IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Carob tree, Distrubution and biochemical composition in Tunisia

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Abstract : The carob tree “Ceratonia siliqua” is a typically Mediterranean tree which is of very significant interest and which has experienced incredible growth in these regions due to the development of the food industry. All components of the tree (leaves, flower, fruit, wood, bark, root) are beneficial, and have ornamental and landscape value. Thus, it is considered one of the fruit and forest trees which represents the greatest potential for valorization thanks to its richness in nutrients which has attracted the attention of several researchers, but especially for its seeds and which are the subject of commercial transactions whose value far exceeds that of timber production.

The pulp is very rich in sugars (40-60%) in particular, sucrose (27-40%), fructose (3-8%) and glucose (3-5%) but poor in lipids (0.4-0. 6%). It also has a very high fiber content (27-50%) and a significant amount of tannins.

***IndexTerms* - Component,formatting,style,styling,insert.**

Introduction

The carob tree (Ceratonia siliqua) growing in Mediterranean regions belongs to the legume family. Several studies have shown that carob has numerous biological properties including anti-microbial (Henis et al., 1964), antidiuretic (Wûrsch 1979; Bremness, 1996; Santos et al., 2005), antioxidant and cholesterol-lowering (Gruendel et al., 2005; Klenow et al., 2007). It is an almost endemic species around the Mediterranean, cultivated for a long time for its derived products but also for its resistance to lack of water (Biner et al., 2007; Avallone et al., 1997).

One of the two main components of the carob fruit is its pod, which is higher in sugar than sugar cane and sugar beets. On the other hand, it contains less proteins and lipids. Carob pods are used in the food and pharmaceutical industries, particularly as an anti-diarrheal. The flour, obtained by drying the pods after removing their seeds, is rich in phenolic compounds which are at the origin of its antioxidant properties (Makris and Kefalas, 2004).

I.Characteristics and botanical description

I.1. Taxonomy

The word "carob" coming from the Arabic "al kharroube", is known under the scientific name of Ceratonia siliqua L. which designates in Greek keratia (Ceratonia) meaning small horn and the species name siliqua, designates in Latin a silique or pod and alluding to the hardness and shape of the fruit. It is also called Carouge, Bread of Saint John the Baptist, Egyptian fig tree, Pythagorean bean (Batlle et Tous, 1997). This species belongs to the genus Ceratonia of the subfamily Caesalpinioïdeae, of the family Fabaceae (Leguminosae), which is part of the order Fabales (Rosales), class Magnoliopsida (Boudy, 1950). Two species of the genus Ceratonia are known, Ceratonia oreothauma and Ceratonia siliqua (Tucker, 1992).

Reign	**Plantae**
Under reign	Trache abionta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Fabales
Family	Fabaceae
Gender	*Ceratoni*
Species	*Siliqua*

I.2. Floral organs

The carob tree is a dioecious and sometimes hermaphrodite tree, of which there are three forms of flowers (male flowers, female flowers and hermaphrodite flowers) which are borne on different feet. Initially, the flowers are bisexual, but during the development of the flower (floral ontogeny), there is suppression of one sex (Rejeb, 1995; Konaté et al., 2007).

The flowers are grouped in pedunculated clusters, purple and sometimes reddish in color, which appear on old wood and sometimes on the trunk.

I.3. The anatomy of the fruit

The fruit of the carob tree, called carob or blackbird, is an indehiscent pod with irregular edges, elongated, straight or curved, 10 to 20 cm long, 1.5 to 3 cm wide and 1 to 2.5 cm thick. The pod is composed of three parts: the epicarp, the mesocarp and the seeds, it is separated internally by transverse pulpy partitions and contains 4 to 16 seeds (Rejeb, 1995; Ait Chitt et al. 2007).

1.4 Ecology

The carob tree, whose distribution area extends into the plateaux and mid-mountain sectors up to 1700 m altitude, is indifferent to the nature of the substrate; it tolerates poor, sandy, heavy loamy, rocky and calcareous, shale, sandstone soils and pHs from 6.2 to 8.6; but it fears acidic and very humid soils (Baum, 1989; Sbay and Abrouch, 2006; Zouhair, 1996).

It adapts to several types of soils with the exception of hydromorphic and salty soils and shale crusts. It is found on marly soils, on poor superficial and rocky limestone soils, on rocky slopes, inaccessible escarpments and uncultivated hills (Nabli, 1989).

It is a typical species of Mediterranean flora, well defined in the humid, subhumid and semi-arid stages. It generally grows in a scattered state in the cedar and Phoenician juniper stages, in holm oak stands and in association with Olea europea and Pistacia lentiscus (Boudy, 1950; Rejeb et al. 1991).

Cyclical drought has revealed that the carob tree is more resistant to lack of water than the holm oak, thuja and oleaster which are associated with it. It is a very plastic, heliophilic, thermophilic species, very resistant to drought (200 mm/year). It plays an important role in protecting soils against degradation and erosion and in combating desertification (Zouhair, 1996).

Studies by Rejeb (1995) confirm that the carob tree behaves like a true drought-resistant species by adapting morphologically and physiologically to lack of water.

The main adaptations can be summarized as follows:

- the stomata are located on one side only,
- the number of stomata is quite high and they are small,
- the root system is developed,
- a significant wax deposit,
- gas assimilation and exchanges depend on the general water status.

Due to its ability to adapt to soil and climate stress, the carob tree could contribute to the development of disadvantaged areas (Gharnit et al., 2006).

Figure 1 : blooming of carob tree (waltarrrrr / flickr.com)

I.4.2. Origin of the carob tree

The place of origin of the carob tree remains doubtful. However, De Candolle (1983) and Vavilov (1951) reported that it was native to the Eastern Mediterranean region (Turkey and Syria).

On the other hand, Schweinfurth (1894) insinuated that it originated in the mountainous countries of southern Arabia (Yemen). Lately, it was considered, by Zohary (1973), as originating from the flora of Indo-Malaysia, grouped with Olea, Laurus, Myrtus and other plants. Furthermore, Ceratonia oreothauma is the only known species native to southeastern Arabia (Oumane) and the edges of the African Horn (northern Somalia) (Hillcoat et al., 1980).

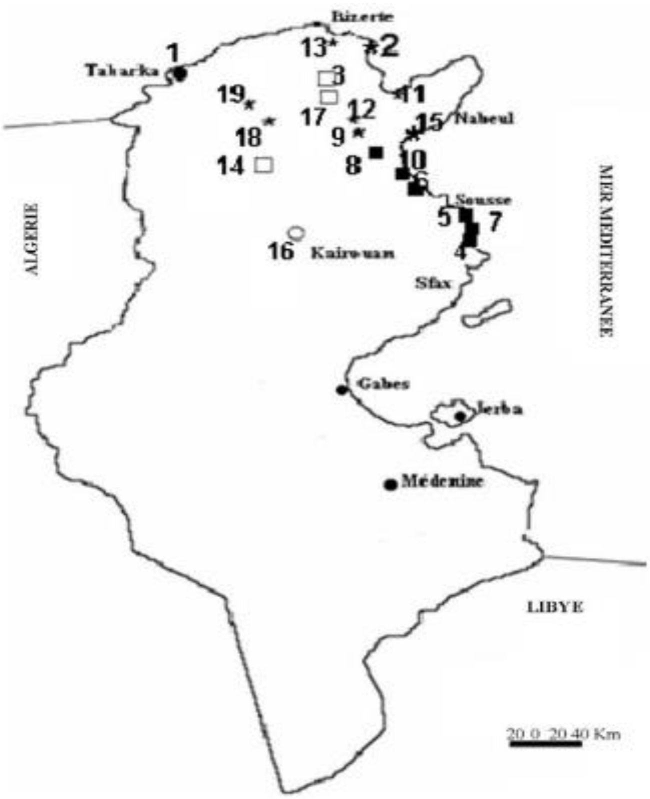
I.4.2. Geographic range

The carob tree is an essentially Mediterranean tree, whose distribution area extends over Asia Minor, North Africa, southern Europe and the Iberian Peninsula, in fact it is found going from Spain and from Portugal to Turkey, via Morocco, Algeria, Tunisia, Libya, Egypt, but also in Syria, Yugoslavia, Greece, Cyprus, Italy and France (Rejeb, 1995 ; Gharnit, 2003). It has been successfully introduced in other countries, notably Australia, South Africa, the United States,

Philippines, as well as in Iran (Rejeb et al., 1991).

Currently, the carob tree is found in several countries, in Europe and North Africa, in the wild in association with oleaster, thuja, pine, holm oak (Aafi, 1996; Batlle and Tous , 1997).

In Tunisia, the Carob tree grows in natural conditions in the wild, in association with the olive tree and the OLEASTRE tree. It is well defined in the humid, subhumid, and upper semi-arid stages, with a warm to temperate variant (Rejeb, 1989). In natural conditions, it is found in the wild in association with the olive tree and in a mixture with callitris, but the clearing of these associations, in favor of food crops and fruit trees, makes this increasingly rare vegetation in Tunisia (Rejeb, 1995).



(1) Tabarka ; (2) Menzel bourguiba ; (3) Ariana ; (4) Zbid 5khnis ; (6) Kalaa ; (7) Sayada ; (8) Jradou ; (9) Zaghouan ; (10) Enfidha ;(11) Hammamet ; (12)Jbel rsas ; (13) Gharelmelh ; (14) Bargou ; (15) Slimen ; (16) Chbika ; (17) Belvedere ;(18) Ain tounga ;(19) Slouguia (*) subhumid (▄) low semiaride(□) upper to middle semiarid (○upper arid (●) low humid

Figure 2 : Geographical distribution of the Carob tree in Tunisia (Naghmouch et al 2009)

I.4.3. Carob cultivation

It can be done by sowing, cuttings, grafting, layering, or by micropropagation.

Sowing is the classic method most used for carob tree propagation. Indeed, germination by seed is easily achievable, but it is hampered by the impossibility of knowing the sex of the plant before maturation and late production, which can take more than 8 years (Rejeb, 1995; Gharnit, 2003).

Cuttings are used less frequently, because they require very careful care and a high edaphic temperature (Rejeb, 1995).

Grafting consists of grafting the male plants by the females. In fact, it involves transferring the buds taken from the female plants and grafting them onto the male plants. The first branches appear at the end of the 3rd week. (Gharnit, 2003; Ait Chill et al.,2007).

Micropropagation or in vitro culture of the carob tree is a promising technique, which makes it possible to obtain a plant conforming to the original plant; it has been carried out from seedlings and adult plants (Sebastian and Mc Comb, 1986; Batlle and Tous, 1997), as well as

of different explants: nodes taken from seedlings resulting from germination (Belaizi et al., 1994), axillary buds (Saidi et al., 2007).

I.5. Description and chemical composition of carob

Each carob weighs approximately 15 grams and contains fleshy pulp consisting of 12.4% sugars (glucose and fructose), 34% starch, 6% proteins and in lower proportions, fats (3%), polyphenols (2 to 20%) and mineral salts (table 1).

Carob is rich in calcium, phosphorus, magnesium, silica, iron and pectin.

Table 1 : chemical composition of carob
(Biner et *al*., 2007).

Composition	**(%)**
Protein	6
Lipid	3
Starch	34
D-glucose	6,4
D-fructose	6
Polyphenols	2 à 20% (Dry matter)

I.6. Interests and uses of the carob tree

The carob tree is a tree of indisputable ecological, socio-economic, industrial and ornamental importance. In terms of products, the tree and all its components (leaves, flowers, fruits, seeds, wood, bark and roots) are useful, particularly the fruit.

I.6.1. Tree

Due to its hardiness and its adaptation to environmental constraints, the carob tree is often used for the reforestation and reforestation of areas affected by erosion and desertification (Rejeb al., 1991; Biner et al., 2007). It is also used as an ornamental plant along roadsides and in gardens (Batlle et al., 1997).

I.6.2. Fruit

I.6.2.1. Animal feed

The fruit of the carob tree, or carob, consists of a pulp enveloping regular seeds. In fact, the sweet pulp of carob has been used for a long time as livestock feed alongside other foods such as barley flour (Ait Chitt et al., 2007).

I.6.2.2. Human food

It is used in the human food industry, thanks to its high content of sugars and phenolic compounds. It is also used for the production of alcohol (ethanol), citric acid and as a cocoa substitute for the manufacture of chocolate, because it does not contain caffeine or theobromine (alkaloids). The flour from the pulp is used in the composition of several foods such as biscuits and dairy flours (Rejeb al., 1991;Youssif et al., 2000; Makris and Kefalas, 2004; Dakia et al., 2007).

Another use of carob is in the making of an artisanal dairy product known as "mekika". This product is prepared by coagulating milk with the extract of green carob pods. "Mekika" is eaten as a dessert, sometimes as a dinner after adding sugar or honey.

I.6.2.3. In pharmacological use

In traditional pharmacopoeia, the pulp is used against diarrhea and for the treatment of certain diseases such as gastritis, enteritis, tonsillitis, colds, cancer (Crosi and
al., 2002; Gharnit, 2003; Ait Chitt et al., 2007).

All the constituents of the carob seed (tegument, endosperm and cotyledon) play an important industrial and medical role, but the gum (endosperm) remains the most important, since it is used as a stabilizing agent, gelling agent, fixative in different areas such as the food industry (cheese, mayonnaise, salads, etc.), cosmetics (creams, toothpastes, etc.), the pharmaceutical industry (medicines, syrups, etc.), tannery, textiles (Battle et al, 1997; Biner et al. , 2007; Dakia et al., 2007).

I.6.3. Other parts of the tree

The other parts of the tree are also exploited, in fact, the flower is used by beekeepers for the production of carob honey or autumn honey, while the leaves are useful for animal feed. The bark and roots are used in tannery thanks to their tannin content. The wood of the carob tree, hard and red in color, is estimated in the charcoal and carpentry (Rejeb al., 1991; Gharnit, 2003).

II. Biochemical composition

II.1. Carob polyphenols

II.1.1. Location

Polyphenols are found in carob pods in the form of light brown granules, sized between 100 and 500 micrometers. These granules are found in the fibrous fraction of carob pulp and can be extracted using polar solvents at high temperatures. The section of a carob pod examined under an electron microscope shows the presence of large parenchymal cells filled with tannin granules resembling pieces of amber. In optical microscopy and X-ray diffraction analysis, the granules do not have any structure crystalline (Abi Azar, 2007).

II.1.2. Tannins

Tannins are substances of plant origin, having the property of "tanning" skins, that is to say making them hard and rot-proof, by attaching to proteins, hence their use. Most important in cleaning leather and making it stable (Haslam, 1989). They are characterized by their astringent effects (drying sensation in the mouth), very useful when there are too many secretions (bronchitis, diarrhea, bleeding wounds).

Tannins can have a positive effect on reducing the amount of food consumed (Reese et al., 1982) and a toxic effect caused mainly by hydrolysable tannins, on the other hand condensed tannins are much less toxic because they do not cross the intestinal barrier (Biaye, 2002).

We can distinguish two large groups of tannins:

• Hydrolyzable tannins

Hydrolysable tannins are characterized by the fact that they can be degraded by chemical (alkaline or acid) or enzymatic hydrolysis. These are esters of oses and phenolic acids (gallic or ellagic acids). They include gallotannins and ellagitannins.

Structural variation between different molecules is caused by the nature of oxidative coupling between gallic acid units or by oxidation of aromatic rings (Mueller Harvey, 2001).

• Condensed tannins

Unlike hydrolyzable tannins, they are resistant to hydrolysis and only strong chemical attacks can degrade them (Dixon et al., 2005). By forming complexes with proteins, condensed tannins are responsible for the astringent character of fruits and drinks as well as the bitterness of chocolate. Certain physiological effects in animals (growth) are also due to these interactions (Cosme et al., 2008).

II.1.3. Characteristics of carob polyphenols

Few studies have been devoted to the analysis of carob polyphenols. The contents and composition of polyphenols differ from one author to another. The fluctuations obtained must be due to different factors such as the variety of carob, the producing country, the part analyzed (pulp, fiber, soluble part or insoluble residual part), the methods used for the extraction of polyphenols or their determination (Marakis, 1996).

Wild varieties are richer in tannins than cultivated varieties (Marakis et al., 1993).

According to Wursch et al. (1984), the content of condensed tannins in carob pods is between 16 and 20% of the dry mass.

Saura–Calixto (1988) also reports a polyphenol content of 19.2% (17.9% of condensed tannins and 1.3% of water-soluble tannins). 94% of these polyphenols are part of carob fiber residue. Carob polyphenols have a very high molecular mass rarely found in other plants (Wursch et al., 1984).

Nearly 50% of tannins have a molecular mass between 3200 and 3600 Dalton (Tamir et al., 1971), the other half is found in the form of granules with a higher molecular mass of around 32000 Da (Wursch et al. , 1984).

The main polyphenols described in carob pods are insoluble, highly polymerized, belonging to condensed tannins and containing a flavan core (Wursch et al., 1984).

The degree of flavanol polymerization, estimated by Kumazawa et al. (2002) is 31.1% and flavanols constitute 23% of total polyphenols.

II.1.4. Biological effects of polyphenols

Over the past ten years, polyphenols have attracted growing interest from nutritionists, food manufacturers and consumers. Indeed, polyphenols are part of what we call phytomicronutrients. These are the most abundant antioxidants in foods since humans consume around 1g/day (Scalbert and Williamson, 2000), i.e. almost ten times more than vitamin C and 100 times more than vitamin E or carotenoids (Grolier et al., 2001).

Polyphenols neutralize free radicals and thus help prevent various degenerative pathologies such as cancer, cardiovascular diseases, cataracts, diseases of the central nervous system or immune deficiencies (Jovanovic et al., 1998; Torres and Bobet, 2001; Vaher and Koel, 2003).

Oligomeric proanthocyanidins (comprising two to seven residues) are considered more effective than monomers. However, polyphenols are characterized by low bioavailability in the body (Arts et al., 2001).

First, intestinal absorption rates of ingested polyphenols can vary widely from one polyphenol to another (Heim et al., 2002). Absorption also depends on other factors such as dosage, vehicle of administration, diet, sex differences and colon microbial population (Heim et al., 2002).

II.1.5. Antioxidant effects of polyphenols

Many pathologies, namely cardiovascular diseases, cancers, inflammatory processes and even neurological diseases, are associated with oxidative stress (Zhang and Jope, 1999).

Antioxidants present in the human diet, particularly polyphenols, may play an important role in the prevention of these diseases (Steinmetz and Potter, 1996).

The ability of phenolic compounds to act as antioxidants depends on the redox properties of their hydroxyl groups and the potential for electron delocalization throughout the chemical structure (Alarcon de la Lastra et al., 2006).

III. Biological activities

III.1.1. Antimicrobial activities of polyphenols

Phenolic compounds can affect the growth and metabolism of bacteria. Depending on their structure and concentration, phenolic compounds can have an activating or inhibitory effect on microbial growth (Reguant et al., 2000).

Indeed, Vaquero and colleagues (2007) analyzed the antimicrobial properties of pure phenolic compounds from different vine species from Argentina and showed that quercetin, belonging to the class of flavonoids, presents the highest activity against Serratia marcescens, Proteus mirabilis, Escherichia coli, Klesbsiella pneumoniae. Regarding non-flavonoids, caffeic acid is the best antibacterial compound.

III.1.2. Renoprotective effects

Diabetic kidney disease is one of the leading causes of death worldwide. This disease induces additional cardiovascular risk. It causes a progressive rise in urinary albumin, thus inducing an increase in blood pressure leading to a reduction in glomerular filtration and leading to renal dysfunction.

The common therapeutic approach that can alleviate the development of this disease is treatment with polyphenols, particularly resveratrol, (Keane and Lyle, 2003).

In addition, resveratrol induces a reduction in the effect of the disease by slowing down its development but also by significantly reducing the weight of the kidneys (Tikoo et al. 2008).

Other studies have shown that this polyphenol is capable of protecting the body against nephrotoxicity induced by bacterial endotoxins (Sebai et al., 2008).

IV. Production

IV.1. Carob tree production

According to FAOSTAT data (2010), the total area of global carob production is estimated at 102,939ha (Table 2). The largest area, 83,574ha, is that of Europe, compared to an area estimated at 13,460ha for the countries of North Africa.

World carob production is estimated at 191355.64 tonnes. It is mainly concentrated in Spain, Italy, Morocco, Portugal, Greece, Turkey, followed by Cyprus, Algeria,
Lebanon, and lastly Tunisia (Table 3).

Table 2 : Distribution Area of carob tree (**FAOSTAT 2010**)

Country	**Area (ha) in 2004**	**Area (ha) in 2008**
North Africa	13526	13460
Europe	92218	83574
World	112711	102939

Table 3 : World Production (**FAOSTAT 2010**)

Country	**Production in tons(2004)**	**Production in tons (2008)**
Spain	67000	72000
Italy	24000	31224
Morocco	40000	25000

Portugal	20000	23000
Greece	19000	15000
Türkiye	14000	12100
Cyprus	7000	3915
Algeria	4600	3600
Lebanon	3200	2800
Tunisia	1000	1000
World	182680	191167

During the last century, world production of carob experienced a dramatic fall, falling from 650,000t in 1945 (Orphanos and Papaconstantinou 1969) to 310,000t in 1997. The great loss was recorded in Spain where production fell from 400,000t in 1930 to 150,000t in 1990 (MAPA, 1994).
According to Batlle (1997), the marked decline in carob production was mainly linked to the drop in prices and to coastal zone development programs at the expense of carob plantations.
The carob tree is found mainly in an isolated state and scattered over large areas. Carobs are a product whose value continues to increase. The surface area is limited
at 365 ha. (The Minister of Agriculture)

IV.1.1. Carob exports

Carob exports from Tunisia reached around 1.4 MD in 2011, a significant increase in value compared to 2007, when export revenues were only 199 thousand dinars. Their share represented 11% of export revenues for the entire Plants and Plant Parts group over the period 2007-2011.
The quantity exported increased from 463 tons in 2007 to around 1900 tons in 2011.
The unit value increased significantly from 69 dt/kg in 2007 to 115 dt/kg in 2011. The main export markets for Carob are: Spain, Italy, Egypt, Morocco.
Note that for this product Tunisia is ranked 38th exporter in the world and is witnessing strong growth in exports of this product. (ministry).

Table 4: Evolution of Carob exports

	2007	**2008**	**2009**	**2010**	**2011**
Carob	199	736	914	730	1382

IV.1.2. Carob exchanges

Carob is part of NSH group 12.12.99. It corresponds more precisely in the Tunisian customs nomenclature to the following codes:
− 1212993001 - Whole carobs, fresh chilled, frozen or dried
− 1212993009 - Carobs crushed into lumps or flour
− 1212994100 - Locust bean seeds, not shelled, crushed or ground, fresh, refrigerated, frozen or dried.
Export revenues corresponding to this product reached approximately 1.4 MD in 2011, a value that is significantly higher than in 2007, when export revenues were only 199 thousand dinars. Their share represented 11% of export revenues for the entire Plants and Plant Parts group over the period 2007-2011.
The quantity exported increased from 463 in 2007 to around 1900 in 2011.
The unit value increased significantly from 69 dt/kg in 2007 to 115 dt/kg in 2011.
The main export markets for Carob are:
− Spain 62%
− Italy 26.4%
− Egypt 4.3%
-Morocco 2,4%

Table 5 : Evolution of carob exports over the period 2007-2011

Export	**2007**	**2008**	**2009**	**2010**	**2011**
1212993001 - Whole carobs, fresh chilled, frozen or dried - In 1000 dt - In Kg	99 99690	40 45090	21 28500		12 40000
1212993009 - Carobs crushed into lumps or flour - In 1000 dt -In Kg	100 363010	216 287850	134 440356	103 363128	418 1548300

1212994100 - Locust bean seeds, not shelled, crushed or ground, fresh, refrigerated, frozen or dried - In 1000 - In Kg	0 0	481 97700	759 182800	627 138000	953 298000
Total CaroB - In 1000 dt -In Kg - In dt/kg	199 462700 69	736 430640 102	913 651656 111	730 501128 107	1382 1886300 115

IV.1.3. Imports of Carob seeds

The value of imports was US$9 billion in 2011. The growth rates in value and volume were 13% and 8% respectively over the period 2007-2011.

The main importers are China, Japan, the United States of America and France.

In 2001, these countries represented 68% of world imports. The main exporters are China, Indonesia, Korea, Chile and the Philippines, which accounted for 77% of global exports in 2011.

Tunisia is ranked 38th world exporter and is witnessing strong growth in exports of this product. (The Minister of Agriculture)

According to the study of the improvement of the quality and the positioning of the PAMs (Programme Alimentaire Mondiale), the carob tree is found mainly in an isolated state and dispersed over large areas. Carobs are a product whose value continues to increase. The surface area is limited to 423 ha.

Table 6: Evolution of the production of PMAs consumed in their state (fresh and/or dried) in tons

	2007	2008	2009	2010	2011	Mean	Part
Carob	595	433	652	557	436	**535**	5,1%

CONCLUSION

The carob tree is an agro-sylvo-pastoral species with enormous socio-economic and ecological interests. Interest in planting carob trees has increased in Mediterranean regions due to the development of the food industry and the increase in demand for carob products.

All components of the tree are useful and have value in several areas in addition to its ornamental value. Thus, it is considered one of the fruit and forest trees which represents the greatest potential for development.

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