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Pomological characterization of carob tree (*Ceratonia siliqua* L.) from the province of Chefchaouen (NW of Morocco)

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Abstract

A pomological survey of two types of carob tree from the Province of Chefchaouen, NW of Morocco (productive "dkar" and "lanta") shows that pods of productive "dkar" type (spontaneous type) present the high yield in seeds (20.5±7.74%) and are more straight than pods of "lanta" type (grafted type) and pod curvature is inversely proportional to tree age. Trees of productive "dkar" type promote endosperm (carob bean gum) content of seeds (47.6±4.53%). The tegument and the embryo-cotyledons complex (carob germ) constitute respectively 22.7% and 19.9% of seed dry weight (dw). According to the provenance, these components would attain in aged grafted-type 23.0% and 21.0% in the same order. Other morphometric parameters of pods and seeds are commented in these carob tree types and especially compared to the Mediterranean cultivars or varieties.

Key words: *Ceratonia siliqua* L., pod, seed, Province of Chefchaouen.

Introduction

The carob tree (*Ceratonia siliqua* L.) is an evergreen tree or shrub up to 15-20 m of height, with leaves of 10 to 20 cm of length and 4 to 10 leaflets (Emberger 1938, Foury 1954, Metro & Sauvage 1955, Quezel & Santa 1962/63). It is generally dioecious or monoecious, rarely hermaphrodite (Bonzom *et al.* 1878, Metro & Sauvage 1955, Batlle & Tous 1997). In mature stage, carob pod has an elongated shape up to 10-20 cm, straight or curved, with 1-4 cm of width and constituted by epicarp (tough), mesocarp (fleshy and sugary pulp) and seeds. The mesocarp is separated by 7 mm-cells, which correspond to 4-16 seeds per pod and c. 5000 seeds per kg of pods (Foury 1954, Bolanos 1955, Metro & Sauvage 1955, INRA 1965, Piotto & Piccini 1996, Cantalejo 1997). Carob seeds have 8-10 mm of length, 7-8 mm of width and 3-5 mm of thickness (Batlle & Tous 1997).

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The carob species represent the *Ceratonia* genera of *Caesalpinoideae, Leguminosae, Angiospermae, Spermatophyta* (Tutin *et al.* 1990/93). It is occurs in habitats of low zone of the Mediterranean vegetation with other species such *Pistacia lentiscus, Olea europaea* var. *sylvestris, Tetraclinis articulata, Juniperus phoenicea, Pinus halepensis* and *Quercus ilex*, forming an association of *Oleo-Ceratonion*, *Pistacio-Rhamnetalia* (Ouchkif 1988, Aafi 1996, Zouhair 1996). The carob culture is exercised in the Mediterranean countries, the Western Asia, Australia, South Africa and USA (Evreinoff 1960).

In Morocco, It is spontaneous or cultivated in the thermo-Mediterranean and the meso-Mediterranean stages, corresponding to the semi-arid and sub-humid bio-climates with minima not inferior than 3°C and altitudes up to 500 m outstandingly 900-1600 m (Foury 1954, Magini & Tulstrup 1955, INRA 1965, Rejeb *et al.* 1991, Zouhair 1996).

In the Mediterranean countries, several infra-specific varieties of carob species have been identified according to the provenance or the tree features (Bonzom *et al.* 1878, Bolanos 1955, Evreinoff 1960, Catarino 1993, Tous *et al.* 1995). Studies led on carob tree from Morocco distinguish between several carob types according to tree sex (Ouchkif 1988) or its domestication importance (Gharnit 1997, Gharnit *et al.* 2001) defining four carob types: unproductive "dkar" or spontaneous male, productive "dkar" or spontaneous female, "lanta" or grafted female and sterile.

Carob pods characters differ in terms of carob tree type (e.g. Bonzom *et al.* 1878). Pomological studies were led in carob cultivars from some Mediterranean countries (e.g. Albanell *et al.* 1996, Russo & Polignano 1996). This paper draws attention to the variability of pod and seed in carob species from the Province of Chefchaouen (NW of Morocco) in order to describe from the pomological point of view, the fructifying types of carob tree: productive "dkar" and "lanta"

Material and methods

The zone survey depends on the Province of Chefchaouen and It is located between 5° 10'-5° 35' W and 34°47'-35°11' N (figure 1). The mean of annual rainfall varies from 440 mm to 1386 mm. The mean temperature is 17 to 18,1 °C and the dry period overlaps 4 months per year. The semi-arid bioclimate dominates in this area and it is followed by the sub-humid and humid ones (DAT & AECI 1996). This zone has an uneven mountainous relief with schistose, marly, flyschy, gritty, siliceous or calcareous facies (Fay 1973, SEP & PNUD 1997).

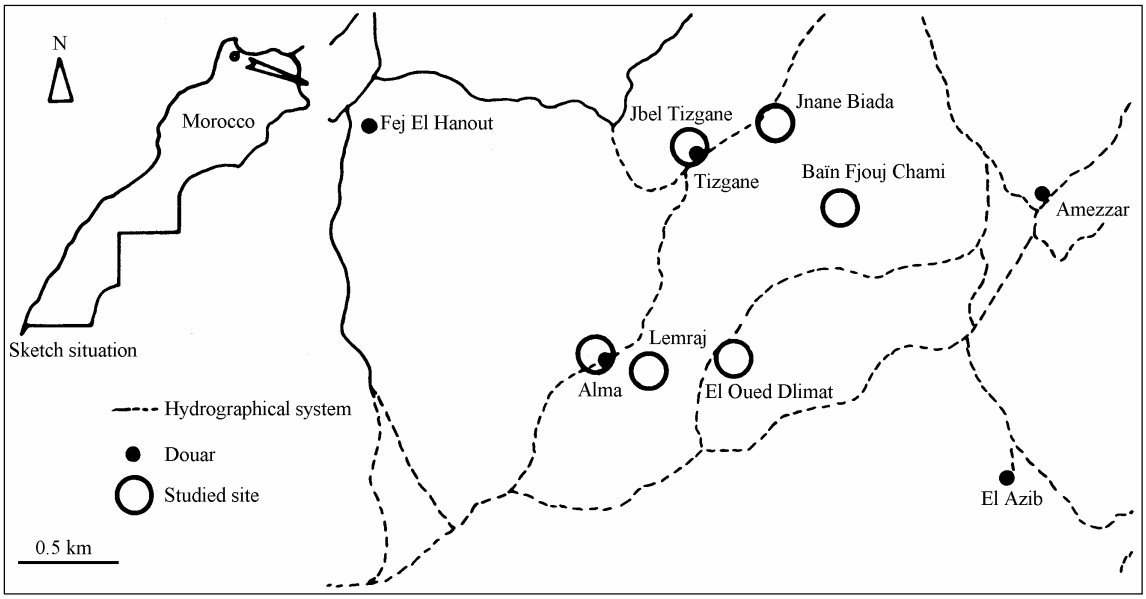

Figure 1. Situation of the survey area (DAT 2000, Road map of Morocco 1/400 000).

In this study, we opted for the Commune of Aïn Beïda of the Province of Chefchaouen seeing that (i) the forested area represents around 60% of soil use (ADL 1997), (ii) the carob tree is more domesticated (grafting, exploitation…) mainly in the cultivated areas and (iii) the various carob tree types are locally protected. We have randomly collected 1320 pods from 44 spontaneous or grafted carob trees (30 pods per tree) belonging to 6 sites. After having measured and weighed pods, the pulp is separated from seeds. Each of these two components is weighed and dried at 85 °C to constant weight. The pod description was carried on basis of 10 parameters: length, width, curvature importance or chord, thickness (figure 2), total weight, partial weights of

seeds and pulp, seeds number and yield, and aborted seeds rate.

Morphometric measures of seed (length, width, thickness, weight; figure 3) have been led at the rate of 30 seeds per tree. Then seeds are soaked in boiling water during 24 h and shredded in three parts: tegument, endosperm or carob bean gum and embryo-cotyledons complex. These different parts are also dried at 85 °C to constant weight and weighed in order to assess the content of every constituent of seed, considering the provenance and tree age. Data processing has been carried out by using the Statistica 5.0 (Statsoft Inc. 1995) software.

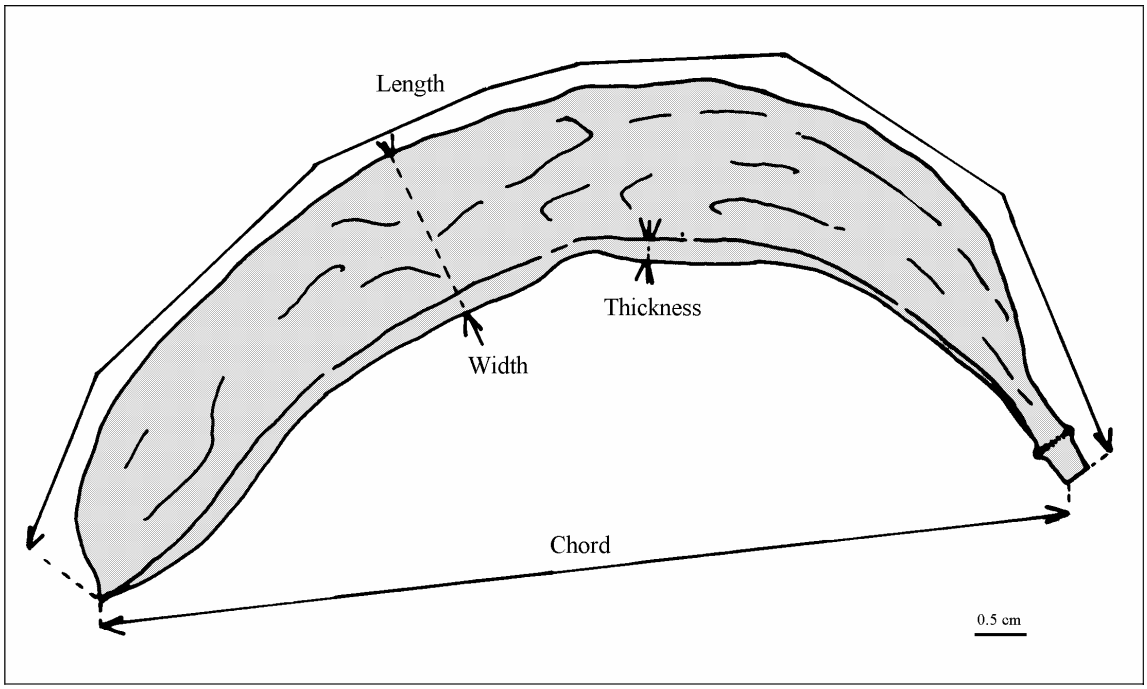

Figure 2. Descriptive schema of carob pod**.**

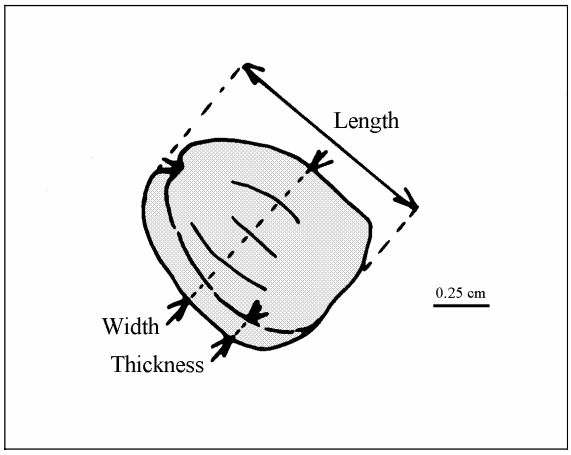

Figure 3. Descriptive schema of carob seed.

Results and discussion

Carob pod

According to pods provenance or tree age, the analysis of variance (ANOVA) showed a very highly significant differences for all variables, excepted aborted seeds rate for which difference is weakly significant (tables 1 and 2), indicating a high heterogeneity in sampled trees due apparently to location circumstances. Furthermore, the provenance effect distinguishes groupings for some variables according to tree domestication and soil texture promoting pod width (2.03±0.20 cm) in El Oued Dlimat, pod weight (11.8±3.82 g) and pulp weight (9.72±3.27 g) in Jnane Biada and seeds weight (2.28±0.46 g) in Lemraj. The maximal chord corresponding to straight pods are observed in locations moderately domesticated (upkeep

and heavy dressing of manure) and with North exposure (e.g. 10.6±2.35 cm in El Oued Dlimat). However, these factors would not influence other studied parameters i.e. pod length and thickness, seeds number and aborted seeds (table 1).

According to the grafting effect, the one-way ANOVA showed weakly significant differences for the aborted seeds rate and very highly significant differences for the other studied variables (table 2).

Pods of productive "dkar" type or spontaneous type present the best seeds yield (20.5±7.74 %) and are more straight (chord/length = 0.76) than pods of "lanta" type or grafted type (c./l. = 0.65). The pod-curvature importance is inversely proportional to tree age in "lanta" type.

Among the grafted trees, the most aged (≥ 50 years) have a longer (14.2±2.18 cm), larger (2.01±0.20 cm), heavier (11.5±3.13 g), fleshier (9.35±2.68 g) pods, with numerous seeds (10.1±2.38) and more significant seeds yield (19.3±4.96 %). The average water content of pod is 18.7±6.3 % coinciding with values mentioned by Batlle & Tous (1997) and Pietri & Rostagno (1991). Bonzom *et al.* (1878) described other different characters of carob pod in wild and grafted trees. The wild pod has a twisted shape and pod originating from the grafted tree is straight or slightly curved. Thus, pod curvature in "lanta" type could originate from grafting by using grafts of productive "dkar" type, having a regular production and curved pods. The aborted seeds rate could not depend on provenance conditions or studied types of carob tree. Other factors such pollination, fertilization or climatic conditions would a main role in this way.

In pod of productive "dkar" type, the correlation coefficient showed that seeds yield is very highly and positively related with pod length and seeds number, and very highly and negatively related with pod width and thickness, and pulp weight (table 3). Hence, the longer pods are more thin and have a high seeds yield. Except for pod width, the table 4 shows similar inferences for "lanta" type.

Albanell *et al.* (1996) have reported in carob pods from Spain an average length of 15.8 cm, a width of 2.11 cm and a thickness of 0.85 cm. Seeds number per pod and aborted seeds rate are 10 and 3.76 % in the same order. In Cyprus, average values of pod length, width and thickness are respectively 16.8 cm, 2.18 cm and 0.81 cm. The seeds number is 10.3 per pod. In Greece, authors have assessed pod length to 15.9 cm and pod width to 1.79 cm (in Albanell *et al.* 1996). In Italy, pod length reaches 14.6 cm. Another survey led in Italy by Russo & Polignano (1996) in four different locations showed that the mean pod length and width reach respectively 17.1 cm and 2.27 cm. Our values for these parameters are the lowest and the average pod length, width and thickness are respectively 13.5 cm, 1.95 cm and 0.69 cm.

Seeds number and aborted seeds rate attain respectively 8.98 per pod and 4.95 %, corresponding meanly to 0.44 aborted seeds per pod. Some factors induced seeds abortion including unsuccessful fertilization (Stephenson 1981). In terms of studied carob types, we note an aborted seeds rate of 5.84 % in "dkar" productive type and from 4.01 to 8.79 % in "lanta" type. These values remain lower than those mentioned by Batlle & Tous (1990): 39 %, 23.7 %, 21.6 % and 19 % respectively in "Negra", "Banya de marrà", "Rojal" and "Banya de cabra" cultivars from Catalonia. Thus, carob pods from Spain Cyprus or Italy are longer, larger and thicker than carob pods from Morocco.

For the quantitative parameters, Albanell *et al.* (1996) have evaluated pod weight to 14.8 g, pulp weight to 13.0 g, seeds weight to 1.88 g and seeds yield to 12.1%. Although we have obtained a low values for pod weight (10.1 g), pulp weight (8.12 g) and a similar value for seeds weight (1.91 g), seeds yield of pods in our case is superior when compared to carob pods from the aforementioned countries reaching 19.1 % vs. 15.3 % in Greece, 12.1 % in Spain, 10.8 % in Cyprus and 10.1 % in Italy.

Table 1. Carob pod characteristics according to the provenance.

Provenance (figure 1)	Length (cm)	Width (cm)	Chord (cm)	Thickness (cm)	Pod Weight (g)	Seeds number	Aborted seeds (%)	Seeds weight (g)	Pulp weight (g)	Seeds yield (%)
Lemraj	14.5±1.73 abd	2.01±0.14 abc	9.66±2.40 abc	0.63±0.08 a	10.4±2.10 abc	10.5±1.85	4.27±2.33 abeh	2.28±0.46 a	8.13±1.72 ab	22.0±2.86 ad
Alma	13.4±2.03	1.98±0.20 ad	9.07±2.62 adf	0.71±0.08	10.5±3.69 a	9.30±2.41a	2.11±1.09 acfi	2.06±0.74 abd	8.38±3.35 ac	20.8±7.95 ae
El Oued Dlimat	14.0±1.87 ace	2.03±0.20 b	10.6±2.35	0.68±0.11	11.1±3.77 b	8.93±2.33 ab	10.08±4.09 d	1.88±1.58 c	9.27±3.40	16.6±9.76 b
Jbel Tizgane	14.0±3.21 bcf	1.98±0.20 ce	9.88±3.75 be	0.65±0.09 ab	9.92±4.00 c	8.68±4.55 b	6.20±2.05 bcdgj	1.92±1.53 bce	7.94±3.12bc	17.5±10.1 bc
Jnane Biada	14.1±2.61def	1.96±0.23 de	9.55±3.74 cde	0.78±0.11	11.8±3.82	9.87±2.30	4.76±4.82 efgk	2.02±0.60 de	9.72±3.27	17.7±3.15 c
Baïn Fjouj Chami	12.2±3.39	1.88±0.26	8.79±3.33 f	0.66±0.10 b	8.03±3.22	8.10±3.52	2.28±1.19 hijk	1.72±0.83	6.23±2.63	21.5±7.09 de
F ratio	45.03	30.26	17.73	124.6	81.76	27.36	3.999	9.627	100.1	37.02
p	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000
Total average	13.5±2.92	1.95±0.23	9.51±3.34	0.69±0.11	10.1±3.88	8.98±3.27	4.95±3.79	1.91±1.08	8.12±3.31	19.1±7.73
Minimum - Maximum	5.1 - 21	1.3 - 2.6	0 - 18	0.32 - 1.2	1.32 - 22.6	0 - 16	0 - 14.9 (N=66)	0 - 14.5	1.06 - 18.7	0 - 85.7

ANOVA to 95 %, N=720. Values followed with the same letters are not significantly different.

Table 2. Carob pod characteristics according to type and age of tree.

Type Age (year)	Length (cm)	Width (cm)	Chord (cm)	Thickness (cm)	Pod Weight (g)	Seeds number	Aborted seeds (%)	Seeds weight (g)	Pulp weight (g)	Seeds yield (%)
Productive "dkar"	13.8±2.93	1.91±0.24	10.5±3.18 a	0.65±0.12	9.29±3.59	9.42±2.98 a	5.84±4.37 abd	1.84±1.00	7.37±3.15	20.5±7.74
"lanta"										
<25	12.2±3.47	1.94±0.24	7.92±3.13	0.68±0.09 ab	8.70±4.12	7.87±3.88	4.07±2.26 ac	1.66±0.89	6.97±3.32	18.8±5.92 ab
25-50	13.3±2.31	2.03±0.21	9.13±2.73	0.68±0.10 a	10.7±3.28	9.39±2.48 a	4.01±2.00 bc	2.04±0.68	8.65±2.80	19.3±4.96 a
≥50	14.2±2.18	2.01±0.20	10.2±2.91a	0.69±0.09 b	11.5±3.13	10.1±2.38	8.79±6.12 d	2.12±1.08	9.35±2.68	18.5±6.93 b
F ratio	90.00	45.00	105.0	11.19	112.9	98.85	3.365	40.95	116.9	9.611
p	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.000	0.000	0.000
Total average	13.5±2.70	1.99±0.22	9.44±3.06	0.68±0.10	10.5±3.60	9.36±2.95	5.68±4.37	1.98±0.95	8.47±3.05	19.0±6.31
Minimum-Maximum	2.3 - 21	1.1 - 2.7	0 - 18	0.32 - 1.2	0.43 - 22.6	0 - 17	0 - 21 (N=44)	0 - 14.5	0.28 - 18.7	0 - 85.7

ANOVA to 95 %, N=1320. Values followed with the same letters are not significantly different.

Table 3. Correlation between studied parameters in carob pod of productive "dkar" type, N= 330.

Length (cm)	Width (cm)	Chord (cm)	Thickness (cm)	Pod Weight (g)	Seeds number	Seeds weight (g)	Pulp weight (g)	Seeds yield (%)	Aborted seeds rate (%)	
1.000	0,210	0,634	0,078	0,691	0,817	0,620	0,585	0,202	-0,652	**Length (cm)**
	1.000	0,191	0,161	0,626	0,157	0,221	0,624	-0,293	-0,008	**Width (cm)**
		1.000	0,048	0,552	0,607	0,520	0,467	0,181	-0,446	**Chord (cm)**
			1.000	0,466	0,050	0,094	0,496	-0,209	-0,030	**Thickness (cm)**
				1.000	0,577	0,548	0,942	-0,147	-0,346	**Pod Weight (g)**
					1.000	0,685	0,432	0,446	-0,607	**Seeds number**
						1.000	0,305	0,649	-0,689	**Seeds weight (g)**
							1.000	-0,405	-0,209	**Pulp weight (g)**
								1.000	-0,4361	**Seeds yield (%)**
									1.000	**Aborted seeds rate (%)**

Table 4. Correlation between studied parameters in carob pod of "lanta" type, N= 990.

Length (cm)	Width (cm)	Chord (cm)	Thickness (cm)	Pod Weight (g)	Seeds number	Seeds weight (g)	Pulp weight (g)	Seeds yield (%)	Aborted seeds rate (%)	
1.000	0,570	0,518	-0,088	0,821	0,808	0,674	0,771	0,112	0,193	**Length (cm)**
	1.000	0,465	0,100	0,714	0,516	0,504	0,697	-0,026	0,111	**Width (cm)**
		1.000	-0,045	0,649	0,580	0,509	0,616	0,064	0,163	**Chord (cm)**
			1.000	0,182	-0,044	0,008	0,215	-0,174	0,060	**Thickness (cm)**
				1.000	0,792	0,719	0,968	0,015	0,186	**Pod Weight (g)**
					1.000	0,789	0,718	0,364	0,024	**Seeds number**
						1.000	0,567	0,636	-0,073	**Seeds weight (g)**
							1.000	-0,175	0,247	**Pulp weight (g)**
								1.000	-0,486	**Seeds yield (%)**
									1.000	**Aborted seeds rate (%)**

By studying "Bravia" and "Injertada" cultivars of carob species from Andalusia, Tous *et al.* (1995) showed that fruit length varies respectively from 15.6 to 17.6 cm and from 16.3 to 17.6 cm; the pod weight varies from 7.04 to 13.2 g and from 12.6 to 21.9 g in the same order. The seeds yield of pods is high in "Bravia" cultivar (16.3 to 23.6 %) vs. 13.5% to 19.5 % in "Injertada" cultivar. These results agree with our data, indicating a high seeds yield in the spontaneous type or productive "dkar" type (20.5 %) vs. 18.5-19.3 % in the grafted type or "lanta" type. Like to the "Injertada" cultivar, pods of "lanta" type are longer (12.2-14.2 cm) and heavier (8.70-11.5 g) than those of productive "dkar" type, having a length of 13.8 cm and a weight of 9.29 g.

Pods of "Rojal" variety have 18 cm of length, 2 cm of width, 1 cm of thickness and a low seeds yield fluctuating between 10 and 13.6 % (Batlle & Tous 1990, 1998). In terms of studied cultivars, seeds yield get to 17.7 % and 15.2 % respectively in "Banya de cabra" and "Banya de marrà" (Batlle & Tous 1990). Otherwise, the Portuguese carob cultivars generate a seeds yield of pods from 12 to 17 %. In Crete, the "Hemere" type shows a lower seeds yield of pods (9 %). Therefore, pods of productive "dkar" type from the Commune of Aïn Beïda has the higher seeds yield (20.5 %) displaying a conspicuous commercial importance.

Carob seed

The one-way ANOVA showed very highly significant differences for all studied characters (table 5). Comparison of provenance data underlines conspicuously an impact of environmental factors on the most studied variables. The domestication importance could increase seed length, which is 9.51±0.57 mm in the Alma vs. 9.26±0.51 mm in Baïn Fjouj Chami. The seed thickness would be favoured in Jnane Biada (4.61±0.39 mm) on very developed soil. The maximum seed weight (0.49±0.45 g) is observed in El Oued Dlimat on chalky substratum. However, environmental circumstances would not induce endosperm content of seeds and tree types would present the main factor characterizing carob seeds.

Regarding tree age and grafting, the one-way ANOVA showed very highly significant differences for all studied variables (table 6). Productive "dkar" type promotes endosperm content of mature seeds, which attains 47.6±4.53 %. We point out also that dry weight of seed (sum of dry weight of seed constituents) represents 78.8±11.5% of its mature weight. The age effect in productive "dkar" type could not be highlighted because it is rarefied in the study area by grafting the young trees.

The correlation between the studied parameters showed that endosperm content of mature seeds is very highly and positively related with seed thickness (r=0.31) and negatively related with mature-seed weight (r=-0.40) (table 7). Therefore the thick and light seeds of productive "dkar" type have a high endosperm yield. For "lanta" type, the endosperm content is very highly and negatively related with seed length (r = -0.12) and highly and negatively related with mature-seed weight (r=-0.94). The seed width and thickness would not have an effect on endosperm yield (table 8). Thus, the short and lighter seeds of "lanta" type have a moderate endosperm yield.

Referring to morphometric characters of carob seed from Spain, Albanell *et al.* (1996) have underlined a slightly superior average for seed length (0.96 cm vs. 0.93 cm) and lower average for seed width (0.70 cm vs. 0.76 cm), thickness (0.38 cm vs. 0.45 cm) and weight (0.19 g vs. 0.35 g). In Cyprus, morphometric characters of seed are similar those from Spain, excepted seed length of 0.89 cm (in Albanell *et al.* 1996). According to the provenance, seeds from the Commune of Aïn Beïda are larger, more thick and heavier than seeds from Spain or Cyprus. Russo & Polignano (1996) have reported in carob cultivars from Italy seed length, width and thickness of 0.93 cm, 0.68 cm and 0.39 cm in the same order. In our case, these parameters correspond respectively to 0.94 cm, 0.77 cm and 0.45 cm, showing an importance of seed width and thickness.

Table 5. Carob seed characteristics in terms of provenance.

Provenance (figure 1)	Length (mm)	Width (mm)	Thickness (mm)	Mature weight (g)	Dry weight (g)	Endosperm (% dw)	Endosperm (% mature weight)	Embryo-cotyledons (% dw)	Tegument (% dw)
Lemraj	9.44±0.37 ab	7.78±0.39 abc	4.53±0.27 ab	0.24±0.03 be	0.19±0.02be	59.6±3.88 ac	49.6±4.24 ac	19.2±1.88 be	21.1±2.61 a
Alma	9.51±0.57 ac	7.74±0.61 adef	4.29±0.38	0.48±0.46 ac	0.29±0.19ac	54.5±8.13 b	41.1±11.9 b	21.3±4.77 ac	24.3±4.11 b
El Oued Dlimat	9.50±0.51bc	7.74±0.43 bdg	4.50±0.29 a	0.49±0.45 ad	0.30±0.19ad	55.9±8.77	42.7±12.7	21.1±4.77 ad	22.9±4.28
Jbel Tizgane	9.26±0.91 de	7.68±0.59 cegh	4.43±0.41	0.21±0.03 bf	0.17±0.03b	60.2±2.79 a	50.1±2.68 ad	18.6±2.19 bf	21.2±2.05 a
Jnane Biada	9.27±0.78 df	7.60±0.76 i	4.61±0.39	0.47±0.44 cd	0.28±0.19cd	54.0±8.18 b	41.6±11.9 b	21.4±4.85 cd	24.6±3.56 b
Baïn Fjouj Chami	9.26±0.51 ef	7.66±0.48 fhi	4.56±0.33 b	0.23±0.03 ef	0.19±0.02e	59.3±2.77 c	49.6±3.81 cd	18.9±1.45 ef	21.7±2.34
F ratio	12.29	4.474	34.71	86.98	79.77	89.62	119.7	59.70	99.01
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total average	9.33±0.67	7.67±0.58	4.51±0.37	0.35±0.33	0.24±0.14	57.3±6.63	45.7±9.72	19.9±3.76	22.7±3.44
Minimum-Maximum	5.24 - 11.2	5.36 - 9.26	3.32 - 6.06	0.11 - 1.34	0.08 - 0.67	37.9 - 72.8	19 - 58.9	9.71 - 32.6	12.3 - 38.6

ANOVA to 95 %, N=720. Values followed with the same letters are not significantly different.

Table 6. Carob seed characteristics in terms of type and age of tree.

Type Age (year)	Length (mm)	Width (mm)	Thickness (mm)	Mature weight (g)	Dry weight (g)	Endosperm (% dw)	Endosperm (% mature weight)	Embryo-cotyledons (% dw)	Tegument (% dw)
Productive "dkar" "lanta"	9.45±0.78 ab	7.29±0.58	4.20±0.38	0.21±0.04	0.17±0.02	57.9±3.52 a	47.6±4.53	20.0±2.14 ab	21.9±2.61
<25	9.31±0.69	7.85±0.57	4.50±0.37	0.42±0.39 a	0.27±0.17a	56.7±8.11	44.9±11.9	20.4±4.43 a	22.8±4.00 ab
25-50	9.45±0.48 ac	7.77±0.49	4.54±0.31	0.33±0.30	0.23±0.13	57.7±6.20 a	46.1±8.61	19.7±3.46 b	22.6±3.37 a
≥50	9.48±0.63 bc	7.72±0.57	4.56±0.33	0.41±0.38 a	0.27±0.16a	55.9±7.95	43.7±11.6	21.0±4.51	23.0±3.92 b
F rapport	12.84	83.73	104.2	39.09	45.61	14.91	17.61	22.51	7.999
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total average	9.44±0.62	7.72±0.57	4.51±0.35	0.37±0.35	0.25±0.15	56.8±7.19	45.0±10.4	20.4±4.05	22.7±3.67
Minimum-Maximum	5.24 - 11.6	4.46 - 9.46	3.12 - 6.06	0.11 - 1.34	0.08 - 0.67	12.9 - 72.8	4.62 - 59.6	9.03 - 40.3	12.3 - 46.7

ANOVA to 95 %, N=1320. Values followed with the same letters are not significantly different.

Table 7. Correlation between studied parameters in carob seed of spontaneous type, N=330.

Length (mm)	Width (mm)	Thickness (mm)	Mature weight (mw, g)	Endosperm (% dw)	Embryo-cotyledons (% dw)	Tegument (% dw)	Dry weight (dw, g)	Endosperm (% mw)	
1.000	0,257	-0,160	0,331	-0,273	0,339	0,090	0,445	-0,130	**Length (mm)**
	1.000	0,279	0,423	-0,241	0,318	0,064	0,683	0,077	**Width (mm)**
		1.000	0,320	0,282	-0,128	-0,275	0,477	0,308	**Thickness (mm)**
			1.000	-0,024	0,194	-0,127	0,705	-0,399	**Mature weight (g)**
				1.000	-0,675	-0,796	-0,134	0,453	**Endosperm (% dw)**
					1.000	0,091	0,261	-0,321	**Embryo-cotyledons (% dw)**
						1.000	-0,033	-0,349	**Tegument (% dw)**
							1.000	0,203	**Dry weight (g)**
								1.000	**Endosperm (% mw)**

Table 8. Correlation between studied parameters in carob pod of grafted type, N=990.

Length (mm)	Width (mm)	Thickness (mm)	Mature weight (mw, g)	Endosperm (% dw)	Embryo-cotyledons (% dw)	Tegument (% dw)	Dry weight (dw, g)	Endosperm (% mw)	
1.000	0,244	-0,089	0,144	-0,145	0,184	0,084	0,188	-0,118	**Length (mm)**
	1.000	-0,049	0,027	-0,029	0,052	0,001	0,056	-0,009	**Width (mm)**
		1.000	-0,012	0,053	-0,024	-0,079	0,006	0,044	**Thickness (mm)**
			1.000	-0,854	0,856	0,745	0,996	-0,940	**Mature weight (g)**
				1.000	-0,947	-0,934	-0,847	0,942	**Endosperm (% dw)**
					1.000	0,770	0,854	-0,916	**Embryo-cotyledons (% dw)**
						1.000	0,733	-0,853	**Tegument (% dw)**
							1.000	-0,918	**Dry weight (g)**
								1.000	**Endosperm (% mw)**

The average of endosperm content in carob seeds from Spain and Cyprus is respectively 51.7 % and 50.4 % dw (Albanell *et al.* 1996), vs. 57.3 % dw or 45.7 % of mature-seed weight in this study. Among 14 carob cultivars from Italy studied by Barbagallo *et al.* (1997), the "Melara" cultivar showed the high endosperm content of seeds (52.5 % dw). In the "Rojal" variety, It reaches 56.2 % dw (Batlle & Tous 1998). In our study, it attains 57.9 % in productive "dkar" type and 57.7 % in "lanta" type corresponding in the same order to 11.9 % and 10.3-11.1 % of endosperm content of pod weight. According to Catarino (1993), the endosperm represents 4 % of pod weight. Seeing the gelling and thickening feature of carob bean gum, carob seeds contribute to more than 60 % of carob pod merchandising (in Cantalejo 1997) since every seed contains 0.14 g of endosperm in our case vs. 0.09 g for carob seed from Spain (Albanell *et al.* 1996). We could also infer that productive "dkar" type can produce 12.4 kg of seeds and 7.20 kg of endosperm per tree while "lanta" type produces only 7.36-7.68 kg of seeds and 4.11-4.43 kg of endosperm per tree.

This survey revealed that the tegument and the embryo-cotyledons complex constitute respectively 22.7 % and 19.9 % of seed dry weight. Elsewhere, they reach 20.8 % and 18.3 % in Spain and 7.4 % and 19.5 % in Cyprus in the same order. Seeds of the "Orleans" cultivar from Italy contain 18.8 % of tegument and 18.2 % of embryo-cotyledons (Barbagallo *et al.* 1997). For this survey a higher values were observed in aged grafted-type: 23.0 % of tegument and 21.0 % of embryo-cotyledons.

Therefore carob seeds from Morocco are larger, thicker and have high contents of endosperm and embryo-cotyledons when compared with those from Spain and Cyprus. Carob seeds from Spain are longer and those from Cyprus present the high tegument content. Seeds of carob productive "dkar" type are larger, thicker and have high endosperm content than "Melara" cultivar and "Rojal" variety. The maximal values of embryo-cotyledons and tegument contents were observed in "lanta" type when compared with "Orleans" cultivar.

From this study, the results showed that environmental conditions could influence morphometric characters of carob pod such width, chord, pod weight, pulp weight and seeds weight. Carob productive "dkar" type presents a high seeds yield and has a straight pod. The aged "lanta" type of this species showed more significant seeds yield. Seeds of productive "dkar" type have high endosperm content. Nevertheless, tegument and embryo-cotyledons complex contents present the high values in "lanta" type. Seeing the industrial importance of carob pods, due to their endosperm contents, we can recommend the productive "dkar" type. Morphometric characters such seed length; width and thickness can serve to select seeds with potential importance for industrial use.

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