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Research Article

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Morocco carob (*Ceratonia siliqua* L.) populations: Morphological variability of Pods and Kernel

El Kahkahi R.[123], Zouhair R.[2], Ait Chitt M.[3] and Errakhi R.[1]*

[1]Laboratory of Molecular Biology Centre of Innovation and Transfer University Moulay Ismail Meknes, Morocco
[2]Laboratory of Plant Biotechnology, Faculty of Sciences Meknes, Morocco
[3]El Bassatine Domaine, Meknes, Morocco
*Corresponding Author E-mail: r.errakhi@umi.ac.ma

ABSTRACT

Forty seven Morocco carob populations from different sites were studied to assess their genetic variation based on pods and kernels measures. The mean of the main descriptive morphological values of pods were length (13.85 cm), width (1.57 cm), central thickness (0.64 cm), number of viable kernels (12.26), yield (kg pods / tree) (113.46 Kg), pulp weight (5.91g), kernels weight (1.76 g), kernel length (0.72 cm) kernel width (0.39 cm), kernel thickness (0.39 cm) and kernel yield (23.12%). Most of the parameters measured showed significant difference ($P < 0.05$ to $P < 0.001$) that indicates a high genetic diversity; type and geographical origin of trees being taken as the source of variation. We recorded more than 60% germination after just 4 days of incubation and 100% germination after 8 days for the chemical agent. However, for water boiling, we chose a germination rate of less than 50% and 95% germination after eight days of incubation.

The relationship among these characters was analysed hierarchical clustering resulting in the separation of these populations classed in three grouped and three ungrouped populations.

Keywords: *Ceratonia siliqua L., Morocco, Kernels, Pods, Morphological diversity, hierarchical clustering, Germination.*

INTRODUCTION

The carob tree (*Ceratonia siliqua* L. 2n = 24) is an angiosperm, dicotyledonous belonging to the order Rosales, family Fabaceae., it tolerates drought explaining its large distribution in the arid and semi-arid Mediterranean climate[10,22,16,17]. Whose origin seems to be the eastern Mediterranean has been domesticated since 4000 BC, and his extensive dates from at least 2000 BC culture, its longevity is considerable (up to 200 years), it can reach up fifteen meters high[3]. It is formerly operated in particular through its feed and food qualities. Thus the tree is useful in human and animal food, ornamental, industry, carpentry, beekeeping and traditional medicines[5,6,30].

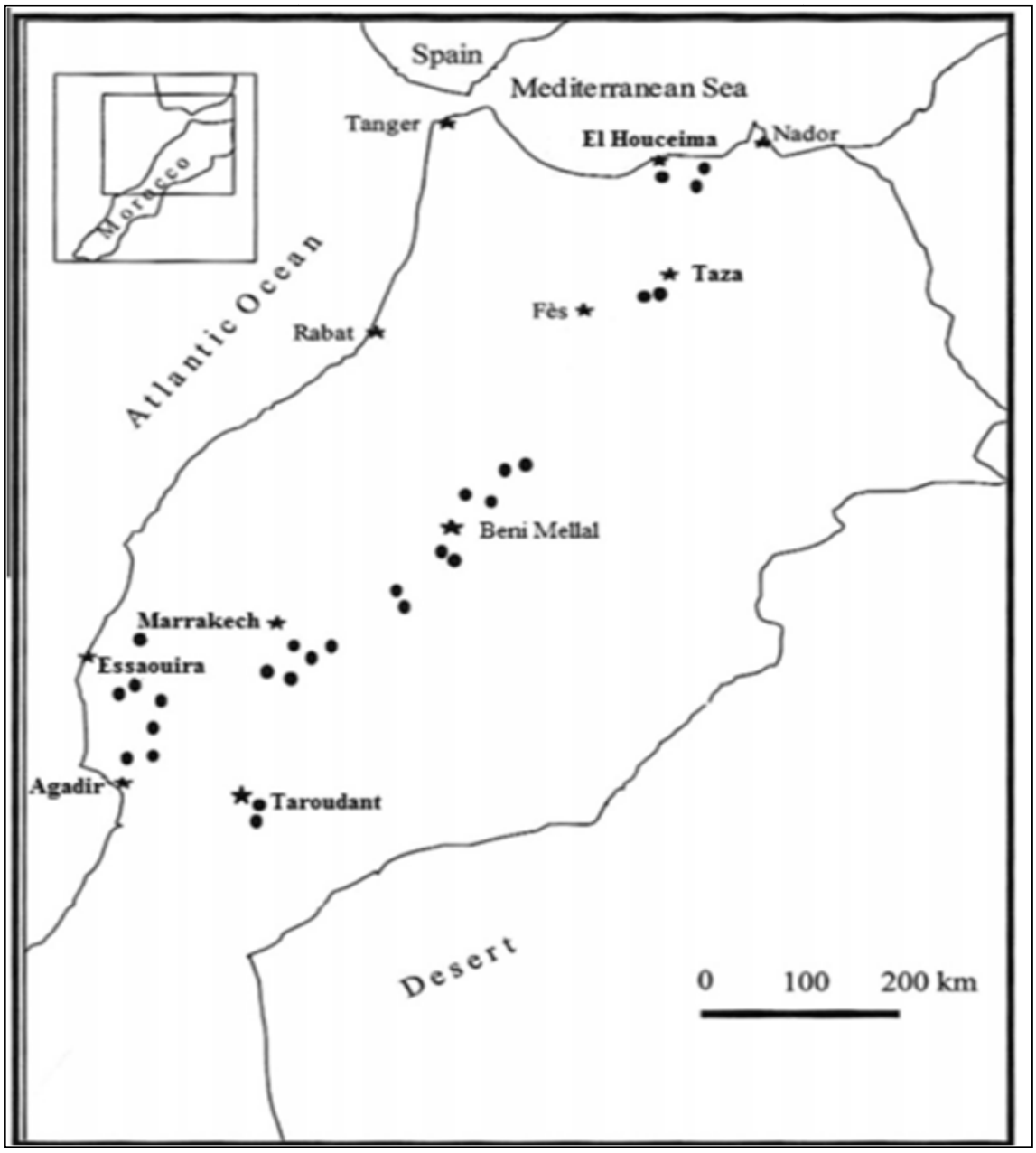
The carob tree is as a forest and arboreal species. It is an important major economic, ecological and social. Currently, it is considered a fruit and forest trees more efficient; since all its parts (leaves, flowers, fruits, wood, bark and roots) are useful and have value in several areas.

In Morocco, the carob tree occupies an area of 30,000 ha [3], this form of natural or artificial plantations in the country up to 1150 m except very arid[14,19,23,27]. It is found in the western and eastern Rif[1]. Stands carob fit in order Pistacio – Rhamnenalia[2], which includes groups matorrals clear wooded or shrubby and are either natural or introduced as generating species forests . The main population spontaneous carob is located in the regions of Meknes, Agadir, Essaouira, Taza, El Hoceima and Khenifra (Tafechna and Aït Ishaq) , in association with the olive (*Olea europea*) , mastic (*Pistacia lentiscus*) cedar (*Junepurus phoenicea*) and the argan tree (*Argania spinosa*) (Fig.1) . Carob production was estimated at only 26 % of the international production. This production is considered second in the world behind Spain (33%)[32].

With exception of a few studies based on morphological data (fruit) conducted the carob tree in Morocco[21,28], no official information on collections and Moroccon germoplansmes is available. Phenotypic characteristics have been and continue to be used as essential components in the final classification of living organisms. Till today, they have been the main descriptive tool used to characterize a given collection or germplasm, to identify and differentiate wild type cultivars[11,26,29].

In this chapter , we are interested in both the agro -morphological traits and seed pods of the carob tree of Morocco and the variability in the integumentary seed hardness to establish a descriptive or technical data sheet and determine preliminary genetic relationships among different populations.

Fig.1: Distribution of the carob tree in Morocco according to bioclimatic Sidina and *al*., 2009



MATERIALS AND METHODS

Plant material

The plant material consists of pods of carob tree. It was collected from four different locations in Morocco. So we brought in the samples to Fez, Meknes, Khemisset and Marrakech laboratory (Table 1).

Table 1: Carob trees accessions analyzed in this study

Accession	Sex	Origin	Latitude N	Longitude W	Altitude (m)	Geographic region	Rainfall (mm)
P1	Female	Fez	34° 03′ 00″	4° 58′ 59″	579	Plateau saïs	600
P2	Female	Fez	34° 03′ 00″	4° 58′ 59″	579	Plateau saïs	600
P3	Female	Fez	34° 03′ 00″	4° 58′ 59″	579	Plateau saïs	600
P4	Female	Fez	34° 03′ 00″	4° 58′ 59″	579	Plateau saïs	600
P5	Female	Fez	34° 03′ 00″	4° 58′ 59″	579	Plateau saïs	600
P6	Female	Fez	34° 03′ 00″	4° 58′ 59″	579	Plateau saïs	600
P7	Female	Fez	34° 03′ 00″	4° 58′ 59″	579	Plateau saïs	600
P8	Female	Fez	34° 03′ 00″	4° 58′ 59″	579	Plateau saïs	600
P9	Female	Meknes	33° 53′ 42"	5° 33′ 17″	560	Plateau saïs	600
P10	Female	Meknes	33° 53′ 42″	5° 33′ 17″	560	Plateau saïs	600
P11	Female	Meknes	33° 53′ 42"	5° 33′ 17″	560	Plateau saïs	600
P12	Female	Meknes	33° 53′ 42″	5° 33′ 17″	560	Plateau saïs	600
P13	Female	Khemisset	33° 49′ 0″	6° 4′ 0″	409	Plateau central	456
P14	Female	Khemisset	33° 49′ 0″	6° 4′ 0″	409	Plateau central	456
P15	Female	Khemisset	33° 49′ 0″	6° 4′ 0″	409	Plateau central	456
P16	Female	Khemisset	33° 49′ 0″	6° 4′ 0″	409	Plateau central	456
P17	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P18	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P19	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P20	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P21	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P22	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P23	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P24	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P25	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P26	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P27	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P28	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P29	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P30	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P31	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P32	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P33	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P34	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P35	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P36	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P37	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P38	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P39	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P40	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P41	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P42	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P43	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P44	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P45	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P46	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500
P47	Female	Marrakech	31° 37′ 48″	8° 00′ 00″	450	Haut Atlas	500

Morpho-agronomic markers

Thirty pods were taken randomly from each carob tree (*Ceratonia siliqua* L.). Seven characters on discriminative pods were measured to know the length, width, thickness, number of seeds, weight of pulp, and yield (seeds weight/ pod weight X 100). Four characters to seeds: the length, width, thickness and the weight seeds.

Germination test

After crushing the pods that they have been agro-morphological studied, forty seeds were taken at random from each population. Each seed lot was left in a sterile vial 250ml. After we added 50 ml of sulfuric acid (H_2SO_4) with 95% concentrate, the vials were subjected to agitation 240 rpm (return per minute) for 30 minutes. The digestive effect of the sulfuric acid on the seed coat of seed is stopped by the addition of sterile distilled water, followed by a series of rinsing (10min, 10min and 15min).

The seeds are then germinated in Petri dishes containing sterile filter paper moistened with sterile distilled with ten seeds per plate, incubated at 30°C in the dark water. The seed is considered germinated when the radicle persian integumentary envelope, the observation and analysis of the results took place every day.

We did the same steps of the previous experiment, but we replaced the chemical agent (H_2SO_4) by the physical agent (boiling water). We repeated these experiments three times. We have carried out this test for comparison between the power of the scarifying sulfuric acid and boiling water.

Data analysis

The numerical values obtained from various parameters measured were, analyzed by SPSS Version 20 software to calculate averages and standard deviations, which facilitated the comparison of fruit trees together along each character. Matrices generated for the different agro-morphological markers are analyzed using software Version 3.2.1 MVSP using the UPGMA method (hierarchical clustering).

RESULTS

Measurement of agro-morphological variables

The mean and standard deviations of all measured values are assigned to variables in the table 2. At the outset, we note that each criterion pod analyzed can be considered as a distinctive means of a shaft to another.

Agro -morphological criteria related to the size of carob pods are variable from one population to another. The pod length varied between 10,21 cm (P9) to 16,63 cm (P18), the width varied between 1.21 cm (P24) to 1.81 cm (P10), the pod thickness varies between 0.45 cm (P7 and P8) to 0.87 cm (P26), the seeds number per pod varies between 08.43 (P12) to 14.18 (P29), seed yield has the highest variation, as it varies between 17.40% (P22) to 27.83% (P2) and yield (kg pods /tree) ranged from 4.5 kg (P38) of pods per tree to 550 Kg (P1, P2, P3 and P4). In addition to the morphological characteristics of the seeds are also varied among populations. Values corresponding to the length , width, thickness and total fresh weight varied respectively 0.75 cm (P6) to 0,92 cm (P24), 0.57 cm (P41) to 0.72 cm (P1, P2, P3 and P4) , 0.32 (P5 and P7) to 0.44 cm (P15) and 1.09 g (P15) to 2.62 g (P1, P2, P3 and P4). These results show that the heaviest seeds belong to the population that has trees : P1, P2, P3 and P4.

The correlation between the analyzed agro-morphological traits are summarized in Table 3. Pod length is correlated positively with the pod thickness, pulp weight, yield (kg pods / tree) and seeds number with respective linear regression coefficients of r = 0.31, 0.725, 0.262 and 0.643. Further more pod length was negatively correlated with the pod width, yield (% of seeds) and seed weight (r = - 0.385, - 0.454 and - 0.542). Seed weight is also correlated with the most criteria pod and seeds, except the pod thickness, pulp weight, yield (Kg of pods /tree) and the thickness of the seeds which shows a low correlation (r = 0.083, - 0.195, 0.22 and 0.22). Yield (Kg pods / tree) has a low correlation with seeds number, yield (% of seed) and negatively correlated with pod width (r = -0,250).

Table 3 : Pearson coefficient correlation morphological characters of pods and seeds of Moroccan carob tree

	1	2	3	4	5	6	7	8	9	10	11
Pod length (1)	1										
Pod width (2)	-,385**	1									
Pod thickness (3)	,310**	-,231									
Seed number (4)	,643**	,055		1							
Pulp weight (5)	,725**	-,027	1	,488**							
Yield (%) (6)	-,454**	,425**	,060	,184	1	1					
Yield (kg pods / tree) (7)	,262*	-,250*	,526**	-,153	-,348**	-,154					
Seeds Length (8)	,033	-,129	-,088	-,148	,501**	,134					
Seeds width (9)	,277*	-,025	,550**	-,071	,271*	-,239	1		1		
Seeds thickness (cm) (10)	,376**	,335*	,679**	,611**	,584**	,349*	,359**		,430**	1	
Seeds weigth (11)	-,542**	,415**	,623**	-,364**	,725**	,581*	,512**		,151	,220	1
			,470**		-,195		,151				
			,083				,220				
								1			
								,455**			
								,379**			
								,512**			

****.** The correlation is significant at 0.01
***.** The correlation is significant at 0.05

The matrix generated for different agro- morphological markers analyzed by the software MVSP version 3.2.1 via the UPGMA method, has established the first genetic relationships among different clones of Moroccan carob. Indeed, the dendrogram (Figure 2) perfectly reveals the existence of a significant level of agro- morphological polymorphism between clones of carob tree. Thus, being placed arbitrarily with 88.27 % of similarity, we obtained seven groups.

The first cluster tree is composed of : P9, P10, P11 and P12, which have only 95.2 % of similarity between them, the second cluster (P5, P6, P7 and P8) correlated to each other at 94.13 % of similarities. While trees (P29, P24, P22, P21, P20, P19 P18 and P17) which share 93.07 % of the measured variables, constitute the third cluster. The fourth cluster (P47, P42, P44, P41, P45 and P39) correlated them to 94.67 %. The fifth cluster (P28, P31, P30 and P25), which have only 96,35% of similarity, the sixth cluster (P13, P14, P15, P16, P23, P26, P27, P32, P33, P34, P35, P36, P37, P38, P40, P43 and P46) correlated them with 92.53 % of similarities and seventh cluster (P1, P2, P3 and P4) correlated them 96.8%.

Seed germination

The results from the germination of seeds of carob tree having undergone scarification with sulfuric acid or treated with boiling water, are inconclusive.

We note after five days incubation the germination rate of seeds that are treated with boiling water has reached a level of 42.5%, 90% for the seeds treated with concentrated sulfuric acid and 12.5% for the control (sterile distilled water).

In twelve days of incubation of the germination rate gradually increases with time, for seeds soaked in sulfuric acid germination rate reaches a maximum value of 100%, the seeds are soaked in boiling water for 80% and soaked in sterile distilled water seeds reach 22.5%.

DISCUSSION

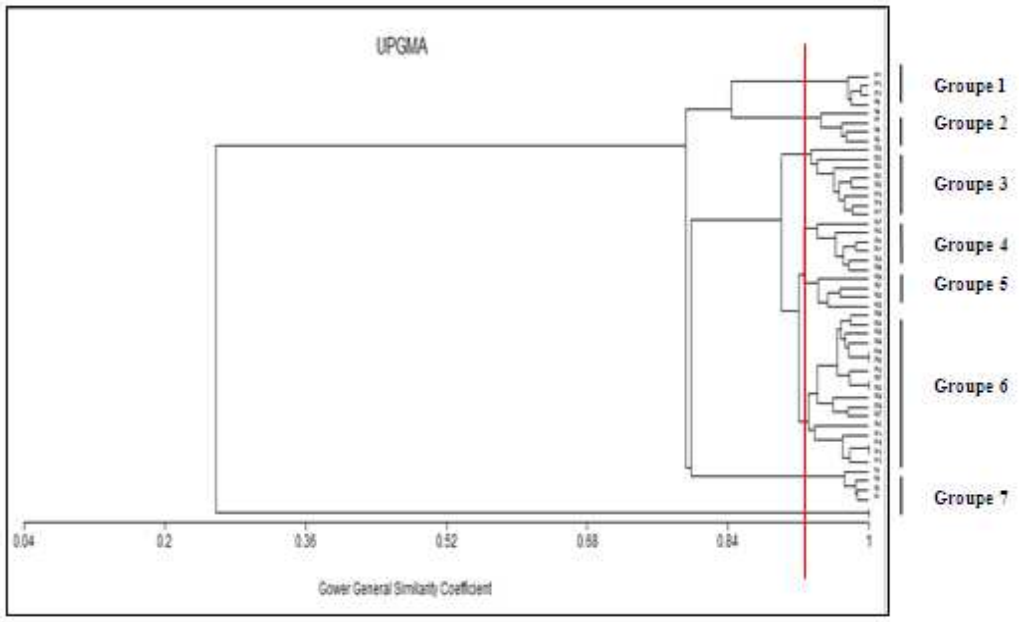
Morphological characters of pods and seeds are widely used quantitative marker identified varieties of carob according to certain criteria (productivity, resistance to disease and environmental stress[4,5,25,31]. They used twelve phenotypic traits for pods and seeds, Barracosa and *al.*,[5] for 15 diverse cultivars of carob in Portugal in cultivars in Spain, Albanell and *al.*,[4] found a high diversity in morphological parameters of pods and seeds agro- morphological traits of pods and seeds show a very high diversity in the population of Tunisian carob ; type and geographical origin of the trees are considered as the source of

variation[25]. Worldwide, about 50 named cultivars are reported in the literature[7] in which nearly half were reported in the Mediterranean basin.

In Morocco, the data published by Ouchkif showed that spontaneous populations produce less than 20% of total production. Carob domesticated in the agro-forestry system constitute the major Moroccan production. The analysis of morphological characters of pods and seeds were found a large phenotypic variation of Moroccan carob[21]. The yield of pods seed grown trees is higher (17.47% to 29.44%) compared to wild trees (15%) reported by Ouchkif (1997), it ranged from 9.99% (population of Essaouira) to 28.54 (population Taounate) Konate and *al.*, 2007. These differences between the cultivated and the wild population relied heavily on the level of selection pressure by farmers.

The comparison of related pods with those described in the Mediterranean region[7], shows an overlap of length, width and thickness of the pods. However, populations of north Morocco carob (Berkane, El Hoceima, Nador and Chefchaouen) appear to be similar to the cultivars of the north part of the Mediterranean basin[4,5]. The populations of the north of Morocco are characterized by relatively long pods, broad, thick and with a significant weight of pods and pulp [Ain Safa (17.27 cm, 1.9 cm , 0.84 cm, 15.69 g and 13.6 g) , Wazzane (16.12 cm, 2.40 cm, 0.81 cm, and 18.19g 15.25g) and Al Houceima (14.36cm , 1.93 cm , 0.77 cm, 13.8 g and 11.52g) Konate and *al.*, 2007] and [Berkane (14.27 cm, 1.76 cm, 0.64 and 9.5), Nador (14.02 cm, 1.85 cm, 0.61cm and 10.3g) El Houceima (13.63cm, 1.85cm, 0.7cm, and 9.43g) and Chefchaouen (14.02cm, 1.85cm, 0.62cm and 8.72g) Sidina and *al.*, 2009. Thus, the seed yield is relatively higher in these populations of northern Morocco. The similarity of characteristics of carob in both sides of the Mediterranean (Northern Morocco and Southern Europe), suggests that there is an exchange of material between the two regions.

Fig. 2: Dendrogram (hierarchical clustering) of 47 tree of Moroccan carob (*Ceratonia siliqua* L.) Based on Morpho-agronomic traits



The analysis via hierarchical clustering (Figure 2) showed that there are seven caroubier populations grown in different regions, based on analyzes of morphological traits of pods and seeds. Throughout its distribution, including wild populations and cultivated carob populations in Morocco, there is a high degree of biodiversity. Many populations are morphologically recognized by farmers, designated as El Horr El Beldi and Dial Eddib some of which are hybrids between wild and cultivated trees. The dominant population in the North of Morocco is El Horr.

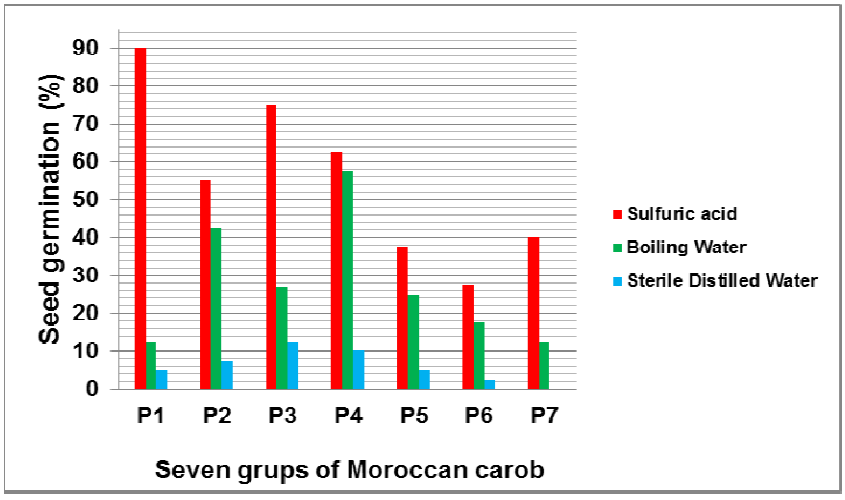
The seeds of carob tree (*Ceratonia siliqua* L.) studied also exhibit various behaviors towards physical and chemical treatments at the time of germination. The results highlight the effect of treatment has a very

important role in seed germination. To bypass the integumentary dormancy and improve seed germination profitable in a short time, several techniques pretreatment seed of the carob tree were adapted. Indeed, these seeds have been wet treatments, boiling water[7], the gibberellin acid[7,15] and sulfuric acid[7,8,12,15,18,20,24] or mechanical treatments[9,13]. Notwithstanding, treatment with sulfuric acid has been widely recognized to be more effective compared to other methods[15,18]. Among the carob, the duration of treatment was sulfuric, according. authors, highly variable She was determined at 10 min (Christodoulakis and *al.*, 2002) , 15min (Cruz and *al.*, 1997) , 30min (Frutos , 1988; Konaté, 2001) , 45 min (Konaté , 2001) and 60 min (Goor and Barney, 1968; Karschon , 1960; Missbah and *al.*, 1996 . Batlle and Tous, 1997 Konaté 2001).

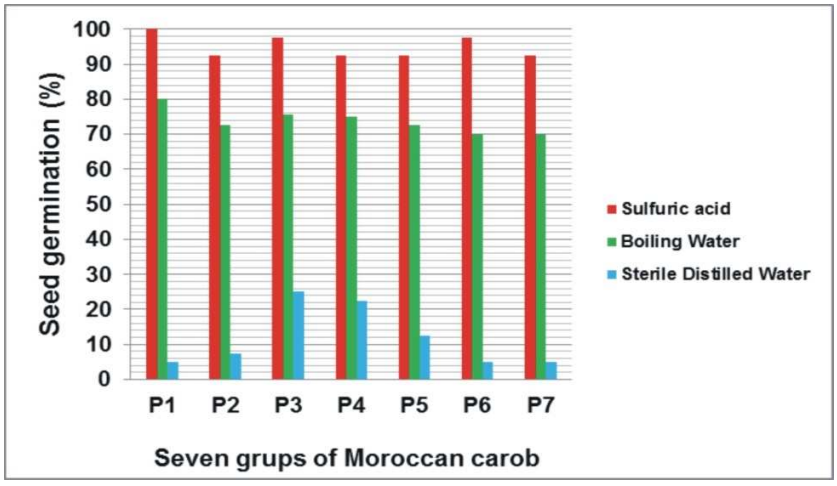
These results show that the Moroccan carob is neglected by research programs and development until now, has a high variability between populations of Moroccan carob , these results mean that a genetic variation in this variability. Indeed, carob grows in arid and warm bioclimatic as Tafraoute and Issafen with rainfall less than 200 mm in temperate and sub-humid bioclimatic zones in northern Morocco including Chefchaouen, with an annual precipitation rate of 700 mm. The carob tree is able to withstand freezing as the population in El Ksiba; for example, Beni Mallal carob exercise tolerance unusual behavior at very low temperatures in winter (2 °C).

These results should be completed by the analysis of other molecular markers (ISSR and RAPD), Biochemical and agronomic (Resistance to abiotic stress).

Fig.3: Influence of scarification with sulfuric acid (95%), boiling water and sterile distilled water of seeds germination the carob tree from different regions of Morocco



a : Results collected after 5 days of germination



b : Results collected after 12 days of germination

Table 2 : Characterization of agro-morphological fruits (pods and seeds) of populations of :carob (*Ceratonia siliqua* L.)

	Length (cm)	Width (cm)	Thickness (cm)	Seeds number / pod	Weight of pulp(g)	yield in seed(%)	Yield (kg pods / tree)	Length (cm)	Width (cm)	Thickness (cm)	Weight of seed (g)
P1	14,07±0,97	1,75±0,02	0,70±0,08	13,15±1,20	6,76±1,73	26,74	550	0,88±0,02	0,70±0,02	0,41±0,02	2,46±0,38
P2	14,26±0,70	1,72±0,01	0,72±0,06	13,15±1,20	6,76±1,73	27,83	550	0,88±0,02	0,70±0,02	0,41±0,02	2,56±0,25
P3	14,10±3,72	1,70±0,19	0,70±0,10	13,15±4,04	6,59±3,39	26,75	550	0,88±0,02	0,70±0,02	0,42±0,04	2,03±1,00
P4	14,05±1,13	1,72±0,01	0,73±0,04	13,65±0,49	7,40±0,82	26,20	550	0,86±0,01	0,70±0,02	0,41±0,02	2,62±0,16
P5	11,77±2,26	1,44±0,05	0,47±0,01	11,60±1,27	3,64±1,22	23,14	150	0,76±0,07	0,65±0,06	0,32±0,01	1,09±0,41
P6	12,62±1,05	1,43±0,06	0,48±0,01	11,98±0,74	3,76±1,05	25,21	150	0,75±0,08	0,58±0,04	0,34±0,01	1,20±0,26
P7	11,71±2,34	1,44±0,01	0,45±0,05	11,95±0,78	3,41±1,55	27,39	150	0,77±0,06	0,58±0,05	0,32±0,01	1,26±0,18
P8	11,47±2 ,67	1,42±0,21	0,59±0,16	10,58±2,72	4,34±0,23	24,61	150	0,81±0,01	0,63±0,03	0,38±0,07	1,41±0,04
P9	10,11±0,49	181±0,10	0,64±0,04	08,90±0,42	4,39±0,23	23,34	450	0,85±0,00	0,66±0,00	0,41±0,01	1,41±0,04
P10	10,42±0,05	1,73±0,01	0,64±0,04	08,53±0,11	4,37±0,21	25,04	450	0,82±0,03	0,65±0,03	0,42±0,01	1,44±0,04
P11	10,61±0,22	1,75±0,03	0,63±0,02	09,33±1,03	4,45±0,33	25,78	450	0,84±0,01	0,66±0,00	0,41±0,01	1,56±0,21
P12	10,25±0,29	1,79±0,08	0,63±0,02	08,43±0,25	4,33±0,15	24,78	450	0,83±0,02	0,66±0,01	0,41±0,00	1,43±0,02
P13	13,65±0,08	1,59±0,06	0,65±0,02	11,90±0,57	6,74±0,81	21,72	100	0,86±0,00	0,66±0,05	0,43±0,01	1,89±0,01
P14	13,24±0,50	1,65±0,15	0,63±0,00	12,40±0,14	5,93±0,33	21,65	100	0,82±0,06	0,61±0,02	0,44±0,01	1,81±0,07
P15	13,57±0,66	1,64±0,04	0,60±0,13	12,02±1,08	7,19±0,62	21,55	100	0,80±0,11	0,61±0,08	0,42±0,01	1,97±0,07
P16	13,20±1,19	1,63±0,06	0,66±0,05	12, 34±0,63	6,41±1,73	22,87	100	0,84±0,06	0,67±0,01	0,42±0,04	1,88±0,06
P17	15,56±1,21	1,24±0,01	0,74±0,02	12,41±1,15	6,58±0,58	20,82	09,00	0,88±0,04	0,65±0,01	0,42±0,01	1,73±0,10
P18	16,63±2,31	1,24±0,05	0,72±0,07	12,05±2,10	6,62±0,87	20,10	09,75	0,87±0,05	0,64±0,01	0,43±0,01	1,65±0,18
P19	14,68±0,48	1,23±0,03	0,74±0,05	11,35±0,74	6,62±0,87	19,21	06,25	0,86±0,07	0,68±0,02	0,42±0,01	1,66±0,05
P20	14,31±0,42	1,23±0,03	0,71±0,01	11,55±0,88	7,10±0,42	20,48	07,50	0,86±0,08	0,64±0,04	0,41±0,02	1,61±0,01
P21	14,20±0,17	1,23±0,02	0,70±0,19	11,26±0,13	6,23±0,80	20,45	12,50	0,84±0,06	0,65±0,07	0,42±0,03	1,62±0,03
P22	16,10±0,13	1,25±0,02	0,69±0,05	11,18±0,39	5,97±0,41	17,40	15,50	0,85±0,05	0,72±0,12	0,40±0,02	1,26±0,18
P23	14,83±0,49	1,26±0,04	0,80±0,03	11,53±0,74	7,08±1,02	22,12	06,50	0,88±0,03	0,69±0,00	0,43±0,00	2,00±0,06
P24	16,24±0,76	1,21±0,03	0,70±0,14	11,95±1,34	6,19±1,42	19,92	10,25	0,92±0,05	0,63±0,00	0,42±0,01	1,52±0,01
P25	14,05±0,25	1,64±0,01	0,79±0,01	13,53±0,74	5,82±0,42	25,26	05,75	0,75±0,01	0,66±0,05	0,41±0,01	1,97±0,48
P26	12,89±0,62	1,51±0,04	0,87±0,06	13,09±0,12	5,18±0,12	25,11	07,50	0,79±0,04	0,64±0,04	0,40±0,00	1,75±0,13
P27	15,05±0,74	1,62±0,03	0,66±0,01	15,43±1,10	6,75±0,21	25,83	09,00	0,80±0,01	0,68±0,01	0,41±0,01	2,33±0,02
P28	14,94±0,27	1,66±0,01	0,67±0,04	14,05±0,64	6,69±0,33	25,48	14,70	0,82±0,02	0,65±0,02	0,39±0,01	2,24±0,13
P29	14,32±0,08	1,57±0,01	0,70±0,05	14,18±0,88	6,13±0,42	25,92	10,00	0,81±0,01	0,65±0,04	0,39±0,04	2,11±0,01
P30	14,41±1,02	1,56±0,11	0,63±0,12	13,70±0,42	5,62±1,13	24,90	15,75	0,79±0,08	0,66±0,07	0,38±0,00	1,88±0,31
P31	13,82±0,69	1,48±0,15	0,67±0,05	12,42±0,03	5,49±0,59	24,23	22,50	0,76±0,12	0,60±0,17	0,35±0,03	1,81±0,15
P32	13,62±0,78	1,71±0,02	0,58±0,01	12,46±1,71	6,04±0,10	22,51	08,75	0,81±0,07	0,59±0,00	0,39±0,02	1,76±0,15
P33	13,83±1,68	1,67±0,12	0,59±0,01	12,30±1,27	6,68±0,74	20,49	08,50	0,81±0,05	0,60±0,01	0,40±0,01	1,75±0,11
P34	14,89±1,68	1,65±0,10	0,59±0,00	12,73±0,11	6,00±0,74	23,15	17,25	0,80±0,02	0,60±0,02	0,40±0,00	1,81±0,01
P35	14,59±0,70	1,69±0,07	0,59±0,02	12,63±1,24	6,83±0,80	21,21	13,25	0,80±0,01	0,59±0,01	0,40±0,01	1,72±0,13
P36	15,19±0,79	1,65±0,06	0,56±0,01	13,90±2,62	6,03±0,78	22,73	11,00	0,78±0,01	0,58±0,01	0,40±0,03	1,83±0,27
P37	14,10±0,85	1,65±0,10	0,60±0,08	13,85±1,63	6,62±0,06	24,06	13,00	0,80±0,03	0,59±0,01	0,42±0,02	2,06±0,03
P38	14,68±1,75	1,68±0,12	0,55±0,06	12,50±2,26	5,51±0,77	21,65	04,50	0,78±0,05	0,59±0,02	0,37±0,03	1,52±0,29
P39	14,75±0,82	1,74±0,01	0,58±0,01	13,02±0,92	6,30±0,08	22,70	06,75	0,81±0,03	0,61±0,01	0,39±0,02	1,85±0,16
P40	15,26±0,23	1,55±0,08	0,67±0,07	13,17±1,65	7,42±0,97	20,41	09,75	0,83±0,02	0,63±0,08	0,45±0,05	1,89±0,04
P41	13,96±0,69	1,55±0,04	0,55±0,05	12,55±0,99	5,35±0,40	22,19	23,25	0,76±0,07	0,57±0,03	0,38±0,01	1,52±0,29
P42	13,47±1,04	1,70±1,11	0,57±0,12	11,53±2,09	5,97±2,14	20,82	08,50	0,80±0,09	0,60±0,01	0,38±0,02	1,57±0,46
P43	15,03±0,38	1,60±0,01	0,58±0,01	13,55±0,28	6,66±0,07	23,16	05,25	0,81±0,04	0,60±0,01	0,40±0,00	2,01±0,02
P44	14,02±1,02	1,60±0,07	0,54±0,00	11,69±0,51	5,30±0,82	22,32	09,75	0,77±0,01	0,59±0,02	0,39±0,01	1,52±0,21
P45	13,98±0,39	1,66±0,03	0,55±0,02	12,96±1,00	5,84±0,02	21,71	08,75	0,79±0,03	0,58±0,02	0,37±0,02	1,62±0,05
P46	14,37±0,61	1,64±0,00	0,58±0,03	13,13±2,65	6,55±0,29	21,64	16,00	0,83±0,05	0,60±0,02	0,41±0,02	1,85±0,47
P47	14,34±0,71	1,70±0,04	0,72±0,08	11,73±0,60	6,36±0,16	19,57	05,75	0,77±0,07	0,61±0,02	0,35±0,05	1,55±0,01

REFERENCES

1. Aafi, A., Note technique sur le caroubier (*Ceratonia siliqua* L.), Centre Nationale de la Recherche Forestière, Rabat (Maroc), pp. 10. (1996)
2. Achhal, A. Akabli, O. Barbro, M. Benabide, A. M'Hirit, O. Peyre, C. Quezel, P. and Rivaz-Martinez, S., A propos de la valeur bioclimatique et dynamique de quelques essences forestières au Maroc. Ecologia Mediterranea, n°5. (1980)
3. Ait Chitt, M. Belmir, M. and Lazrak, A., Production des plantes sélectionnées et greffées du caroubier. Transfert de technologie en Agriculture, N°153, IAV Rabat, pp.1-4. (2007)
4. Albanell, E. Caja, G. and Plaixats, J., Characteristics of Spanish carob pods and nutritive value of carob Kibbles. Cahiers Options Me ´diterrane ´ennes, **16**: 135–136 (1991)
5. Barracosa, P. Osorio, J. and Cravador, A., Evaluation of fruit and seed diversity and characterization of carob (Ceratonia siliqua L.) cultivars in Algarve region. *Sci. Hortic*. **114**: 250–257 (2007)
6. Batista, M.T. Amaral, M.T. and Proença Da Cunha, A., Carob fruits as source of natural oxidant. In: Proceedings of the Communication in Third International carob Symposium, Tavira, Portugal, June, pp. 19–23 (1996)

7. Batlle, I. and Tous, J., Promoting the Conservation and Use of Underutilised and Neglected Crops 17 Carob Tree Ceratonia Siliqua L. Institute of plant genetics and crop plant research, Gatersleben/International Plant Genetic Resources Insti-tute, Rome, Italy, 92 pp. (1997)
8. Christodoulakis, N. S. Menti, J. and Galatis, B., Structure and development of stomata on the primary root of *Ceratonia siliqua* L. *Annals of Botany*, **89**: 23-29 (2002)
9. Coit, J.E., Carob or St. John's Bread. Eco. Bot. **5**: 82-85 (1951)
10. Correia, P.M. and Martins-Loucao, M.A., Preliminary studies on Mycorrrhizae of Ceratonia siliqua L. In New York Botanical Gardens: Mycorrhizas in integrated systems from genes to plant development. NY Bronx. 86 - 88. (1994)
11. Crossa-Raynaud, P., Caroubiers. Annales Inst. Nat. Recherche Agric. Tunisie. **33**:79-83 (1960)
12. Cruz, C. Lips, S.H. and Martins-Loução, M.A., Changes in the morphology of roots and leaves of carob seedling induced by nitrogen source and atmospheric carbon dioxide. *Annals of Botany*, **80**: 817-823 (1997)
13. El-Shatnawi, M.K. and Ereifej, K., Chemical composition and livestock ingestion of carob (*Ceratonia siliqua* L.) seeds. *J. Range Manage*. **54**: 669-673 (2001)
14. Emberger, L. and Maire, R., Catalogue des plantes du Maroc (Spermaphytes et Pteridophytes). Imprimerie Minerva. Alger. (1941)
15. Frutos, D., Efecto de los ácido sulfúrico y giberelico (GA3) en la germinación del galgarrobo (*Ceratonia siliqu* L.). pp. 265-280 *in* Proceeding of the *II International Carob Symposium (P. Fito and A. Mulet, eds.). Valencia, Spain* (1988)
16. Gharnit, N. Mtili, N. El. Ennabili, A. and Sayah, F., Importance socio-économique du caroubier (*Ceratonia siliqua L.)* dans la Province de Chefchaouen (nord-ouest du Maroc), Rev. Tela Botanica Base de Données Nomenclaturale de la Flore de France BDNFF, **4**: 02 N°33 (2006)
17. Gharnit, N. Et Mtili, N. Ennabili, A.T. and Ennabili, A., Social characterization and exploitation of carob tree (*Ceratonia siliqua* L.) from Mokrisset and Bab Taza (NW of Morocco). *Sci. Lett*. 3 n°2. (2001)
18. Goor, A.Y. and Barney, C.W., Forest tree planting in arid zones. New York: Ronald Press. 409 p.(1968)
19. Guinochet, M. and Vilmorin, R., Flore de France. Edit. CNRS, Paris. (1984)
20. Karschon, R., Studies in nursery practices for carob (Ceratonia siliqua L.). *J. South African Forestry Association*, **4**:78-80 (1960)
21. Konate, I., Diversité Phénotypique et Moléculaire du Caroubier (*Ceratonia siliqua* L.) et des Bactéries endophytes qui lui sont associées, Université Mohammed V-Agdal Faculté Des Sciences Rabat, thèse de doctorat. (2007)
22. Lo Gullo, M. A. and Salleo, S., Different strategies of drought resistance in tree Mediterranean sclerophyllous trees growing in the same environmental conditions. New Phytol. **108**: 267-276 (1988)
23. Metro et Sauvage, Flore des végétaux ligneux de la Maâmora. La nature au Maroc 1, Sco. Sci. Nat. Physi. Rabat (Maroc). 498p. (1955)
24. Missbah, M.E.I., Aujjar, N. Belabed, A. Dessaux, Y. and Filali-Maltouf, A., Characterization of rhizobia isolated from carob (*Ceratonia siliqua* L.). J. App. Bacteriol. **80**: 165-173 (1996)
25. Naghmouchi, S. Khouja, M.L. Romero, A. Tous, J. and Boussaid, M., Tunisian carob (*Ceratonia siliqua* L.) populations: Morphological variability of pods and kernel. *Scientia Horticulturae*, **121**: 125–130 (2009)
26. Navaro, V., Estudio y mejora del algarrob. In II Jornadas Sobre Experimentación en Fruticultura. Moncada (Valencia) (1992)
27. Quezel, P. and Santa, S. 1962/63. Nouvelle flore de l'Algérie et des régions désertiques méditerranéennes. Tome 1. Edit CNRS. Paris.
28. Sidina, M.M. El Hansali, M. Wahid, N. Ouatmane, A. Boulli, A. and Haddioui, A., Fruit and seed diversity of domesticated carob (Ceratonia siliqua L.) in Morocco Sci. Hortic. **123**: 110–116. (2009)

29. Tous, J. Romero, A. Plana, J. et Batlle, I., Current situation of carob plant material. *In* Proceedings of the III International Carob Symposium. Cabanas-Tavira. Portugal (1996)
30. Vourdoubas, J. Makris, P. Kefalas, J. and Kaliakatsos, J., Studies on the production of bioethanol from carob. In: The 12th National Conference and Technology Exhibition on Biomass for Energy. Industry and Climate Protection, Proceedings, Amsterdam, pp. 489–493 (2002)
31. Yousif, Ali K. and Alghzawi, H.M., Processing and characterization of carob powder. Food Chem. **69**: 283–287 (2000)
32. FAOSTAT (2010) www.fao.org