfar ML17	48.20±12.13	15.67±1.30	6.75±0.20	2.45±0.21	26.40±5.18	21.80±7.12	171
Baladi Asfar SL18	116.36±25.91	18.21±2.54	4.24±1.50	3.21±1.06	48.72±14.70	65.72±14.27	270
Baladi Asfar SL19	86.95±15.27	19.46±2.07	5.57±0.96	3.91±1.03	40.68±8.08	44.21±9.50	217
Franji Asfar SL20	81.80±17.82	16.16±1.15	4.76±1.94	2.55±0.94	44.16±25.03	45.60±11.82	251
Franji Asfar Chmaii SL21	73.40±9.61	19.85±0.87	5.82±0.78	2.52±0.78	36.40±4.51	37.00±9.80	260
Baladi Asfar SL22	108.00±15.03	20.31±0.51	6.46±0.26	3.99±0.44	56.60±5.13	51.40±10.99	322
Baladi Asfar SL23	106.09±16.84	17.83±2.39	5.18±0.89	3.09±1.07	40.57±9.25	64.38±11.49	297
Franji Asfar SL24	131.04±28.93	18.92±1.85	4.54±1.72	3.31±0.86	54.04±12.36	69.64±15.37	282
Franji Ahmar SL25	122.60±14.41	20.54±1.98	3.15±0.52	2.72±1.03	43.10±8.25	77.90±7.59	303
Baladi Asfar SL26	105.96±19.22	18.82±1.55	3.88±1.21	3.02±0.61	46.96±8.09	56.00±14.27	269
Franji Asfar SL27	91.95±20.57	18.05±1.77	4.98±1.42	3.16±0.85	34.80±8.62	54.40±15.93	270
Franji Asfar SL28	74.84±15.92	18.06±2.71	6.12±1.50	2.82±0.53	33.08±7.05	41.48±10.60	233
Baladi Asfar SL29	94.91±30.30	21.68±2.60	6.69±1.85	4.76±2.74	49.05±22.71	45.55±15.74	209
Franji Ahmar SL30	123.40±17.77	20.40±2.51	5.95±1.40	3.97±0.90	60.60±5.32	62.80±14.65	235
Baladi Asfar SL31	83.56±16.90	15.66±1.51	5.46±1.01	3.22±0.69	38.56±8.85	43.84±9.73	251
Franji Ahmar SL32	98.80±19.49	20.21±2.05	4.83±0.96	3.19±0.14	49.20±7.33	49.60±12.22	260
Baladi Asfar BH33	90.13±33.76	18.03±1.81	5.95±0.72	2.29±0.70	34.73±16.28	55.40±18.73	285
Baladi Asfar BH34	87.84±19.70	18.50±2.44	5.44±1.40	3.67±0.88	38.76±6.55	49.08±13.90	251
Franji Ahmar Asfar BH35	54.80±8.87	15.10±1.47	6.86±1.50	3.11±0.65	23.87±4.42	30.93±5.87	198
Franji Ahmar BH36	93.70±14.17	17.97±1.79	5.84±1.15	2.42±0.88	41.40±9.97	52.30±10.25	239
Ourdouni Asfar BH37	117.80±10.94	17.28±1.07	7.46±0.52	3.84±0.34	52.00±3.16	65.80±8.67	353
Franji Asfar BH38	106.70±12.85	21.31±1.98	3.21±1.05	4.25±1.27	45.20±7.93	61.50±12.43	277
Franji Asfar NL39	105.56±28.20	19.25±3.10	4.93±1.41	2.84±1.19	42.88±10.74	62.68±19.50	270
Franji Asfar NL40	82.80±11.02	19.90±2.27	6.61±3.57	3.73±1.11	41.75±5.32	41.05±7.80	253
Brazili Abyad NL41	115.00±31.99	25.83±2.20	0.00±0.00	2.28±0.54	36.80±9.01	76.80±22.33	289
Franji Asfar NL42	74.44±17.21	16.52±1.57	7.93±1.48	3.65±1.25	40.40±9.50	34.04±9.80	260
Franji Ahmar NL43	117.40±29.08	25.97±3.97	3.78±1.87	6.59±2.30	71.60±20.18	45.80±12.31	261

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Table 5. Quantitative juice characteristics for the 43 prickly pear accessions.

Accession Name	PH	TSS (°Brix)	TA (%)
Baladi Asfar ML1	5.91±0.15	10.59±1.62	0.43±0.55
Baladi Asfar ML2	6.14±0.11	10.93±2.42	0.12±0.04
Franji Asfar ML3	5.58±0.68	11.88±2.15	0.17±0.10
Franji Asfar ML4	5.82±0.13	11.19±0.80	0.22±0.10
Franji Asfar ML5	5.92±0.26	11.65±1.58	0.12±0.04
Franji Asfar ML6	6.13±0.19	12.21±0.72	0.16±0.03
Franji Asfar ML7	6.08±0.13	11.19±1.25	0.13±0.05
Franji Asfar ML8	6.16±0.13	11.42±1.47	0.17±0.12
Franji Asfar ML9	5.92±0.31	12.69±1.11	0.12±0.03
Baladi Asfar ML10	6.05±0.41	9.25±1.72	0.20±0.17
Franji Asfar ML11	6.06±0.17	10.97±1.50	0.24±0.31
Franji Asfar ML12	6.12±0.47	11.55±1.03	0.13±0.03
Franji Asfar ML13	6.00±0.13	11.47±1.74	0.10±0.03
Franji Asfar ML14	5.73±0.64	11.40±1.68	0.11±0.04
Espani Asfar ML15	6.07±0.19	11.11±1.47	0.20±0.04
Franji Violet ML16	6.12±0.14	12.72±0.48	0.44±0.14
Franji Asfar ML17	6.36±0.23	7.14±1.45	0.24±0.05
Baladi Asfar SL18	6.09±0.22	12.28±1.62	0.10±0.05
Baladi Asfar SL19	5.98±0.18	12.24±1.12	0.15±0.11
Franji Asfar SL20	5.86±0.35	12.29±2.62	0.19±0.11
Franji Asfar Chmaii SL21	6.15±0.11	12.24±0.68	0.16±0.02
Baladi Asfar SL22	6.13±0.25	7.30±0.46	0.24±0.08
Baladi Asfar SL23	5.06±0.69	12.80±1.36	0.12±0.04
Franji Asfar SL24	5.69±0.69	11.98±1.54	0.26±0.13
Franji Ahmar SL25	5.97±0.13	12.05±1.11	0.15±0.09
Baladi Asfar SL26	5.82±0.29	11.99±1.56	0.20±0.14
Franji Asfar SL27	5.93±0.37	10.58±2.22	0.15±0.04
Franji Asfar SL28	6.09±0.58	10.56±2.39	0.12±0.03
Baladi Asfar SL29	6.09±0.14	10.72±1.86	0.29±0.20
Franji Ahmar SL30	6.17±0.08	11.32±1.24	0.16±0.20
Baladi Asfar SL31	6.30±0.17	10.17±1.81	0.14±0.11
Franji Ahmar SL32	5.98±0.12	14.24±0.45	0.16±0.07
Baladi Asfar BH33	6.09±0.11	11.09±2.09	0.18±0.05
Baladi Asfar BH34	5.99±0.15	12.34±1.42	0.12±0.03
Franji Ahmar Asfar BH35	6.16±0.09	11.65±1.25	0.24±0.09
Franji Ahmar BH36	5.99±0.08	14.04±0.84	0.19±0.06
Ourdouni Asfar BH37	6.02±0.11	12.82±0.33	0.23±0.04
Franji Asfar BH38	5.88±0.07	12.48±2.31	0.10±0.01
Franji Asfar NL39	5.89±0.15	12.06±0.86	0.20±0.05
Franji Asfar NL40	6.05±0.18	12.13±2.24	0.21±0.08
Brazili Abyad NL41	6.02±0.39	11.18±0.73	0.08±0.02
Franji Asfar NL42	5.51±0.20	12.41±2.21	0.21±0.07
Franji Ahmar NL43	6.07±0.18	10.69±2.53	0.20±0.07

3.4 Descriptors validation

Principal component analysis has been conducted in order to determine which of the 23 morphological descriptors were the most discriminating for the 43 accessions studied (Table 6). The first 3 components represent 45.7 % of the total variation. The first component characterized by 21.4 % of variation is represented by fruit weight, juice weight, pulp weight and seed number. The second component counting 13.3 % of the total variation is explained by the peel thickness, plant vigor, habit and shape. The third component represents 10.9 % of the total variation and is characterized by the receptacle diameter and cladode shape. Based on the Principle Component Analysis (Table 6) and among the 23 studied descriptors, 10 characters of the shrub and the fruit, proved to be the most discriminating characteristics (as per the first three components) between the prickly pear accessions cultivated in Lebanon. The Shannon Weaver Diversity Index (H') calculated for the most discriminate descriptors were globally high varying between 2.35 and 3.40 (Table 7). The highest values were recorded for tree quantitative characters that are mostly influenced by agroclimatic conditions and cultural practices. For *Baladi* accessions, the lowest H' of 2.35 was recorded for tree habit while the highest value was 2.48 and obtained for fruit weight. For foreign accessions, H' recorded respectively the highest value of 3.40 for plant shape and the lowest value of 3.33 for plant vigor. Friedman's Q test revealed that H' index calculated according to the studied descriptors, is significantly different between the *Baladi* accessions and the others at α=0.01.

3.5 Relationships between accessions

The PCA bi-plot (Fig. 2) showed a relative separation between accessions with high fruit weight present in the positive part of PC1 from accession with low fruit weight present in the negative part of PC1. Furthermore, PC2 separated accessions of the PC1 positive part based mainly on the peel thickness, with *Franji Ahmar NL43* (6.59 mm) and *Brazili Abyad NL41* (2.28 mm) being the most dissimilar accessions. Also, PC2 separated accessions of the PC1 negative part based mainly on plant vigor, *Baladi Asfar SL22* being the less vigorous and *Baladi Asfar SL31* the highest one. Moreover, there was not a likely spatial differentiation between the accessions according to their areas of cultivation in the country whether of South, North, Mount Lebanon or Baalbek Hermel neither to their country of origin whether local or imported.

The dendogram constructed on the base of the 23 characters showed a large variability among the 43 accessions studied (Fig. 3). *Brazili Abyad NL41* was the most different one compared to all other 42 accessions, privileged by a yellowish green peel and a white pulp. On the other hand, results showed that *Brazili Abyad NL41* and *Baladi Asfar SL22* were the most dissimilar accessions (84.74 %) due to significant differences in fruit, seed and tree characteristics except for the fruit weight, receptacle diameter and juice pH at full maturity time. The closest accessions were *Baladi Asfar SML18* and *Baladi Asfar SL26* both cultivated in South Lebanon with 1.35% of dissimilarity resulting from

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Table 6. Principle Component Analysis (PCA) of the different characteristics evaluated for the 43 prickly pear accessions.

Variable	F1	F2	F3	F4	F5
Plant habit	0.076	-0.356	0.186	-0.130	-0.168
Plant shape	-0.088	0.361	-0.192	0.176	-0.082
Plant vigor	-0.056	0.320	-0.035	0.209	-0.230
Cladode shape	-0.192	0.164	0.292	0.080	0.061
Spines	-0.051	-0.053	0.224	0.132	0.520
Plant glochids	0.036	-0.209	-0.118	0.173	-0.501
Fruit glochids	0.027	-0.269	0.058	0.255	0.066
Fruit shape	0.117	0.212	0.274	0.079	-0.101
Receptacle position	-0.220	0.189	-0.280	-0.003	-0.118
Peel color	0.106	-0.107	0.273	0.374	-0.303
Pulp color	0.122	0.080	0.156	0.438	-0.130
Pulp firmness	0.030	0.241	-0.250	0.252	0.159
Fruit weight	0.417	0.115	-0.121	-0.174	-0.005
Receptacle diameter	0.251	0.124	0.392	-0.030	0.026
Receptacle depth	-0.361	0.129	-0.129	-0.114	-0.028
Peel thickness	0.061	0.336	0.358	-0.156	0.028
Peel weight	0.287	0.281	0.062	-0.271	-0.009
Juice weight	0.393	-0.047	-0.224	-0.046	-0.007
Pulp weight	0.410	-0.024	-0.216	-0.065	-0.009
pH	-0.100	-0.084	0.091	-0.382	-0.292
TSS	0.208	0.017	-0.135	0.279	0.056
TA	-0.129	0.077	0.138	-0.113	-0.325
% variance	19.792	14.280	11.030	8.879	8.019

Table 7. Shannon diversity index for the 10 most discriminating characteristics of the plant, fruit and juice for the 43 prickly pear accessions.

Traits	H' Baladi	H' other
Fruit weight	2.48	3.37
Peel thickness	2.47	3.37
Juice weight	2.46	3.35
Pulp weight	2.47	3.36
Seeds number	2.45	3.37
Plant vigor	2.41	3.33
Plant shape	2.44	3.40
Plant habit	2.35	3.40
Cladode shape	2.35	3.34
Receptacle diameter	2.43	3.36

significant differences in pulp firmness and TA%. On the other hand, many cases of close similarity were found between accessions growing in different agro-climatic conditions. For instance, close similarity was noticed between *Franji Asfar ML11* from Mount Lebanon and *Franji Asfar SL28* from the South with 1.67% of dissimilarity retained from peel color, spine density and TA%; *Franji Asfar ML14* growing in Mount Lebanon and *Franji Asfar NL39* from North Lebanon (2.75%); *Franji Asfar Chamii SL21* and *Franji Asfar SL28* from the South with *Franji Asfar ML11* from Mount Lebanon (2.78%); *Baladi Asfar ML2* cultivated in Mount Lebanon and *Baladi Asfar SL29* from the South; *Baladi Asfar SL31* from South and *Baladi Asfar BH33* cultivated in the province of Bekaa Hermel (3.35%).

Globally the genetic relationship between accessions displayed three main groups at 88.56 % of dissimilarity based on Euclidean distance (Fig. 3), according to fruit size and peel color. Thus *Brazili Abyad NL41* with white peel, shallow receptacle and low TA% (0.08%) was well differentiated from the other accessions alone in one group. Group II was constituted of both *Baladi and Franji* accessions with average to big sized fruits (88 - 141 g) while Group III gathered *Baladi and Franji* accessions with small sized fruits (48 - 108 g).

At 30.92% dissimilarity, six clusters were differentiated with sub-clustering of Group II into two subgroups and Group III into three sub-groups.

- Sub-group II.1 is the largest one regrouping 23 accessions of which 19 *Franji* and four *Baladi* accessions characterized by the highest fruit weight for the majority of accessions and the second highest peel weight (after accessions of Sub-group II.2).
- Sub-group II.2 is constituted of accessions *Franji Asfar ML9* and *Franji Ahmar NL43* that differ from the others accession by their very large and low depth receptacle diameter that place them close to *Brazili Abyad NL41*. Moreover, these two accessions are differentiated by having the highest values for peel thickness (5.8-6.6 mm) and weight (62.4-71.6 g).
- Subgroup III.1 regroups nine *Franji* accessions cultivated in the different eco-geographical regions of the south *(Franji Asfar SL20, Franji Asfar Chmaii SL21, Franji Asfar SL27, Franji Asfar SL28),* north *(Franji Asfar NL42),* Mount Lebanon *(Franji Asfar NL40 (Franji Asfar ML11, Franji Asfar ML17),* and Baalbek-Hermel (*Franji Ahmar Asfar BH35*) and sharing elliptical cladode shape and small to intermediate sized fruits.
- Sub-group III.2 regroups the two *Baladi Asfar SL31* and *Baladi Asfar BH33* having in common an upright habit and elongate plant shape.
- Sub-group III.3 is constituted of three *Baladi* accessions cultivated in South and three other *Baladi* from Mount Lebanon characterized by large receptacle diameter (17.23 to 21.59 mm) and ovate cladodes.

3. Discussion

This study is the first report on the assessment of prickly pear varieties growing in Lebanon. Out of 43 accessions collected in different agro-climatic areas, 12 accessions putatively named *Baladi* were considered as local while the 31 others designated as *Franji* accessions were initially introduced from overseas such as Brazil, Spain and Jordan, and currently constitute much of the prickly pears cultivated in the country. Nevertheless, none of these foreign varieties is known by its authentic name as it is often the case for many fruit crops cultivated in the region (Chalak *et al*, 2007 and 2013; Hmimsa *et al*, 2012). Moreover, none of these foreign accessions were found to be directly introduced from cactus area of origin. However, according to Saenz et al (2013), prickly pear species were introduced from Mexico into Spain to be quickly spread throughout the Mediterranean Basin. As to the Lebanese farmer's requirements, foreign varieties have been initially preferred for spineless cladodes and their different fruit colors giving good returns since *Baladi* accessions used to produce spiny cladodes and yellow fruits mainly. Similarly, Bendhifi *et al* (2013) considered the absence of spines in prickly pear accessions as a main morphological trait selected by

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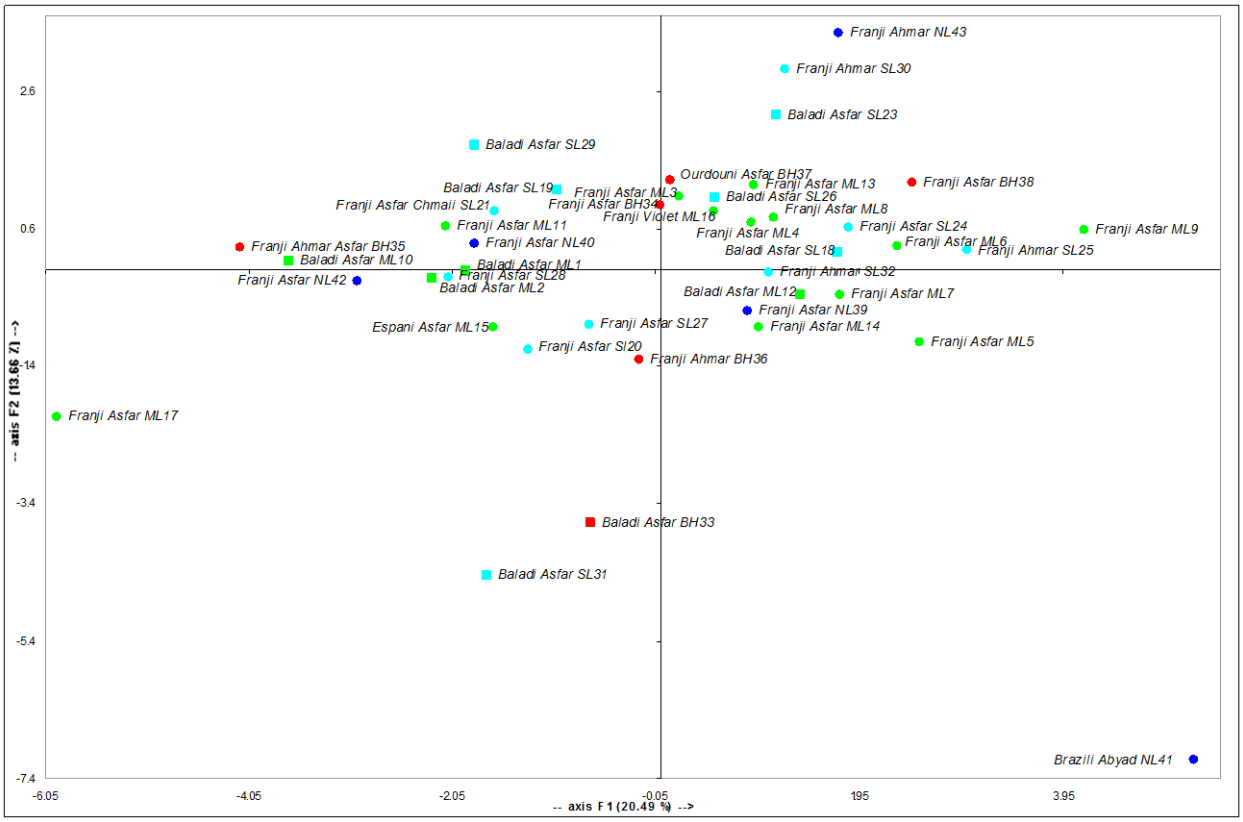


Fig. 2: PCA plot of 43 prickly pear accessions based on the first two principal axes accounting for 34.15% of the total genetic variation (first axis =20.49% and second = 13.66% of total variation). Accessions are colored depending on their geographic origin (blue color to north Lebanon, red to Baalbek-Hermel, green to Mount Lebanon and turquoise to south Lebanon).

Tunisian farmers. Additionally, Pena-Valdivia *et al* (2007) find a clear separation between prickly pear Mexican accessions according to the spines presence on cladodes. On the other hand fruit color constitutes an important criterion for the consumers in many countries such as Tunisia (El-Guizani *et al*, 2012). Nevertheless, despite the importance of the spineless cladode trait and the fruit size and quality characteristics, no efforts are locally deployed by farmers or research institutions in terms of breeding and genetic improvement.

As to cladodes and fruit qualitative and quantitative characteristics recorded for our studied accessions, they may recall those previously reported on other varieties cultivated in different countries. Thus some of our *Franji* foreign accessions, e.g. *Franji Ahmar SL32*, would look like the Italian commercial varieties 'Rossa', 'Bianca' and 'Gialla' (Barbera *et al*, 1992) as well as the Turkish variety 'Boron' (Karababa *et al*, 2004) and some Mexican varieties (Chessa and Nieddu, 1997). As for the local *Baladi* accessions globally characterized by their small sized fruits (<80 g), they rather resemble to the Turkish ones particularly the one called "Adana" and assumed as wild compared to the improved varieties characterized by their large sized fruits (Karababa *et al*, 2004). Such similarity is not surprising and may result from the historical commercial exchange between these two countries located in the eastern shore of the Mediterranean. As to the chemical juice traits, our accessions showed mostly a high pH and a low to moderate sugar content (7.14 to 14.24 °Brix). These traits analysis should be repeated in the coming years with respect to the environmental conditions and the maturity period as previously suggested in a similar study (Duru and Turker, 2005; El-Samahy *et al*, 2006).

Regarding the descriptors used in this study, both PCA and Shannon Weaver Diversity Index indicated that fruit quantitative traits (fruit weight, peel weight, pulp weight, and juice weight and peel thickness) were significant when assessing the level of variation among prickly pears accessions and are hence considered as the most discriminate traits. Nevertheless cladode traits contributed less to the discrimination between the accessions as previously noticed in other prickly pear accessions cultivated in other countries as in Mexico (Pena-Valdivia *et al*, 2007).

When comparing the variability of *Baladi* accessions to the others imported, Shannon Weaver Diversity Index (H') was medium for *Baladi* accessions with values ranged between 2.35 and 2.48 (fruit weight) and higher for the foreign accessions with a maximum value of 3.33 (plant size). The highest (H') values were recorded for fruit quantitative characters that are mostly influenced by agroclimatic conditions and agricultural practices. Actually the potential effect of such factors on morphological variability of prickly pears growing in Lebanon could not be excluded as previously shown for other prickly pear varieties that performed differently in various agro-ecological conditions

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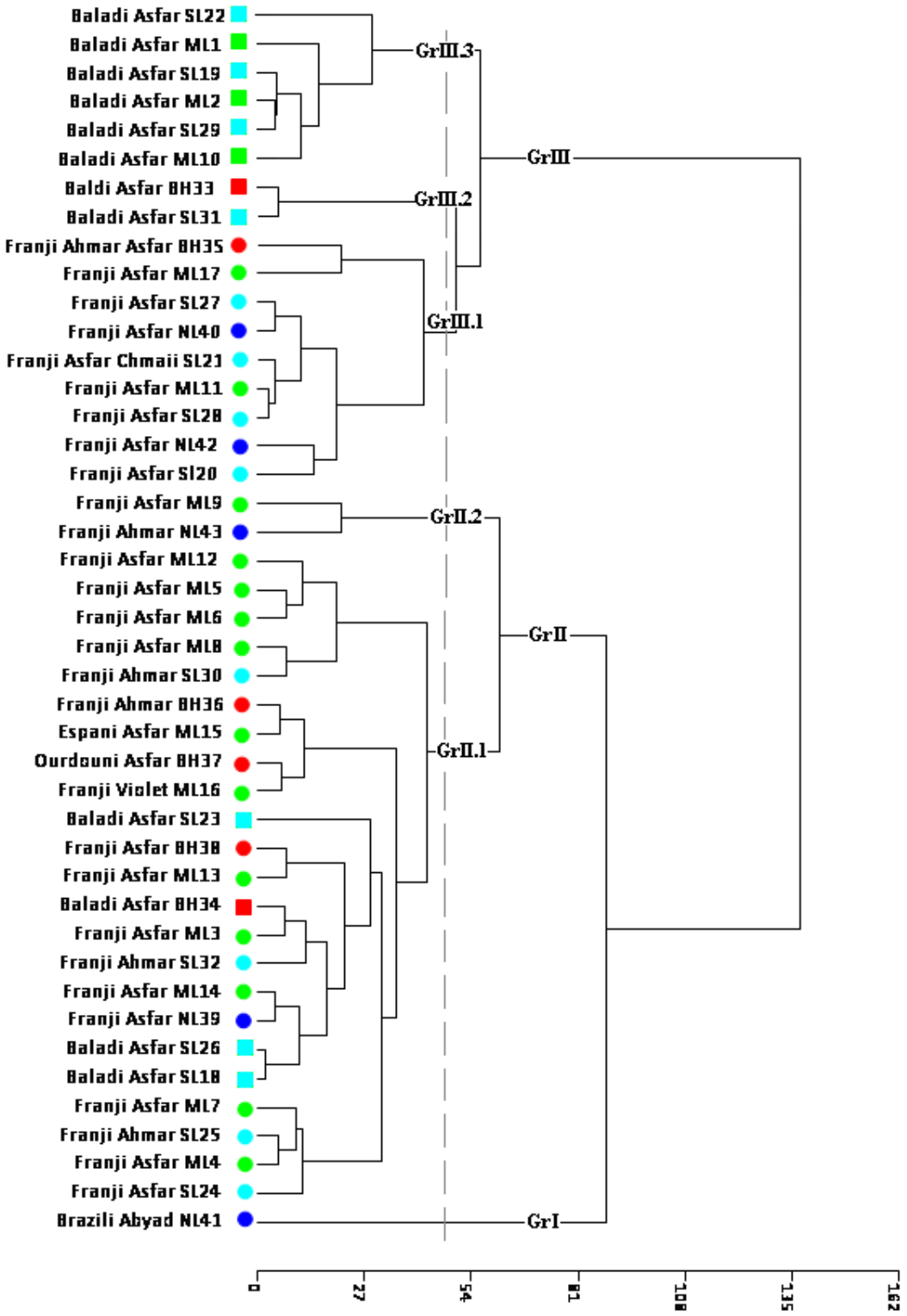


Fig. 3: Dendrogram based on Euclidean distance using Ward's method, to study the genetic relationships among the 43 prickly pear accessions characterized by their morphologic traits. Circle indicates local accessions called *Baladi* and square indicates the others. Accessions are colored depending on their geographic origin (blue color to north Lebanon, red to Baalbek-Hermel, green to Mount Lebanon and turquoise to south Lebanon).

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in South-African due to the interaction effect of genotypes with environmental conditions (Wit *et al*, 2010). However, the variability revealed in both *Baladi and Franji* accessions could also be attributed to genetic factors, as many accessions with the same denomination and from the same location presented different fruit traits. This variability is quietly expected in *Baladi* accessions which have long been propagated mostly by seeds. Surprisingly, much variability was observed in *Franji a*ccessions assumed to be propagated vegetative through cladodes; this could be due to the initial diversity of propagating materials and their multiple origins coming from different countries such as Jordan, Spain and Brazil. On the other hand, the close similarity observed between nine *Franji* accessions growing in different agroclimatic zones of the country may indicated the existence of clones locally exchanged through cladodes between farmers. Such clonality was also noticed between two *Baladi* accessions cultivated in Baalbek-Hermel and South Lebanon. These results are in line with those previously reported in Tunisia where the same genetic material was found to be growing in different geographical areas (Bendhifi *et al*, 2013).

Regarding the genetic relationships among the accessions studied, there was no likely a spatial differentiation between them according to whether they are local (*Baladi)* or imported *(Franji*), except for the accession introduced from Brazil that was clearly differentiated from the others by its yellowish green peel color and white pulp color. Likewise, many foreign accessions were clustered independently of their areas of cultivation in the country whether in the South, North, Mount Lebanon or Baalbek Hermel. Among these foreign accessions, the one assumed to be introduced from Jordan and the other from Spain are found close to each other; this may indicate initially one common geographical area of origin associated to a mislabeling problem. Remarkably, *Baladi* accessions were found to be distributed in three subclusters confirming again the important variability for this local material.

Although these results are preliminary, this high morphological diversity found within the Lebanese prickly pear germplasm could be mainly due to genetic heterozygosity, since the local *Baladi* prickly pears have been propagated by seed for a long time, while many other prickly pear varieties with bigger fruits have been introduced from different countries. Similarly, an extensive genetic variation was found in the prickly pear germplasm in other productive countries such as Tunisia (Bendhifi *et al*, 2013) and Morocco (El-Finti *et al*, 2013), resulting mostly from genetic variability associated to a broad geographic distribution and various environmental conditions. In Mexico and Argentina the presence of natural hybrids further enriches the germplasm and tends to develop a series of new commercial varieties (Felker *et al*, 2005).

4. Conclusions and Prospects

The morphological characterization of any species is a first indicator of its diversity status and a key step towards its valorization and conservation in specific collection. Our results clearly indicate a high diversity among both local and introduced prickly pear accessions that should be subject to further investigation by a DNA analysis as per the SSRs markers previously identified in this species (Helsen *et al*, 2007) and used to assess the genetic diversity of prickly pear in Mexico (Caruso *et al*, 2010) These genetic markers are useful, not only to avoid duplications or mislabeling of the genotypes studied, but also to clarify their geographic origin and to highlight the influence of environmental conditions and agricultural practices on the variability in the prickly pear germplasm (Aranzana *et al*, 2002; Caruso *et al*, 2010).

On the other hand, prickly pears accessions assessed in this study are already gathered into comparative field trials located in different environmental conditions including the semi-arid conditions of North Bekaa where annual precipitations do not exceed 150 to 200 mm, in order to evaluate their agronomic potential and to identify distinguished genotypes for further propagation and uniform plantation.

Finally based on the morphological, molecular and agronomic characterization of prickly pear accessions, a diversification strategy could be implemented in order to promote its cultivation in the country as a promising multi-purpose crop resilient to drought.

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