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Some physical properties in nut and kernel of two almond varieties ('Marcona' and 'Tuono') grown in Northern Morocco

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Abstract. Cultivated almonds (*Prunus dulcis* [Mill.] D.A. Webb) are the second fruit culture in importance after olive trees in Morocco. The present work was carried out to evaluate some physical properties in nut and kernel of two almond varieties ('Marcona' and 'Tuono') widely grown in northern Morocco. 30 fruits were collected in three marked almond trees randomly around the canopy between August, 15 and September, 10 of the 2014 season in three different sites namely Aknoul (Taza), Bni Hadifa (Al Hoceima) and Tahar Souk (Taounate). ANOVA analyses indicated that environmental effect accounted for low variation percentages for most of studied traits except nut length and kernel thickness where it explained half of variation. Genotypic effect was more important in describing variation in the majority of characters. Mean comparison revealed that no significant differences were encountered among sites for nut thickness, spherecity and kernel weight and volume. For the others traits, Tahar Souk showed the lowest values. Between varieties, 'Marcona' presented higher values for most of characters except for length and shelling percentage.

Keywords. *Prunus dulcis* – Nuts – Kernels – Physical properties – Northern Morocco.

Quelques caractères physiques de l'amande et l'amandon chez deux variétés d'amandier ('Marcona' et 'Tuono') cultivées au nord du Maroc

Résumé. *L'amandier (Prunus dulcis [Mill.] D.A. Webb) est le deuxième arbre fruitier le plus cultivé au Maroc après l'olivier. Le présent travail a été mené dans le but d'évaluer quelques propriétés physiques de l'amande et l'amandon chez deux variétés d'amandier ('Marcona' et 'Tuono') largement cultivées dans le nord du Maroc. 30 fruits ont été collectés sur trois arbres sélectionnés au hasard dans le champ entre le 15 Août et le 10 Septembre 2014 dans trois sites différents à savoir : Aknoul (Taza), Bni Hadifa (Al Hoceima) et Tahar Souk (Taounate). Les analyses de la variance ont indiqué que l'effet du milieu a contribué faiblement à la variabilité de la plupart des caractères étudiés à l'exception de la longueu de l'amande et l'épaisseur de l'amandon, chez lesquels il a expliqué la moitié de la variabilité obtenue. Effet génotypique a contribué fortement dans la variabilité de tous les caractères. La comparaison des moyennes n'a révélé aucune différence significative entre les sites pour l'épaisseur de l'amande et la sphéricité, le poids et le volume de l'amandon. Pour les autres caractères, Tahar Souk a montré les valeurs les plus basses. Entres les variétés, 'Marcona' s'est révélée supérieure à 'Tuono' pour la majorité des caractères à l'exception de la longueur et du rendement au cassage.*

Mots-clés. Prunus dulcis *– Amandes – Amandons – Caractères physiques – Nord du Maroc.*

I – Introduction

The almond (*Prunus dulcis* [Miller] DA Webb) is a widely grown fruit tree throughout the world. It is a major tree nut grown in areas of Mediterranean climate. In Morocco, almond is the second fruit culture in importance after olive trees in Morocco. It is grown in several regions from north to south, under different environmental conditions, mostly on non-irrigated lands (Kodad *et al*., 2015). The total almond national acreage is about 146.100 ha. Taza-Al Hoceima-Taounate region accounted for more than 37% of total cultivated area and for more than 18% of total production (Ministry of Agriculture, 2013). In this region, almond trees are conducted following the traditional system where one or more environmental requirements are limiting including water during the growing season, soil depth, and nutrient availability (Mahhou and Dennis, 1992). At present, harvesting and handling of almond fruits carried out manually in the region. For optimum performance of threshing, conveying, sorting, storing and other processes of almond nuts and kernels, their physical and mechanical properties must be known (Mirzabe *et al*., 2013). Previous studies on physical traits in almonds were undertaken in Turkey (Kalyoncu, 1990; Aydin, 2003), Iran (Mirzabe *et al*., 2013), Australia (Zheng and Fielke, 2014) and Spain (Valverde *et al*., 2005). Kodad *et al*. (2015) studied physical fruit traits in almond local populations in northern and central Morocco. This work describes a comparative study of some physical properties of nuts and kernels in two almond varieties ('Marcona' and 'Tuono') from three representative sites of Taza-Al Hoceima-Taounate region (northern Morocco).

II – Materials and methods

This study was carried out in three sites of northern Morocco (Fig. 1), namely Aknoul (60 km from Taza, 34°39′0″ N, 3°52′0″ W), Bni Hdifa (50 km from Al Hoceima, 35°1′22″ N, 4°8′27″ W), and Tahar Souk (50 km from Taounate, 35°1′22″ N, 4°8′27″ W). Plant material consisted on two almond varieties ('Marcona' and 'Tuono') widely grown in northern Morocco.

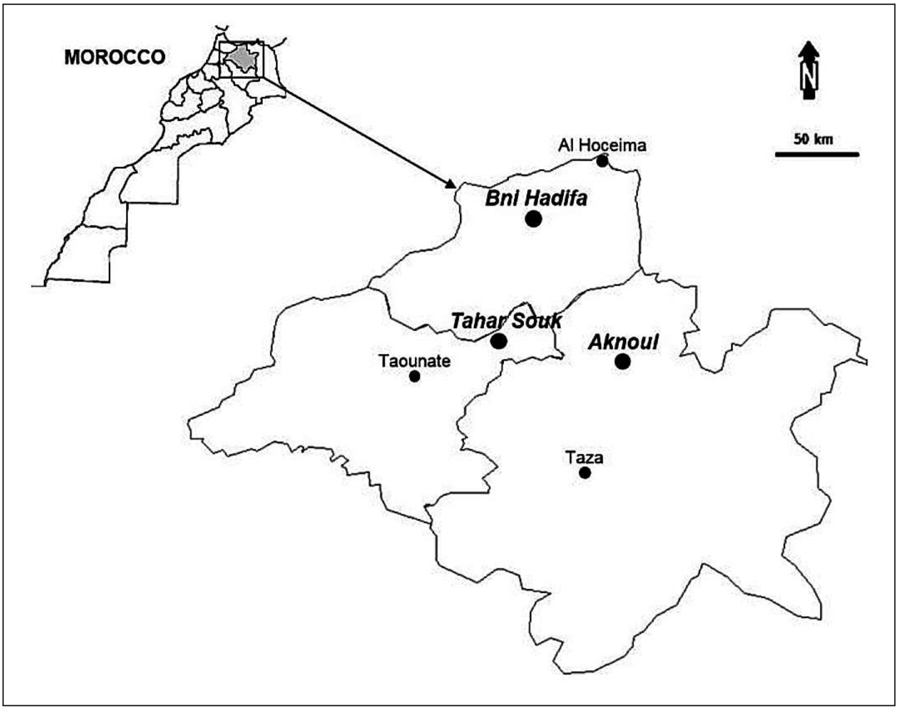

Fig. 1. Geographic localisation of the studied sites (Aknoul, Bni Hadifa and Tahar Souk).

Before harvest, three individual trees were selected in each site between August, 15 and September, 10 of the 2014 season. A sample of 30 fruits was collected randomly from the marked plants at maturity, when fruit mesocarp was fully dried and split along the fruit suture and peduncle abscission was complete.

After harvesting, all nuts were cleaned to remove foreign matter such as soil and stones, as well as immature fruit. For each individual almond nut, three main dimensions (Fig. 2), namely length (L), width (W), and thickness (T) were measured. For measuring principal dimensions of the kernel, almond nut was broken; then length (L), width (W) and thickness (T) of the kernel were measured. For all measurements, a digital caliper with accuracy of 0.01 mm was used. Nut and kernel mass was measured with an electronic balance of 0.001 g sensitivity.

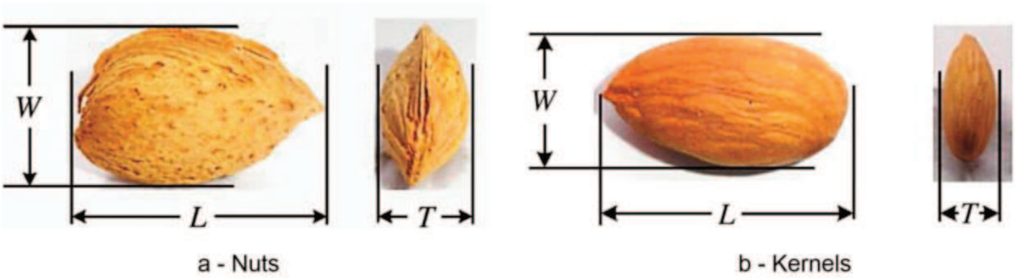

Fig. 2. Almond size parameters: L = length; W = width; T = thickness (Zheng and Fielke, 2014)

The geometric mean diameter (Dg) and sphericity (Φ) were calculated by using the following equations (Mohsenin, 1970): $Dg = (LWT)^{1/3}$ and $\Phi = (LWT)^{1/3} \times 100/L$, respectiveley. The volume (V) were calculated as follow (Mirzabe *et al.*, 2013): $V = (\pi \times Dg^3) / 6$. Combined analyses of variance and Duncan's test were performed for measured and calculated parameters by using the SAS program (SAS, 2004).

III – Results and discussion

Results from the combined analyses of variance for almond nuts (Table 1) showed that site affected at a lesser extent the variability for the majority of characters except for length where it explained the half and it was not significant for some parameters such as thickness and sphericity. In contrast, variety effect was very significant and predominant accounting for more 75% of variability for most characters. Concerning almond kernels (Table 1), the same picture was reflected. In fact, site effect had a lower influence except for thickness and shelling percentage; while variety effect was significant for all traits and explained more than 70% of total variation. Site by variety interaction was of a lower extent and only significant in kernel characters.

Mean comparison among sites (Table 2) revealed that, for almond nuts, Aknoul and Bni Hadifa showed higher values for unit mass (3.88 and 4.40 g, respectively), length (30.61 and 32.04 mm, respectively), width (23.58 and 24.02 mm, respectively), geometric mean diameter (22.06 and 22.85 mm, respectively) and volume (5314 and 6258 mm^3, respectively). For the rest of traits, no significant differences were obtained. For almond kernels, Tahar Souk presented the highest value for thickness (7.38 mm), sphericity (61.61%) and shelling percentage (30.18%) while it had a lower score for length and width. For the remaining traits, no significant differences were encountered.

Mean comparison between varieties (Table 3) demonstrated the superiority of 'Marcona' for the majority of characters in nuts and kernels except for length where 'Tuono' presented higher values (31.33 mm in nut and 22.34 in kernel). 'Tuono' was also superior to 'Marcona' in shelling percentage (28.69%).

Table 2. Mean values of sites for unit mass, length (L), width (W), thickness (T), geometric mean diameter (Dg), sphericity (F), volume (V) and shelling percentage (SP) of almond nuts and kernels. Means for each character followed by the same letter are not significantly different at P < 0.05

Sites	Mass (g)	L (mm)	W (mm)	T (mm)	Dg (mm)	F (%)	Φ (mm^3)	SP (%)
Nuts								
Aknoul	3.88 b	30.61 b	23.58 a	14.96 a	22.06 a	72.13 a	5314 a	
Bni Hadifa	4.40 a	32.04 a	24.02 a	15.60 a	22.85 a	71.70 a	6258 a	
Tahar Souk	3.13 c	28.43 c	20.91 b	15.13 a	20.76 b	73.14 a	4740 b	
Kernels								
Aknoul	0.87 a	21.89 a	14.19 a	5.95 c	12.25 b	55.91 c	984 a	22.39 b
Bni Hadifa	1.01 a	22.34 a	14.21 a	6.87 b	12.93 a	58.45 b	1132 a	23.39 b
Tahar Souk	0.87 a	20.18 b	12.85 b	7.38 a	12.39 ab	61.61 a	1000 a	30.18 a

Table 3. Mean values of varieties for unit mass, length (L), width (W), thickness (T), geometric mean diameter (Dg), sphericity (F), volume (V) and shelling percentage (SP) of almond nuts and kernels. Means for each character followed by the same letter are not significantly different at P < 0.05

Sites	Mass (g)	L (mm)	W (mm)	T (mm)	Dg (mm)	F (%)	Φ (mm^3)	SP (%)
Nuts								
'Marcona'	4.63 a	29.39 b	24.88 a	16.66 a	23.01 a	78.28 a	6412 a	
'Tuono'	2.97 b	31.33 a	20.79 b	13.80 b	20.77 b	66.37 b	4729 b	
Kernels								
'Marcona'	1.01 a	20.60 b	15.28 a	7.16 a	13.09 a	63.68 a	1174 a	21.95 b
'Tuono'	0.83 b	22.34 a	12.22 b	6.31 b	11.96 b	53.64 b	903 b	28.69 a

Our results are in concordance with those obtained by El-Amrani *et al*. (2012) in Al Hoceima region. In fact, most of the studied characters were under genetic dependency. It has been demonstrated that nut mass and dimensions were controlled genetically (Kodad *et al*., 2011). Kernel mass is determined by genetic additive effects (Spiegel-Roy *et al*., 1981), with a heritability of 0.64 (Kester *et al*. 1977). Almond shells are generally characterized by their hardness and shelling percentage. Hard shells can reduce the proportion of nut meats recovered after shelling if adequate equipment is not utilized (Socias i Company *et al*., 2008). In our work, 'Marcona' presented a very hard shell in comparison to 'Tuono'. In a study with local populations of almonds carried out in northern and central Morocco, Kodad *et al*. (2015) reported that all genotypes produced a hard to very hard shells. It has been noticed that with this kernel protection the nuts can be stored for a long time if not exposed to sunlight due to the fact that intact hard shells protect kernels from both insect damage and deterioration from molds. Kernel size is commercially important, as larger sizes are generally better valued (Socias I Company *et al*., 2008). Kernel size depends on kernel mass and in our work it ranged, upon Gülcan classification (Gülcan, 1985), from very small (0.83 g for 'Tuono') to small (1.01 g for 'Marcona'). Kernel mass may be reduced by severe drought conditions (Goldhamer and Viveros, 2000. In the three sites of our study, almonds are grown under no-irrigation and may suffer from late drought resulting in small kernel mass and size. For kernel thickness, and according to Gülcan descriptors, 'Marcona' produced medium kernels while 'Tuono' presented thin kernels. These low values could be explained by the fact that kernel thickness is more dependent on final seed filling, which is more vulnerable to late-season environmental stresses, mainly drought and diseases (Kester and Gradziel, 1996).

IV – Conclusions

It can be concluded that because of narrow distances between the three sites of this study, climatic conditions may not vary for a large degree resulting in a lesser effect on physical properties of almond nuts and kernels in our region. In contrast, the origin of the two studied varieties 'Marcona' (Spain) and 'Tuono' (Italy), which affect strongly their genetic pool, could be the reason for major differences between these two varieties for all studied traits. Furthermore, 'Marcona' was clearly superior for most of parameters confirming its large use in traditional and modern almond systems in Morocco.

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