Original article

# Morphological characterization of cultivated almonds in Lebanon

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## Morphological characterization of cultivated almonds in Lebanon.

**Abstract – Introduction**. Although almond (*Prunus dulcis* L.) is one of the most important cultivated fruit trees in Lebanon, cultivated accessions have not yet been inventoried, and the identity of the varieties is unknown. Our study therefore aimed at assessing the genetic diversity of cultivated almonds in Lebanon using morphological characters. **Materials and methods**. Field surveys were performed in 2002-2003 with the aim of collecting different accessions of cultivated almond trees throughout the country. Thirty-six accessions were characterized in their cultivated habitats by using 20 qualitative and quantitative traits related mainly to the fruit, according to descriptors previously established by the International Plant Genetic Resources Institute (IPGRI). **Results**. A large diversity was revealed among accessions, probably due to genetic differences. Based on the qualitative studied traits, the dendogram indicated that most of the accessions were clearly distinguishable and only two cases of synonymy were observed. They have been clustered into three main groups at 0.37 of Jaccard similarity distance. **Conclusion**. This study needs to be completed by a DNA analysis, in order to highlight the influence of environmental conditions on the variability in the *P. dulcis* germplasm and to confirm the genetic distances among accessions.

**Lebanon / *Prunus dulcis* / genetic variation / genetic resources / germplasm / agronomic characters / nuts**

## Caractérisation morphologique des amandiers cultivés au Liban.

**Résumé – Introduction**. Bien que l'amandier (*Prunus dulcis* L.) soit l'une des espèces fruitières les plus importantes au Liban, les formes cultivées n'ont pas encore été inventoriées ou identifiées. Notre étude a donc consisté en une caractérisation morphologique des amandiers du Liban. **Matériel et méthodes**. Des prospections menées en 2002–2003 ont permis de collecter 36 accessions d'amandier et de les caractériser dans leurs habitats naturels. Vingt descripteurs qualitatifs et quantitatifs, du fruit principalement, précédemment établis par l'Institut international des ressources phytogénétiques (IPGRI), ont été utilisés. **Résultats**. Une diversité importante est apparue au sein des accessions étudiées ; elle pourrait être d'origine génétique. Le dendogramme construit sur la base des caractères qualitatifs étudiés indique que la plupart des accessions se distinguent bien les unes des autres et seulement deux cas de synonymie ont été repérés. Ces accessions ont pu être structurées en trois groupes à une distance de Jaccard de 0.37. **Conclusion**. Cette étude a besoin d'être complétée par une analyse d'ADN, afin d'examiner l'influence des facteurs environnementaux sur la variabilité du germplasm d'amandier et de confirmer les distances génétiques révélées entre les accessions.

**Liban / *Prunus dulcis* / variation génétique / ressource génétique / germplasm / caractère agronomique / fruits à coque**

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## 1. Introduction

Almond (*Prunus dulcis* L.) is one of the most important cultivated fruit trees in Lebanon. Its fruits are consumed entire, fresh, green and immature (in March), as fresh mature kernels (in May and June) or as dried kernels. They are also processed for various purposes. The Lebanese production of almonds was estimated at 27 500 t of fresh fruits·year$^{-1}$ in 2004[1]. The importation of dried kernels is necessary to cover the national needs. Due to its high adaptability to the semi-arid conditions and to its extending market, much attention is being directed to almond culture in Lebanon.

Cultivated orchards are mostly planted with local accessions grafted onto seedlings. Recent commercial orchards have been planted with a limited number of varieties, leading to a reduced genetic diversity. In addition, recent introductions of foreign varieties with blossom when the risk of late frosts is not high (*Ferragnès*) will undoubtedly contribute to the genetic erosion of local varieties.

Almond accessions growing in Lebanon have not yet been inventoried, and the identity of the varieties is unknown. Even if characterization of local varieties has been initiated [1], it remains to be completed.


**Figure 1.**
Location of *Prunus dulcis* L. trees studied in Lebanon for their characterization.

[1] See http://faostat.fao.org/site/336/default.aspx.

In many countries, several phenotypic traits have been considered to characterize almond varieties and to assess the genetic diversity [2–5]. The heritability of a large number of nut and kernel traits has been studied [6–9].

The aim of our study was to characterize the Lebanese germplasm of almond by using morphological characters and to contribute to a better knowledge of almond accessions cultivated in Lebanon in order to initiate a breeding program for the near future.

## 2. Materials and methods

### 2.1. Plant material

Field surveys were performed in 2002–2003 throughout Lebanon with the aim of collecting different accessions of cultivated almond. Twelve stands were visited from cultivated habitats; they were concentrated in two zones (*figure 1*): the littoral zone, characterized by high humidity and a lush environment and the inland zone, which is more xerophytic with very low humidity and lower rainfall. The number of accessions (each consisting of an individual tree) sampled per location ranged from one to seven depending on stand size and habitat diversity.

Prospected orchards were chosen depending on their productivity (minimum of 10 almond trees per orchard), their sanitary state and the quality of cultural practices. A total of 36 accessions was collected, with 30 accessions from nine stands in the littoral zone and six accessions from three stands in the inland zone (*table I*). Samples of 45 mature fruits were collected from one of each accession studied.

### 2.2. Morphological descriptors

Characterization of almond accessions was based on almond descriptors, which were defined by the International Plant Genetic Resources Institute (IPGRI) [3].

Ten phenological and qualitative traits were examined: relative bloom time (when

**Table I.**
Geographical (GPS) and climatic [13] characteristics of twelve locations surveyed to characterize the Lebanese almond cultivars.

| Location (Region) | Elevation (m) | Latitude (N) | Longitude (E) | Rainfall ($mm \cdot year^{-1}$) | Minimal temperature (°C) | Accession name |
|---|---|---|---|---|---|---|
| Idbel (North) | 394 | 34° 31' 46" | 36° 06' 05" | 900 | 8.7 | *Awja 1*<br>*Bandouk Awja 2*<br>*Istanbouli*<br>*Itali 1*<br>*Halwani double*<br>*Khachabi 7* |
| Deir Aamar (North) | 142 | 34° 27' 37" | 35° 55' 33" | 920 | 7.0 | *Itali 2*<br>*Khachabi* |
| Btaboura (North) | 323 | 34° 16' 26" | 35° 46' 00" | 1120 | 9.2 | *Oum Omar*<br>*Halwani 4* |
| Jdabra (North) | 388 | 34° 14' 34" | 35° 41' 28" | 1010 | 9.2 | *Bandouk Awja 1*<br>*Melkani*<br>*Nahali*<br>*Halwani males*<br>*Halwani mwabbar*<br>*Khachabi tawil*<br>*Khachabi 6* |
| Fghale (Mount Lebanon) | 227 | 34° 12' 18" | 35° 39' 48" | 1120 | 9.2 | *Khachabi 1*<br>*Khachabi 3*<br>*Khachabi 4* |
| Nammoura (Mount Lebanon) | 523 | 34° 03' 57" | 35° 40' 47" | 1045 | 7.1 | *Abou soumegh* |
| Bdadoune (Mount Lebanon) | 375 | 34° 48' 38" | 35° 34' 20" | 1170 | 9.1 | *Halwani 1*<br>*Halwani 3*<br>*Khachabi 2*<br>*Khachabi 9* |
| Bourjane (Mount Lebanon) | 441 | 33° 39' 01" | 35° 28' 35" | 1040 | 8.2 | *Halwani 2*<br>*Khachabi kabir* |
| Ablah (Bekaa) | 975 | 33° 51'4 5" | 35° 56' 13" | 615 | 0.3 | *Awja 3*<br>*Biadi* |
| Ferzol (Bekaa) | 976 | 33° 51'4 0" | 35° 56' 35" | 685 | 1.9 | *Halwani 5*<br>*Half Khachabi*<br>*Khachabi 10* |
| Aitanit (Bekaa) | 870 | 33° 34' 22" | 35° 40' 56" | 560 | 2.1 | *Metwi* |
| Tambourite (South) | 134 | 33° 30' 47" | 35° 24' 55" | 1050 | 9.5 | *Awja 2*<br>*Khachabi 5*<br>*Khachabi 8* |

50% of flowers are opened) and maturity time (when 90% of mesocarps are opened), flower color (white or pink), nut shape (ovate, extremely narrow, cordate or oblong), marking of outer shell, shell suture opening, shell retention by mesocarp, kernel shape (elliptic, oblong, round or cordate), kernel shriveling and shell softness. Ten quantitative traits were measured: nut and kernel weight (g), length (mm), width (mm) and thickness (mm); breaking yield [kernel weight / nut weight) × 100] [10], and percentage of double kernels.

## 2.3. Data analysis

Means of the quantitative traits were calculated for a sample of 45 fruits for each accession.

For the qualitative traits, scores were assigned into categories based on almond descriptors as 1 for the presence and 0 for the absence. For instance, nut shape trait displaying four states (extremely narrow, ovate, cordate and oblong), an accession with ovate shape was scored as '0, 1, 0, 0'. The relationships among accessions were analyzed with the SIMQUAL procedure of the NTSYS P.C. 2.0 package [11], according to Jaccard similarity distance [12]. Trees were produced by clustering the data with the outweighted pair-group method (UPGMA) with SAHN–clustering and tree programs of NTSYS.

## 3. Results and discussion

### 3.1. Description of prospected stands

Cultivated almond stands were distributed throughout the country at altitudes ranging from 134 m (Tambourite stand) to 976 m (Ferzol stand), with latitudes from 33° 30' 47" N (Tambourite stand) to 34° 48' 38" N (Bdadoune stand) and longitudes from 35° 24' 55" E (Tambourite stand) to 36° 06' 05" E (Idbel stand) (*table I*). The minimal winter temperature ranged from 0.3 °C to 9.5 °C and the annual rainfall from (560 to 1170) mm [13]. Hence, these areas display very contrasting ecological conditions.

The majority of the plantations (85%) were composed of grafted trees; the remaining ones consisted of self-rooted trees. They were mostly located on marginal lands, in mixture with other fruit trees of major importance such as olives, or as scattered trees at the periphery of orchards.

Surprisingly, 30 commercial orchards were found with a surface ranging from (0.2 to 3) ha and mainly composed of the accession denominated *Halwani*. These were located mainly in the inland zone (Bekaa valley), where the risk of frost damage is high. The survey also revealed the presence of wild stands of *Prunus dulcis* (data not shown) in both the littoral and the inland zones, as Lebanon falls within the center of origin of this species [14]. However, these wild stands are threatened by expansion of agricultural lands or hazardous urbanism.

Agricultural practices were limited to the commercial plantations, consisting of a traditional surface irrigation (furrow irrigation), fertilization, pruning and pest treatments.

### 3.2. Morphological characterization

All the accessions, except *Istanbouli* (pink flower), have white flowers. Relative bloom and maturity dates were determined in comparison with *Awja* and *Bandouk Awja* accessions which were considered early in blooming (from February 15 to 28) and in maturity (first of August), despite their different environmental conditions. The eight *Halwani* accessions and *Melkani, Itali, Oum Omar* and *Abou soumegh* accessions were intermediate in blooming (from March 1 to 10) and early in maturity; thirteen *Khachabi* accessions were intermediate in blooming and late in maturity (end of August) and the two accessions *Half Khachabi* and *Metwi* were considered intermediate in blooming and in maturity (mid-August). *Istanbouli* and *Biadi* accessions were considered late in blooming (from March 11 to 20), while *Nabali* was the latest, flowering at the end of March. All of them were early in maturity (*table II*).

Regarding the fruit traits (*table II*), nut shapes varied according to accessions among cordate, ovate, oblong and extremely narrow. The majority of the accessions presented an elliptic kernel shape. The shell was not retained by the outer part of the nut, except for two accessions of *Khachabi*. The outer shell varied between sparsely, intermediate and densely pored. The majority of the accessions presented a mucron at the base of the nut. For the shell softness, accessions were classified into four categories: four accessions with an extremely hard shell, twelve accessions with a hard shell, seven accessions with an intermediate shell and thirteen accessions with a soft shell. All the extremely hard and hard shell accessions presented a non-opening suture (excellent seal), whereas the majority

**Table II.**
Qualitative traits of trees and fruits for 36 Lebanese almond accessions studied in different locations in Lebanon.

| Accession name | Blooming date | Maturity date | Nut shape | Marking of outer shell | Suture of the shell | Shell retention | Kernel shape | Shriveling of kernel | Softness of the shell |
|---|---|---|---|---|---|---|---|---|---|
| *Abou Soumegh* | Intermediate | Early | Ovate | Sparsely pored | Open | None retained | Broad | Intermediate | Soft |
| *Awja 1* | Early | Early | Extremely narrow | Pored | Excellent seal | None retained | Narrow | Wrinkled | Hard |
| *Awja 2* | Early | Early | Extremely narrow | Densely pored | Excellent seal | None retained | Narrow | Wrinkled | Extremely hard |
| *Awja 3* | Early | Early | Extremely narrow | Pored | Excellent seal | None retained | Extremely narrow | Wrinkled | Extremely hard |
| *Bandouk Awja 1* | Early | Early | Cordate | Sparsely pored | Open | None retained | Intermediate | Wrinkled | Intermediate |
| *Bandouk Awja 2* | Early | Early | Cordate | Sparsely pored | Open | None retained | Intermediate | Wrinkled | Soft |
| *Biadi* | Late | Early | Cordate | Sparsely pored | Excellent seal | None retained | Intermediate | Intermediate | Hard |
| *Halwani 1* | Intermediate | Early | Cordate | Sparsely pored | Very wide | None retained | Broad | Intermediate | Soft |
| *Halwani 2* | Intermediate | Early | Ovate | Pored | Open | None retained | Intermediate | Intermediate | Soft |
| *Halwani 3* | Intermediate | Early | Oblong | Sparsely pored | Open | None retained | Broad | Intermediate | Soft |
| *Halwani 4* | Intermediate | Early | Ovate | Pored | Open | None retained | Broad | Slightly wrinkled | Soft |
| *Halwani 5* | Intermediate | Early | Oblong | Sparsely pored | Open | None retained | Intermediate | Slightly wrinkled | Soft |
| *Halwani double* | Intermediate | Early | Oblong | Pored | Open | None retained | Broad | Intermediate | Soft |
| *Halwani males* | Intermediate | Early | Oblong | Pored | Very wide | None retained | Broad | Slightly wrinkled | Soft |
| *Halwani mwabbar* | Intermediate | Early | Ovate | Sparsely pored | Open | None retained | Broad | Slightly wrinkled | Soft |
| *Half Khachabi* | Intermediate | Intermediate | Oblong | Pored | Open | None retained | Intermediate | Intermediate | Intermediate |
| *Istanbouli* | Late | Early | Oblong | Pored | Very wide | None retained | Broad | Slightly wrinkled | Intermediate |
| *Itali 1* | Intermediate | Early | Oblong | Pored | Open | None retained | Broad | Intermediate | Soft |
| *Itali 2* | Intermediate | Early | Oblong | Pored | Open | None retained | Broad | Intermediate | Soft |
| *Khachabi* | Intermediate | Late | Oblong | Pored | Excellent seal | None retained | Broad | Slightly wrinkled | Hard |
| *Khachabi 1* | Intermediate | Late | Cordate | Sparsely pored | Excellent seal | None retained | Intermediate | Intermediate | Hard |
| *Khachabi 10* | Intermediate | Late | Cordate | Sparsely pored | Excellent seal | None retained | Narrow | Intermediate | Intermediate |
| *Khachabi 2* | Intermediate | Late | Oblong | Pored | Excellent seal | Retained | Broad | Wrinkled | Hard |
| *Khachabi 3* | Intermediate | Late | Ovate | Pored | Excellent seal | Retained | Extremely broad | Slightly wrinkled | Hard |
| *Khachabi 4* | Intermediate | Late | Cordate | Pored | Excellent seal | None retained | Intermediate | Intermediate | Hard |
| *Khachabi 5* | Intermediate | Late | Oviform | Densely pored | Excellent seal | None retained | Broad | Intermediate | Extremely hard |
| *Khachabi 6* | Intermediate | Late | Oblong | Pored | Excellent seal | None retained | Intermediate | Intermediate | Hard |
| *Khachabi 7* | Intermediate | Late | Oblong | Pored | Excellent seal | None retained | Broad | Intermediate | Hard |
| *Khachabi 8* | Intermediate | Late | Oblong | Pored | Excellent seal | None retained | Intermediate | Intermediate | Hard |
| *Khachabi 9* | Intermediate | Late | Oblong | Sparsely pored | Excellent seal | None retained | Intermediate | Intermediate | Hard |
| *Khachabi kabir* | Intermediate | Late | Oblong | Pored | Excellent seal | None retained | Broad | Slightly wrinkled | Hard |
| *Khachabi tawil* | Intermediate | Late | Extremely narrow | Pored | Excellent seal | None retained | Narrow | Intermediate | Extremely hard |
| *Melkani* | Intermediate | Early | Cordate | Sparsely pored | Open | None retained | Narrow | Intermediate | Intermediate |
| *Metwi* | Intermediate | Intermediate | Oblong | Pored | Open | None retained | Intermediate | Intermediate | Intermediate |
| *Nahali* | Late | Early | Oblong | Pored | Excellent seal | None retained | Broad | Intermediate | Intermediate |
| *Oum Omar* | Intermediate | Early | Ovate | Sparsely pored | Open | None retained | Extremely broad | Intermediate | Soft |

of intermediate to soft shell accessions showed an opening suture. The kernels varied among slightly wrinkled, intermediate and wrinkled (*table II*).

Regarding the quantitative traits (*table III*), *Khachabi 5* was distinguished by the largest nut (9.41 g) and kernel (1.94 g), while *Khachabi 4* presented the smallest nut (1.39 g) and kernel (0.48 g). Among the 36 accessions studied, only 15 accessions presented nuts with only one kernel. The other accessions presented (7 to 33)% double kernels, except for three of the *Halwani* accessions where 87% double kernels were

**Table III.**
Nut and kernel quantitative traits of Lebanese almond accession fruits. Means ± standard deviation of 45 repetitions per accession.

| Accession name | Nut weight (g) | Nut length (cm) | Nut width (cm) | Nut thickness (cm) | Kernel weight (g) | Kernel length (cm) | Kernel width (cm) | Kernel thickness (cm) | Breaking yield | % of double kernel |
|---|---|---|---|---|---|---|---|---|---|---|
| *Abou Soumegh* | 1.62 ± 0.44 | 2.78 ± 0.19 | 1.86 ± 0.12 | 1.35 ± 0.15 | 0.96 ± 0.09 | 2.13 ± 0.11 | 1.22 ± 0.07 | 0.82 ± 0.07 | 66.10 | 13.33 |
| *Awja 1* | 5.31 ± 1.76 | 4.88 ± 0.44 | 2.49 ± 0.25 | 1.78 ± 0.19 | 1.48 ± 0.37 | 3.37 ± 0.18 | 1.38 ± 0.14 | 0.67 ± 0.14 | 31.64 | 6.67 |
| *Awja 2* | 7.82 ± 1.80 | 4.74 ± 0.59 | 2.54 ± 0.21 | 1.93 ± 0.17 | 1.76 ± 0.40 | 3.25 ± 0.26 | 1.39 ± 0.23 | 0.87 ± 0.19 | 23.10 | 0 |
| *Awja 3* | 4.13 ± 0.89 | 6.08 ± 0.43 | 2.31 ± 0.31 | 1.62 ± 0.19 | 0.92 ± 0.32 | 3.13 ± 0.32 | 1.19 ± 0.18 | 0.58 ± 0.16 | 21.9 | 0.15 |
| *Bandouk Awja 1* | 2.60 ± 0.54 | 3.56 ± 0.23 | 2.27 ± 0.13 | 1.38 ± 0.13 | 1.18 ± 0.14 | 2.54 ± 0.19 | 1.35 ± 0.12 | 0.70 ± 0.15 | 55.48 | 26.67 |
| *Bandouk Awja 2* | 2.56 ± 0.61 | 3.32 ± 0.29 | 2.03 ± 0.23 | 1.34 ± 0.15 | 1.38 ± 0.16 | 2.45 ± 0.15 | 1.33 ± 0.08 | 0.90 ± 0.06 | 62.05 | 20 |
| *Biadi* | 2.95 ± 0.41 | 3.63 ± 0.28 | 2.34 ± 0.16 | 1.51 ± 0.12 | 0.92 ± 0.14 | 2.38 ± 0.18 | 1.31 ± 0.10 | 0.57 ± 0.04 | 31.00 | 0 |
| *Halwani 1* | 2.41 ± 0.52 | 3.07 ± 0.25 | 2.10 ± 0.16 | 1.48 ± 0.13 | 1.33 ± 0.25 | 2.34 ± 0.16 | 1.35 ± 0.09 | 1.23 ± 0.26 | 65.67 | 13.33 |
| *Halwani 2* | 2.97 ± 0.42 | 3.43 ± 0.19 | 2.34 ± 0.10 | 1.53 ± 0.13 | 1.18 ± 0.17 | 2.53 ± 0.21 | 1.36 ± 0.14 | 0.85 ± 0.12 | 65.89 | 86.67 |
| *Halwani 3* | 2.10 ± 0.62 | 2.37 ± 0.20 | 1.75 ± 0.14 | 1.31 ± 0.14 | 1.19 ± 0.23 | 1.89 ± 0.14 | 1.21 ± 0.07 | 1.03 ± 0.09 | 58.42 | 0 |
| *Halwani 4* | 1.66 ± 0.32 | 2.47 ± 0.14 | 1.75 ± 0.12 | 1.37 ± 0.16 | 0.68 ± 0.08 | 1.95 ± 0.16 | 1.16 ± 0.16 | 0.74 ± 0.06 | 67.88 | 80 |
| *Halwani 5* | 2.62 ± 0.35 | 3.94 ± 0.36 | 2.36 ± 0.27 | 1.29 ± 0.09 | 1.44 ± 0.18 | 2.82 ± 0.11 | 1.51 ± 0.16 | 0.69 ± 0.08 | 55.34 | 0 |
| *Halwani double* | 2.11 ± 0.42 | 3.03 ± 0.13 | 2.03 ± 0.10 | 1.44 ± 0.17 | 1.00 ± 0.15 | 2.22 ± 0.21 | 1.26 ± 0.11 | 0.84 ± 0.08 | 72.57 | 66.67 |
| *Halwani males* | 2.02 ± 0.30 | 2.84 ± 0.16 | 1.88 ± 0.11 | 1.38 ± 0.10 | 1.23 ± 0.11 | 2.22 ± 0.23 | 1.33 ± 0.08 | 0.95 ± 0.10 | 66.24 | 13.33 |
| *Halwani Mwabbar* | 1.73 ± 0.22 | 2.47 ± 0.12 | 1.90 ± 0.10 | 1.46 ± 0.10 | 1.00 ± 0.10 | 1.92 ± 0.08 | 1.25 ± 0.05 | 0.86 ± 0.09 | 60.61 | 6.67 |
| *Half Khachabi* | 2.60 ± 0.36 | 3.49 ± 0.16 | 2.29 ± 0.20 | 1.59 ± 0.13 | 1.12 ± 0.15 | 2.47 ± 0.14 | 1.33 ± 0.10 | 0.64 ± 0.06 | 43.33 | 0 |
| *Istanbouli* | 2.75 ± 0.43 | 3.46 ± 0.23 | 2.33 ± 0.32 | 1.59 ± 0.14 | 1.48 ± 0.22 | 2.35 ± 0.10 | 1.39 ± 0.11 | 0.89 ± 0.05 | 53.71 | 0 |
| *Itali 1* | 2.25 ± 0.25 | 3.20 ± 0.17 | 2.16 ± 0.09 | 1.23 ± 0.05 | 1.58 ± 0.20 | 2.49 ± 0.13 | 1.42 ± 0.10 | 0.91 ± 0.03 | 69.92 | 0 |
| *Itali 2* | 2.91 ± 0.58 | 3.45 ± 0.24 | 2.12 ± 0.41 | 1.37 ± 0.11 | 1.77 ± 0.21 | 2.66 ± 0.20 | 1.58 ± 0.11 | 0.85 ± 0.0 | 63.92 | 6.67 |
| *Khachabi* | 4.40 ± 0.78 | 2.72 ± 0.20 | 2.08 ± 0.11 | 1.60 ± 0.06 | 1.20 ± 0.16 | 2.02 ± 0.14 | 1.30 ± 0.07 | 0.91 ± 0.06 | 27.81 | 0 |
| *Khachabi 1* | 2.39 ± 0.36 | 2.55 ± 0.16 | 1.67 ± 0.14 | 1.35 ± 0.06 | 0.65 ± 0.08 | 1.81 ± 0.12 | 1.00 ± 0.13 | 0.74 ± 0.04 | 27.30 | 0 |
| *Khachabi 10* | 2.70 ± 0.62 | 2.97 ± 0.21 | 1.80 ± 0.13 | 1.51 ± 0.14 | 1.13 ± 0.29 | 2.26 ± 0.21 | 1.06 ± 0.10 | 0.88 ± 0.16 | 42.11 | 0 |
| *Khachabi 2* | 2.82 ± 0.52 | 2.47 ± 0.13 | 1.88 ± 0.10 | 1.72 ± 0.15 | 0.72 ± 0.17 | 1.80 ± 0.15 | 1.11 ± 0.08 | 0.80 ± 0.09 | 28.06 | 13.33 |
| *Khachabi 3* | 1.49 ± 0.26 | 1.92 ± 0.09 | 1.49 ± 0.08 | 1.29 ± 0.10 | 0.47 ± 0.07 | 1.45 ± 0.10 | 1.05 ± 0.22 | 0.80 ± 0.17 | 35.41 | 20 |
| *Khachabi 4* | 1.39 ± 0.32 | 2.35 ± 0.18 | 1.36 ± 0.12 | 1.12 ± 0.26 | 0.48 ± 0.09 | 1.66 ± 0.13 | 0.85 ± 0.06 | 0.75 ± 0.05 | 36.45 | 6.67 |
| *Khachabi 5* | 9.41 ± 1.57 | 3.95 ± 0.20 | 3.12 ± 0.22 | 2.05 ± 0.12 | 1.94 ± 0.40 | 2.74 ± 0.19 | 1.80 ± 0.11 | 0.82 ± 0.09 | 20.51 | 0 |
| *Khachabi 6* | 6.38 ± 1.18 | 3.28 ± 0.14 | 2.40 ± 0.12 | 1.82 ± 0.23 | 1.48 ± 0.20 | 2.60 ± 0.11 | 1.40 ± 0.09 | 0.82 ± 0.11 | 26.66 | 20 |
| *Khachabi 7* | 3.46 ± 0.47 | 3.30 ± 0.16 | 2.31 ± 0.10 | 1.50 ± 0.10 | 1.10 ± 0.18 | 2.44 ± 0.11 | 1.39 ± 0.11 | 0.69 ± 0.06 | 34.32 | 13.33 |
| *Khachabi 8* | 4.56 ± 1.08 | 3.23 ± 0.26 | 2.11 ± 0.17 | 1.55 ± 0.12 | 1.02 ± 0.21 | 2.28 ± 0.19 | 1.22 ± 0.20 | 0.83 ± 0.10 | 27.74 | 33.33 |
| *Khachabi 9* | 3.41 ± 0.54 | 3.07 ± 0.18 | 1.88 ± 0.12 | 1.40 ± 0.09 | 0.86 ± 0.11 | 2.14 ± 0.11 | 1.14 ± 0.07 | 0.75 ± 0.06 | 26.70 | 6.67 |
| *Khachabi Kabir* | 6.30 ± 1.00 | 3.38 ± 0.19 | 2.50 ± 0.17 | 1.83 ± 0.19 | 1.49 ± 0.18 | 2.48 ± 0.17 | 1.40 ± 0.19 | 0.91 ± 0.09 | 28.22 | 26.67 |
| *Khachabi Tawil* | 4.96 ± 0.51 | 4.15 ± 0.17 | 2.27 ± 0.10 | 1.55 ± 0.07 | 1.19 ± 0.10 | 2.92 ± 0.11 | 1.31 ± 0.04 | 0.65 ± 0.04 | 24.04 | 0 |
| *Melkani* | 2.09 ± 0.28 | 3.35 ± 0.18 | 1.92 ± 0.14 | 1.37 ± 0.05 | 0.89 ± 0.12 | 2.39 ± 0.13 | 1.13 ± 0.07 | 0.71 ± 0.06 | 42.73 | 0 |
| *Metwi* | 2.61 ± 0.30 | 3.47 ± 0.19 | 2.27 ± 0.20 | 1.61 ± 0.15 | 1.15 ± 0.14 | 2.43 ± 0.15 | 1.33 ± 0.10 | 0.66 ± 0.06 | 44.29 | 0 |
| *Nahali* | 2.03 ± 0.51 | 2.52 ± 0.17 | 1.93 ± 0.24 | 1.52 ± 0.16 | 0.90 ± 0.27 | 1.85 ± 0.15 | 1.17 ± 0.11 | 0.83 ± 0.17 | 49.65 | 20 |
| *Oum Omar* | 1.78 ± 0.16 | 2.71 ± 0.14 | 2.36 ± 0.10 | 1.40 ± 0.06 | 1.11 ± 0.14 | 2.15 ± 0.10 | 1.50 ± 0.10 | 0.93 ± 0.07 | 62.12 | 0 |

observed. Actually, in Lebanon, a high percentage of double kernels is preferred by the local market for fresh consumption and is selected by growers while this trait is consistently considered as an undesirable one that is dependent on both environmental and genetic factors [15, 16].

Our results suggested a high variability among the studied accessions, probably due to genetic differences, as some accessions with the same denomination and from the same location presented different fruit traits. Actually, in the Bdadoune stand, two accessions denominated *Halwani* varied in nut shape and size, suture of the shell, kernel weight and percentage of double kernels. On the other hand, fruit traits did not seem to vary according to environmental conditions.

For instance, similar traits were noticed between stands situated at different elevations and receiving different annual rainfall. In the stands of Ablah (975 m elevation, 615 mm of rainfall·year$^{-1}$), and Idbel (394 m elevation, 900 mm of rainfall·year$^{-1}$), *Awja* accessions shared in common 16 similar traits out of 20 traits studied. Also, in stands located in areas with similar rainfall and elevation, such as in the Btaaboura and Jdabra stands, *Halwani* accessions presented different sizes of kernel [(1.7 and 2.8) cm$^3$] and different percentages of double kernels [between (7 and 80)%]. These results are in agreement with those previously reported on *P. dulcis* in Lebanon, indicating variable sizes of leaves and fruits in similar environmental conditions [17].

### 3.3. Classification of accessions

Based on the ten qualitative studied traits, the 36 almond accessions were classified into 31 different genotypes (*figure 2*), reflecting a high variability in the collected almond germplasm. Indeed, several cases of homonymy were found. For instance, among the accessions denominated *Khachabi* according to their shell hardness, eleven accessions among thirteen studied were clearly distinguished mainly by the nut and kernel shape and the marking of the outer shell. Similarly, the eight accessions denominated *Halwani* due to the shell softness were different in the nut and kernel shape.

In addition, some accessions with different denominations were similarly close to each other (*Itali* accessions and *Halwani double*; *Half Khachabi* and *Metwi*), resulting in two cases of synonymy.

The largest distance value was noticed at 0.9 of similarity distance between *Khachabi 3* and *Bandouk Awja*, as they were different for all qualitative traits studied except for flower color.

### 3.4. Relationships between accessions

Although there was a certain degree of variability within each group, the dendogram based on the ten qualitative studied traits resulted in three main groups at 0.37 of Jaccard similarity distance (*figure 2*). One of these groups included 14 accessions, presenting in common a soft to intermediate shell (*Abou soumegh, Oum Omar, Melkani, Metwi, Istambouli, Nahali, Itali* and *Halwani* accessions). The second group included all *Khachabi* accessions with intermediate blooming time, late maturity time and a hard to extremely hard shell. The third group, including all accessions with early blooming time, is divided into two subgroups: the first one clustering three *Awja* accessions with a large and extremely narrow nut shape and hard to extremely hard shell; the second subgroup including two *Bandouk Awja* accessions with a cordate

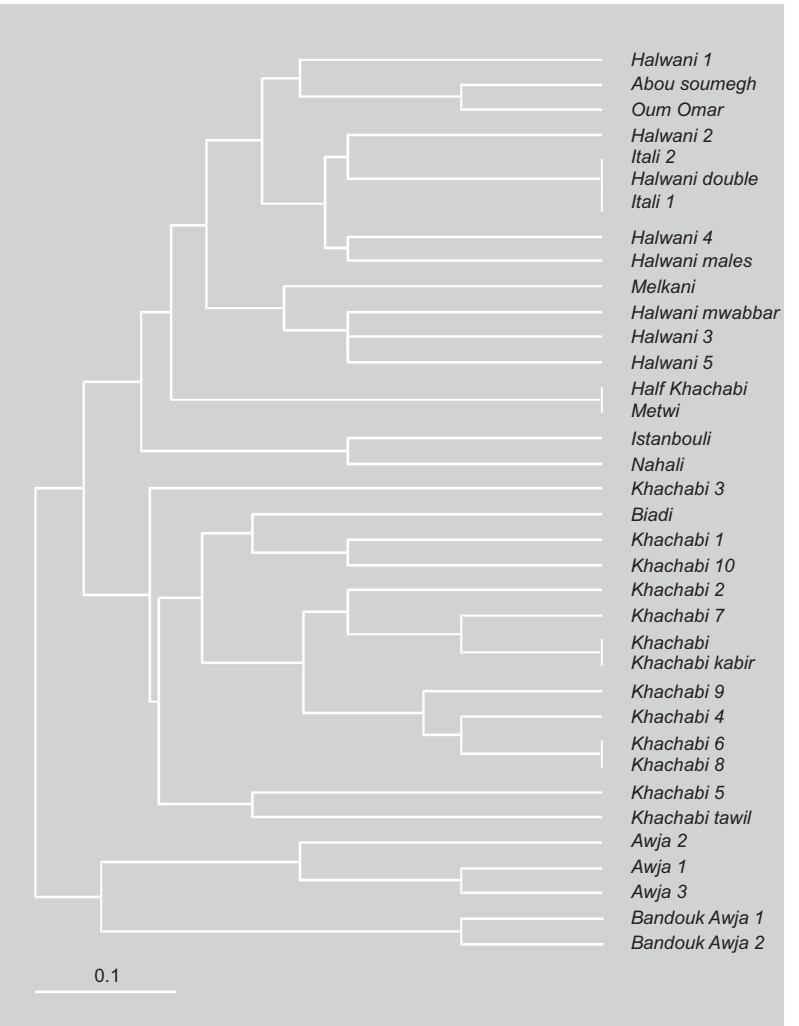


**Figure 2.**
Dendogram of 36 *Prunus dulcis* L. accessions studied in Lebanon, constructed from 10 qualitative traits, using Jaccard distance and the unweighted pair-group method (UPGMA) for clustering.

kernel shape and an intermediate to soft shell.

## 4. Discussion

For the first time, almond accessions cultivated in Lebanon were characterized. While some accessions (such as *Khachabi*) could be native to the country, the characteristics of *Itali* accessions suggest they are ancient introductions of French or Italian cultivars (*Cavaliera*).

Discussions with farmers and observations of the local market revealed that the majority of almond accessions are preferred for fresh green consumption of the immature fruits, which is popular, and the most desired and expensive variety is *Awja*. *Halwani* accessions, characterized by their shell softness, are preferred for fresh consumption of the mature kernel. Although people in many countries in the Mediterranean Basin and Asia consume the entire immature fruits [18], no efforts have been made to improve fruit characteristics for this market need. Large fruit sizes and organoleptic criteria would be desirable traits for this purpose.

As the commercial orchards are mostly planted with *Halwani* accessions characterized by intermediate blooming dates, efforts should be made in the diversification of the commercial orchards, focusing on varieties with late blooming dates in order to overcome the risk of frost damage.

A significant morphological diversity was found among the accessions studied. This result could be mainly due to genetic heterozygosity, since cultivated almonds in Lebanon have been propagated by seed for a long time, in particular for *Khachabi* accessions. In Morocco, an extensive genetic variation was found in the Moroccan almond germplasm, resulting from a broad geographic distribution, different environmental conditions, the prevalence of seed propagation and the presence of peach-almond natural hybrids [19].

## 5. Conclusion

The morphological characterization of almond accessions established in this study should be completed by a DNA analysis. Microsatellite markers [20, 21] would be useful, not only to avoid duplications or mislabeling of the genotypes studied, but also to highlight the influence of environmental conditions on the variability in the almond germplasm.

The almond accessions listed in our study should be gathered into specific collections located in different environmental conditions, in order to evaluate their agronomic potential (autofertility, bloom and maturity dates, yield, organoleptic quality, nutritive composition and disease resistance). Based on the morphological and molecular characterization and agronomic evaluation of almond accessions, conservation strategies need to be implemented. The selected material should constitute a potential wealth of genetic diversity, which can be used for the improvement of *Prunus dulcis* L. in Lebanon and elsewhere.

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## Caracterización morfológica de los almendros cultivados en el Líbano.

**Resumen – Introducción**. A pesar de que el almendro *(Prunus dulces* L.) sea una de las especies fruteras más importantes en el Líbano, las formas cultivadas no se han inventariado ni identificado aún. Por ello nuestro estudio ha consistido en una caracterización morfológica de los almendros en el Líbano. **Material y métodos**. Unas prospecciones llevadas a cabo en 2002-2003 permitieron recolectar 36 muestras de almendro y caracterizarlos en su respectivo hábitat natural. Se emplearon veinte descriptores cualitativos y cuantitativos, del fruto principalmente, anteriormente establecidos por el instituto internacional de recursos filogenéticos (IPGRI). **Resultados**. Surgió una diversidad importante en el seno de muestras estudiadas, ésta podría ser de origen genético. El dendogramo construido sobre la base de caracteres cualitativos estudiados indica que la mayoría de las muestras se distinguen bien las unas de las otras; y solamente se han señalado dos casos de sinonimia. Dichas muestras han podido estructurarse en tres grupos a una distancia de Jaccard de 0.37. **Conclusión**. Este estudio necesita completarse por un análisis de ADN, con el fin de examinar la influencia de los factores medioambientales en la variabilidad del germoplasma del almendro y con el fin de confirmar las distancias genéticas desveladas entre las muestras.

**Líbano / *Prunus dulcis* / variación genética / recursos genéticos / germoplasma / características agronómicas / frutos secos**