quality is excellent. Therefore nuts reach 
an average Ø of 32 mm.

Some scientific papers show results on higher sensitivity of novel bred walnut var-
ieties. The novel Hungarian bred walnut va-
rieties are also a bit more sensitive to 
new compared to standard varieties (Rozsnyay 
2006, Rozsnyay-Szügyi, 2009). Growers 
agree that they have to spray the novel 
bred varieties a couple of times more, 
but they obtain higher yields using hybrid in-
stead of landscape selected varieties.

‘Alsoszentivani 117’ and ‘Milotai 10’ are the 
most important and largely planted vari-
eties. ‘Alsoszentivani 117’ has the earliest 
ripening time and therefore is very popular. 
‘Milotai 10’ has the best shell and kernel 
quality and therefore is highly appreciated 
by growers. Usage of novel bred walnut 
varieties was started in the last decade.

When establishing a new walnut orchard, 
growers plant double tree rows on a one 
hectare orchard to obtain first yields as high 
as possible. Tree thinning is made at the 
13th to 20th leafing out after planting, when 
canopies get really close to each other.

Today, irrigation is an important issue in 
walnut production, as average yearly pre-
cipitation (500 to 700 mm yearly) is not 
enough. Hungarian growers do not irrigate 
walnut orchards, but they are considering 
it. In order to achieve stable productions 
and good fruit quality, the Hungarian wal-
nut orchards must be irrigated in the fu-
ture. There is enough water available and 
growers have the right to use it.

The most important disease is 
Xaj (Xan-
thomonas arboricola pv. juglandis), which can 
gain great damage, mainly on novel bred 
hybrid varieties’ fruits and leaves. The most 
sensitive variety is ‘Milotai intenzív’, while the 
less sensitive are ‘Milotai kései’, ‘Alsoszen-
tivani késeli’ and ‘Bonifac’. Phoma/Phomop-
sis is spreading in Hungarian walnut or-
chards (Vajna – Rozsnyay, 2005).

At present, the walnut husk fly (Rhagoletis 
complete Cresson) has not been isolated 
yet in Hungary. The most important pest is the 
coding moth (Cydia pomonella L.).

The Research Institute for Fruit growing and 
Ornamentals, Budapest-Erd, has 
made numerous innovations in the field of 
mechanization since the 1970s. Therefore, 
it is common to see the most suitable ma-
chines in the walnut orchards and process-
ing plants. As mechanization also includes 
post-harvest technology, Dr. Andor has 
pieced together a special line which con-
tains a husk removal machine, a washing 
and a drying machine, a sizer, as well as a 
manipulation line and/or cracking adapter.

There are 14 processing plants in the 
country, which capacity covers the whole 
Hungarian walnut processing capacity.

It is not easy to decide on the best way 
growers may sell their products. Walnut 
products can be commercialized in shelled 
or kernel form. Hungarian growers prefer 
shelled walnuts, because Hungarian bred 
walnut varieties ripe first on the Northern 
Hemisphere and their fruit size is larger 
than the competitor’s varieties. Also, their 
shell colour and surface are excellent.

Unfortunately, Hungary has no field advi-
sor system supported by the State. The 
Ministry of Regional Development used to 
stimulate the establishment of new walnut 
orchards. Today, growers or co-operatives 
the possibility to apply for developing 
projects in agreement with the EU policy.

Thus, the Hungarian walnut industry is in-
creasing year after year, due to a good 
and stable market situation. In order to in-
crease the success of the Hungarian wal-
nut industry, a Walnut Association will be 
founded by Industry members in the near 
future, with the hope that Hungary may 
stabilize its current success in the future.

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INTRODUCTION

PERSIAN OR ENGLISH WALNUT (Juglans regia L.) is native to the mountainous regions of 
Central Asia (Leslie and McGranahan, 1998). It is a traditional fruit crop in North 
Africa and its first introduction into the Maghreb is attributed to the Romans (Ger-
main, 1992). Walnut covers an area of 
7,600 ha in Morocco, being considered by 
local farmers and populations as a forestry 
fruit tree. Walnuts are found in mountain-
ous and remote areas between 800 and 
1,800 m above sea level and under differ-
ent environments (Lansari et al., 1999). Its 
ods are easily stored and transported 
over long distances. Thus, the walnut 
tree can be found in humid and warm Moun-
tains (north of Morocco), semi-arid and 
cooler Mountains (high Atlas Mountains) and arid regions in the southeast of Mo-
roco. More than half of the trees are 
seedlings resulting from the prevailing 
form of propagation known by farmers, 
since grafting is unusual. The genetic vari-
ability of Moroccan walnut groups, defined 
as “populations” or “geographic prove-
ances” and named by sampling site, was 
investigated using morphological traits 
(Kodad, 2000; Lansari et al., 2001). The 
results of these studies showed that the 
genetic variability of the local Moroccan 
walnut populations is assumed to be very 
large. Morocco, as well as other countries 
with forestry resources, is paying great at-
tention in protecting seedling stands as 
valuable tools for biodiversity conserva-
tion, and as a source of high quality plant 
material. Moreover, the selection of pro-
ductive and drought tolerant genotypes 
with high kernel quality could be essential 
for the conservation of walnut in different 
producer regions of Morocco. Taking into 
account the climate change scenarios 
from drought and heat stress, low rainfall 
and increase of biotic stresses, the selec-
tion of the seed source may be crucial for 
the success of future plantations (Hemery, 
2008). Moreover, Callaham (1994) re-
ported that the provenance research pro-
vides an excellent basis for the selection 
of seed sources and refers to the geo-
graphical origin of seeds or trees. In fact, 
several studies reported that the physical 
fruit traits (McGranahan and Leslie, 1990) 
and chemical kernel profile (Amaral et al., 
2003; Crews et al., 2005; Martinez et al., 
2006) depend on the genotypes, with a 
strong effect of the environmental condi-
tions. The present study aims at the eval-
uation of genetic diversity and genotype
performance of the local walnut seedlings from different Moroccan eco-geographical provenances.

MATERIAL AND METHODS

Plant material. This study was carried out with walnut genotypes from four different regions rich in genetic resources: Bni M'tir in the Middle-East of the Atlas Mountains, Imlil and Oukaimeden in the high Atlas Mountains (Central-Southern Morocco), Midelt situated in the high valley of Moulouya in Central-Eastern Morocco, and Er-Rich in South-Eastern Morocco. A total of 25 local genotypes from different zones of each region were selected because of the general status of the plant (vigour, foliar density and appearance), lateral fructification, and kernel physical quality appreciated by the local population. These genotypes were unique seedlings; therefore each genotype was a single tree. These genotypes were marked and fruits were collected in winter in 2010. The nuts were collected when the fruit mesocarp had split and peduncle abscission was complete. After cracking, the kernels were soaked in liquid nitrogen and then ground using an electrical grinder (IKA, Janke & Kunkel, Germany) to obtain fine flour.

Physical fruit traits. Nut thickness and width were measured at the midpoint of the length, perpendicular to each other, considering width the larger dimension. Length, width, and thickness were measured with a precision of 0.01 mm in all nuts with a digital caliper. After measurements, nuts were cracked to obtain the kernel and determine the shelling percentage by weight using an electronic balance. Length, width, and thickness were similarly measured in all nuts.

Kernel chemical determination. Oil was extracted from 5 grams of ground walnut kernel using a fat extractor Soxtec during 5 hours and using hexane as a solvent (AOCS Ce 2-66 modified). The oil content was expressed as the difference in weight of the dried kernel samples before and after extraction. The protein content was obtained indirectly by determining the total N content obtained by the Kjeldahl method (AOAC, 1995) and multiplying by nitrogen-protein conversion factor (Kc =6.25) (% Protein = Kc * % Total nitrogen).

Statistical analysis. All statistical analyses were performed with the SAS program. Analysis of variance was performed with a two random factors design. The factor genotype was hierarchical to the factor population because the trees were not repeated between sites. To draw a general conclusion from the four walnut locations, the population was considered as a random effect (Steel and Torrie, 1960). The Principal Component Analysis (PCA) was applied to describe the pattern of walnut diversity.

RESULTS AND DISCUSSION

Genotype and location variability. The analysis of variance was carried out on some nut and kernel traits considered as important quality parameters in walnut. This analysis showed high variability between genotypes for nut and kernel weight, shell hardness, kernel ratio, protein and oil content (Table 1). The range of variability for oil content was between 51.59 and 69.91%, and between 9.21% and 13.77% for protein content (Table 2). The protein content agreed with previous reports (Amaral et al., 2003), as well as

<table>
<thead>
<tr>
<th>Variable</th>
<th>d.l</th>
<th>Mean squares</th>
<th>F-Value</th>
<th>P</th>
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<tr>
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<td>Population</td>
<td>4</td>
<td>86.09</td>
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</tr>
<tr>
<td>Error</td>
<td>365</td>
<td>0.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kernel weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
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<td>3.96</td>
<td>249.82</td>
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<td>Error</td>
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<td></td>
</tr>
<tr>
<td>Shell weight</td>
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<tr>
<td>Error</td>
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<td></td>
</tr>
<tr>
<td>Kernel weight/Nut weight</td>
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<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
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<td>37.27</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Genotype(population)</td>
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<td>16.91</td>
<td></td>
<td>&lt;.0001</td>
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<tr>
<td>Error</td>
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<td>Protein content</td>
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<td>Population</td>
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<td>25.59</td>
<td>24.06</td>
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<td>Genotype(population)</td>
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<td>&lt;.0001</td>
</tr>
<tr>
<td>Error</td>
<td>25</td>
<td>1.06</td>
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</tbody>
</table>

Walnut population in High Atlas Mountain in Morocco.
the fat content, although the lowest value obtained was lower than any previous report (Amaral et al., 2003; Bada et al., 2010). The range of variability for nut weight was between 6.6 and 14.9 g; and 1.7 and 5.8 g for kernel weight; and between 25.75% and 48.19% for kernel ratio (Table 2). For oil and protein content the growing conditions have been reported to affect fruit and kernel weight (Diaz et al., 2005). For oil and protein content the growing conditions appear to affect these components in walnut (Amaral et al., 2003; Martinez et al., 2005), but also on the gene pool origin. Similar results have been reported in almond (Kodad et al., 2010; 2011). The present results show a clear effect of geographical origin on the physical and chemical components of the walnut kernels placing the emphasis on selecting the promising genotypes in each cultivation area in Morocco.

**Genetic diversity.** Statistical methods such as principal component analysis and cluster analysis are useful tools for studying the genetic diversity and have been applied to tree nut species such as almond (Lansari et al., 1994; Kodad et al., 2011). The best model with the minimum number of dimensions explaining the data structure was selected by the exclusion rule, based on the amount of residual variability to be tolerated, retaining a sufficient number of PCs capable of explaining a percentage of variance > 80%. With this rule, the first three PCs were enough because they described 78.58% of the sample variability.

The contribution of each PC to the total variance is shown in Table 3. Nut, kernel, shell and wall weight, and nut length and width were primarily responsible for the separation on the PC1. The second component is represented by oil content and kernel ratio and the third component is represented negatively by shell thickness and positively by kernel ratio. The present results confirm that nut and kernel physical traits are the most variable among walnut genotypes in local Moroccan seedlings (Lansari et al., 2001).

When means were plotted on the three principal axes (Fig. 1), more than 56% of the genotypes showed intermediate to low nut and kernel weight and dimension and oil content (Table 2). When the analysis focused on the origin of the genotypes, it appears that genotypes from Bni Mtr (Middle-East Atlas Mountains) and genotypes from Midelt (High Valley of Moulouya) showed the lowest values for nut and kernel weight and dimensions (Fig. 1; Table 2). However, some genotypes such as BM1 from Bni Mtr and MT3 from Midelt showed high oil content. In contrast, almost all genotypes from the high Atlas Mountains showed intermediate to high values for nut and kernel weight and dimensions and fat content. These results are in accordance with those found applying analysis of variance (Table 1).

At individual level, the genotypes AM2 from Er-Rich (South of Morocco), IM10 from Imlile and O3 from Oukaimeden (High Atlas) had a very high positive value on PC1. This showed the highest values for kernel and nut weight, nut length and width, and the highest shell hardness (Table 2). On the second component, these genotypes had slightly positive values showing an intermediate value of kernel ration and oil content (Table 2). Regarding the third component, these genotypes had a negative value indicating that these genotypes show low values for protein content (Table 2). Genotype AM2 from Er-Rich (Southern Morocco) is very interesting because of its high positive value on PC1 and PC2 (Fig. 1), indicating its heavy nut and kernel and high fatty content (Table 2). Furthermore, genotypes IM4, IM12, O1 and O2 (High Atlas mountains) showed a high value on PC3 (Fig 1), indicating that these genotypes had very high protein content.

The results of the multidimensional analysis clearly showed that walnut grown in Morocco is characterized by the high variability of physical and chemical traits of nut and kernel. This variability could be used to select the best genotypes with adapted traits, high productivity and good kernel in each region to be propagated vegetatively as new local cultivars or to select the genotypes with high productivity and fatty kernel to be used as source seed for extending the recovery of degraded walnut forests in Morocco. Taking into account the relevance of high lipid contents as a source of carbon and energy during germination and seedling growth (Chenvard et al., 1994), the genotypes IM5 from Imlile (high Atlas mountain), BM1 and BM3 from Bni Mtr (Middle-Eastern Atlas Mountain), AM3 from Er-Rich (Southern Morocco) and MT3 from Midelt (high valley of Moulouya) could be considered as seed sources for walnut propagation in each walnut productive region in Morocco as a tool to recover from forest degradation, since the choice of the seed source is considered crucial for the success of future plantations in silvicultural management (Hemery, 2008; Callaham, 1994).

ACKNOWLEDGEMENTS

This research was funded by grants of the “Healthy Food for Life” programme Marie Curie IRSES, and the Research Group A12 of Aragon.

### Table 3. Eigenvectors of the three principal components axes from PCA analysis of the Moroccan walnut seedlings.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Axe 1</th>
<th>Axe 2</th>
<th>Axe 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein content (% DM)</td>
<td>0.07</td>
<td>-0.29</td>
<td>0.37</td>
</tr>
<tr>
<td>Oil content (%DM)</td>
<td>0.05</td>
<td>0.58</td>
<td>-0.27</td>
</tr>
<tr>
<td>Nut length (mm)</td>
<td>0.29</td>
<td>-0.26</td>
<td>0.05</td>
</tr>
<tr>
<td>Nut width (mm)</td>
<td>0.36</td>
<td>-0.19</td>
<td>0.25</td>
</tr>
<tr>
<td>Nut thickness (mm)</td>
<td>0.36</td>
<td>-0.18</td>
<td>0.23</td>
</tr>
<tr>
<td>Nut weight (g) (A)</td>
<td>0.41</td>
<td>0.13</td>
<td>-0.01</td>
</tr>
<tr>
<td>Shell thickness (mm)</td>
<td>0.31</td>
<td>0.09</td>
<td>-0.38</td>
</tr>
<tr>
<td>Kernel weight (g) (B)</td>
<td>0.35</td>
<td>0.14</td>
<td>0.26</td>
</tr>
<tr>
<td>Partition weight (g)</td>
<td>0.32</td>
<td>0.09</td>
<td>-0.23</td>
</tr>
<tr>
<td>Shell weight (g)</td>
<td>0.40</td>
<td>-0.03</td>
<td>-0.19</td>
</tr>
<tr>
<td>Kernel ratio (B/A)</td>
<td>-0.02</td>
<td>0.54</td>
<td>0.61</td>
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</table>
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PISTACHIO RESEARCH IN TUNISIA: PAST, CURRENT AND FUTURE INVESTIGATIONS

INTRODUCTION

The cultivation of pistachio nut trees in Tunisia is probably very old. Archaeological studies bear witness to the presence of pistachio nuts during the Carthaginian period (Hurst and Stager, 1978). The need to develop pistachio culture in Tunisia increased since the Robert Willard Hodgson mission (1930-1931). Hodgson (1931) highlighted the potential economic and social gains of pistachio culture due to its adaptation to the extreme conditions of arid areas and its fruit quality. However, its expansion was very limited until the 1960s. In 1984, pistachio cultivation occupied only 30 ha mainly in the central and south part of the country. The two FAO-INRAT projects (1964-1972) greatly contributed to the extension of this crop. Many technical problems related to crop multiplication were resolved, new varieties and rootstocks were introduced and orchards were installed in different bioclimatic areas to study the behavior of local and foreign genotypes. Currently, pistachio cultivation occupies 37,000 to 43,000 ha with a total annual production of 2100 to 2700 tons (official national data, 2011; FAO, 2012). The FAO world classification of pistachio cultivation placed Tunisia in the 5th position regarding cultivated area, 9th for production and 17th for productivity (FAO, 2012). Despite the relatively large land occupation, the crop domestic productivity does not exceed 60 kg/ha on average. Tunisian pistachio research started in 1948 at the National Agronomic Research Institute of Tunis (INRAT) previously known as “Service Botanique et Agronomique de Tunis (SBAT)” and is still ongoing by different teams in a few other national research institutions such as the Olive Tree Institute (IO) and the National Agronomic Institute of Tunisia (INAT). This report overview the main axes developed and related results.

PROPAGATION AND MICROPARTITION

Pistachio propagation was one of the earliest concerns of pistachio research in Tunisia. Seeding and budding techniques were studied since 1948 by Crossa-Raynaud and allowed for the production of hundreds of plants in Gafsa (southeastern Tunisia). During the 1964-1972 years, several collections of varieties and rootstocks were installed in different areas of the country (Jacqy, 1972). Budding suc-