Journal of the American Pomological Society 62(4):144-150 2008

Fruiting and Kernel Production Characteristics of Ten Mediterranean Carob Cultivars Grown in Northeastern Spain

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Abstract

The carob (*Ceratonia siliqua* L.) is a leguminous fruit tree commonly grown in Mediterranean coastal areas. Carob bean gum is extracted from the pod seed and is a valuable stabilizer and thickener for the food industry. The identification of carob cultivars that produce high seed yields in northeastern Spain, and similar environments, would be of interest to growers. Vegetative, fruiting and pod characteristics were examined for ten carob cultivars with six cultivars originally from Spain ('A-19', 'Bugadera', 'Gastor-1', 'Gaucin-1', 'Sayalonga' and 'Rojal'), three from Portugal ('Aida', 'Galhosa', and 'Mulata') and one cultivar from Italy ('Albarcara'), in a replicated trial in northeastern Spain (Catalonia). This rainfed trial (500 mm of average rainfall) was planted in 1991 using seedling rootstocks budded in 1992. The trees were trained to free vase at a 8 x 9 m spacing (139 trees/ha including 12% pollinizers). 'Aida', 'Rojal' and 'A-19' were the most precocious cultivars. Significant differences were observed for cumulative pod production 13 years after budding. With respect to the cumulative kernel yield, 'Albarcara' and 'Aida' gave the highest production (over 33 kg/tree). The lowest tree vigour (as estimated by trunk-cross sectional area) was observed in 'Sayalonga' and 'A-19'. 'Rojal' and 'Mulata' trees produced the largest pods (over 20 g of fruit weight) and lowest kernel content (10-12%) while 'Gaucin-1' and 'Albarcara' produced the smallest fruits (weighting 13.0 g and 14.1 g respectively) with the highest kernel content (14.8% and 20.6% respectively). Thus, regarding kernel and pod production, 'Aida', 'Albarcara', 'Galhosa', 'Gaucin-1' and 'Mulata' seem to be the best performing female cultivars for planting new carob orchards.

The carob tree (*Ceratonia siliqua* L.) shows interesting commercial potential for some coastal Mediterranean growing areas. It can be an alternative crop for small or part-time farmers and for reforestation (5, 9). Carob beans and seeds are used for many purposes including food, fodder, and industrial products such as sugar, alcohol and gums (2, 4, 25). The European Union (specifically Spain, Italy, Portugal, Greece and Cyprus) produces more than 70 % of the world crop, estimated currently around 300,000 MT of pods, with most of the production concentrated in Spain (80,000 MT) (24). The remaining production occurs mainly in Morocco, Turkey, Algeria, Tunisia, Israel and Lebanon. The carob bean gum (CBG and also known as locust bean gum-LBG) is extracted from the pod kernel and is a valuable stabilizer and thickener for the food industry (2, 11, 15, 19). During the last few decades, this use has increased the interest in carob cultivation (17, 21).

Currently, there is limited information concerning the agronomic performance of carob cultivars (3, 7, 8, 20). The reports that have been published concerning production characteristics of commercial cultivars and wild types of carob indicate large differences among genotypes in pulp production, seed yield and seed gum content (6, 12, 18, 23, 24). Varietal structure of carob in the Mediterranean basin is not well-characterized and genetic cross phenomena between *C. siliqua* cultivars and wild-growing trees may easily occur (26). Carob is characterized by a great diversity of genotypes each with small geographic dispersion, except for a few female cultivars, such as 'Negra' (Catalonia), 'Matalafera' (Valencia), 'Bugadera' (Majorca island), 'Rojal' (Catalonia) and 'Sayalonga' (Andalusia) from Spain, 'Gibiliana' and 'Amele' from Italy (Sicily and Apulia respectively), 'Mulata' and 'Galhosa' from Portugal (Algarve) and 'Tylliria' from Cyprus (2, 14, 16, 19, 20). Male and hermaph-

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roditic trees are normally used as pollinizers for carob orchards. Pollen transport from staminate to pistillate flowers is mainly done by insects (bees, flies, wasps and night-flying moths) and also possibly by wind (2). The main cultivars grown in Spanish orchards and other traditional Mediterranean countries have high pulp content and low seed yield and, consequently, are not suitable for the new industry uses aimed at kernel production (20). With this increased interest in seed or kernel production, there has been renewed interest in screening carob germplasm banks and cultivar trials for this trait (22, 23, 24). At the same time, it is important to know the tolerance to mildew (*Oidium ceratoniae* C.), the most important disease of carob, because traditionally this crop has not been sprayed.

The objective of this study was to identify carob cultivars that produce high seed yields for production in northeastern Spain. A trial was conducted to examine vegetative and yield characteristics of nine female and one hermaphroditic carob genotypes with different origins, grown in a rainfed orchard located near the coast of Tarragona (northeastern Spain), in order to select the most promising for planting new orchards.

Materials and Methods

The rainfed carob cultivar trial was planted in 1991, in Perafort (Tarragona, Spain) (latitude 41º 10' N, longitude 4º 51' E, altitude 120 m), an area with a Mediterranean coastal climate, with high humidity during spring and summer (about 71%), and average annual rainfall of 500 mm. Average winter and summer temperatures were 9.5ºC and 23.7ºC respectively. The female carob cultivars used in this trial were 'Bugadera', 'Gastor-1', 'Gaucin-1', 'Rojal' and 'Sayalonga' from Spain, 'Aida', 'Galhosa', and 'Mulata' from Portugal and 'Albarcara' from Italy. These cultivars were chosen mainly for their commercial importance in these three countries (Table 1). Pollinizers ('A-19', hermaphrodite type) were interplanted at 12 % of the trees in the orchard in order to provide pollen to female cultivars. The soil type was a loamy fine sand, with very low organic matter (0.8 %), calcareous and basic (pH 8). Seedling rootstocks were planted at an 8 x 9 m spacing (139 trees/ha) and were tied to stakes. The following growing season (May of 1992) cultivars were T-budded. Trees were then trained to a free vase form. The soil was mechanically disked between the rows and herbicides were applied under the tree canopies for weed control.

Table 1. Description of the ten Mediterranean carob cultivars included in the trial.

Cultivar	Origin	Growing area	Main interest
A-19	Spain	Alicante (C.Valenciana)	Pollinizer. Agronomic interest (early bearing and high pod yield)
Bugadera	Spain	Majorca Island	Large growing surface and commercial importance
Gastor-1	Spain	Cadiz (Andalusia)	Commercial interest (high kernel yield)
Gaucin-1	Spain	Malaga (Andalusia)	Commercial interest (high kernel yield)
Rojal	Spain	Tarragona (Catalonia)	Reference (good agronomic performance)
Sayalonga	Spain	Malaga (Andalusia)	Large growing surface and commercial interest (gum quality)
Aida	Portugal	Algarve	Agronomic (high pod yield) and commercial interest (gum quality)
Galhosa	Portugal	Algarve	Commercial interest (medium-high kernel yield and gum quality)
Mulata	Portugal	Algarve	Large growing surface and commercial importance
Albarcara	Italy	Sicily	Commercial interest (high kernel yield)

The experimental design for the trial consisted of randomized complete blocks with seven replications and one tree per replication and cultivar. Fruiting and vegetative characteristics examined from 1996 to 2005 (four to thirteen years after budding) included: trunk cross sectional area (TCSA, at 20 cm above the bud union), canopy volume (as oblate spheroid shape, Vol=4/3 π x diameter^2 x height), growth habit (erect, open or weeping), precocity (first year after budding with crop over 1 kg/tree and five first cumulative crops), annual and cumulative production and kernel yield (kg/tree), productivity (cumulative yield 1997-2005/TCSA 2005), yield efficiency (cumulative yield 1997-2005/canopy volume in 2005), tolerance to mildew, and fruit and seed characteristics were recorded. Mildew tolerance was assessed by observation of dark white powder on leaves and green pods, occurring mainly in the spring.

Pods were harvested from the ground after knocking down the pods with the help of long bamboo poles or wooden sticks. Carob samples (15 kg per cultivar and block) were taken every year in September from 1998 to 2003. Twenty-five pods were randomly sampled from each tree (75 pods/cultivar). For each pod, we recorded weight (g), length (cm), width (cm), pulp weight (g, as pod weight minus seed weight), number of seeds, number of aborted seeds and kernel content (%). On samples of 10 seeds per replication (30 seeds/cultivar), weight, length, and thickness were measured. Statistical analysis was conducted using the SAS 8.2 computer program (SAS Institute, Cary, NC). Analysis of variance and Duncan's multiple range test were applied to data using a level of significance of $P \leq 0.05$. Correlation analysis between some pomological variables was conducted by means of Pearson product-moment.

Results and Discussion

Agronomic characteristics. Yield and growth characteristics differed significantly among cultivars (Tables 2 and 3). 'Aida', 'Rojal' and 'A-19' cultivars were more precocious than the other seven cultivars. Significant differences were observed for total cumulative pod yield among cultivars, at the 13th year after budding, ranging from 59 kg/tree for 'Sayalonga' to 251 kg/tree for 'Aida'. With respect to cumulative seed yield for the

Table 2. Precocity and yield (kg/tree) of ten Mediterranean carob cultivars (in order of cumulative pod yield 1997-2005) planted in 1991 (grafted 1992) at a planting distance of 8x9m (139 trees/ha).

Cultivar	Origin	Precocity (year)^z	Early bearing 1997-2001 (kg/tree)	Average yield 2002-2005^y (kg/tree)	Average yield 2002-2005^y (kg/ha)	Cumulative yield/tree 1997-2005 (kg pod)	Cumulative yield/tree 1997-2005 (kg seed)
Aida	Portugal	5.8 d^w	70.4 a	48.8 a	6,783 a	251 a	33.1 ab
Mulata	Portugal	6.2 cd	65.3 ab	34.5 bc	4,796 bc	203 ab	25.4 abc
Albarcara	Italy	7.3 ab	46.1 ab	38.6 ab	5,365 ab	201 ab	41.3 a
Gaucin-1	Spain	6.2 cd	61.7 ab	28.7 bc	3,989 bc	178 ab	25.5 abc
Galhosa	Portugal	7.0 b	38.0 b	37.7 ab	5,240 ab	177 ab	26.1 abc
Rojal	Spain	5.8 d	63.9 ab	27.8 bc	3,864 bc	174 ab	17.5 bcd
A-19^x	Spain	5.0 e	60.9 ab	25.0 bc	3,475 bcd	156 ab	22.2 bcd
Gastor-1	Spain	6.6 bc	39.2 ab	21.8 cd	3,030 cd	127 bc	16.3 cd
Bugadera	Spain	6.8 bc	38.4 b	21.7 cd	3,030 cd	120 bc	21.4 bcd
Sayalonga	Spain	7.8 a	5.0 c	13.3 d	1,849 d	59 c	8.6 d

^{z} Defined as the first year after budding with a crop of over 1 kg/tree
^{y} Average yield (10 th to 13 th year after budding), number of replicates = 7.
^{x} Hermaphrodite cultivar
^{w} Means within a column followed by the same letter are not significantly different at P ≤ 0.05 by Duncan's multiple range test.

Table 3. Vegetative and productive characteristics of ten Mediterranean carob cultivars, 14 years old (13th year after budding) in order of yield efficiency. The values are means over the period from 1997 to 2005.

Cultivar	Growth habit	Trunk cross-sectional area, 2005 (cm^2)	Canopy volume, 2005 (m^3/tree)	Canopy volume, 2005 (m^3/ha)	Productivity ($\sum kg/m^3$ 2005)	Cumulative yield efficiency[z] ($\sum kg/m^3$ 2005)
Rojal	Erect	391 bc[y]	79 ns	10,981 ns	0.51 a	2.61 a
Aida	Erect	517 ab	120	16,680	0.46 ab	2.05 ab
Galhosa	Erect	614 a	104	14,456	0.34 abc	1.97 ab
Mulata	Open	572 ab	118	16,402	0.35 abc	1.72 bc
Bugadera	Open-weeping	501 abc	84	11,676	0.26 bc	1.59 bc
Gaucin-1	Open	405 bc	111	15,429	0.45 ab	1.56 bc
A-19	Erect	362 c	97	13,483	0.41 ab	1.54 bc
Albarcara	Erect	609 a	123	17,097	0.32 abc	1.43 bc
Gastor-1	Open	405 bc	86	11,954	0.31 abc	1.43 bc
Sayalonga	Open	367 c	66	9,174	0.17 c	1.06 c

[z] Cumulative pod yield for 1997-2005/tree canopy (m^3) in 2005; number of replicates = 7.

[y] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ by Duncan's multiple range test (ns= not significant)

same period, 'Albarcara' showed the highest production (41.3 kg/tree) and the lowest was 'Sayalonga' (8.6 kg/tree). Average annual yield per tree for mature carob (10th –13th year after budding) ranged from 13.3 kg for 'Sayalonga' to 48.8 kg for 'Aida'; 'Albarcara' and 'Galhosa' cultivars were also productive (Table 2). Productions recorded in 'Aida' trees (average yield 6,783 kg/ha) are similar to those reported by Tous et al. (manuscript in preparation) in Spain and Goor et al. (10) in Israel, but are higher than the average for traditional orchards, 2000-3000 kg/ha with only 50 trees/ha (20).

The lowest TCSA was observed in 'Sayalonga' and 'A-19' (Table 3) fourteen years after planting, while canopy volumes on bearing trees were not significantly different among cultivars. In order to quantify the balance between productive and vegetative performance of ten cultivars, during the bearing phase, the "productivity" and cumulative yield efficiency were evaluated (Table 3). The highest values for these indices were observed in 'Rojal' (0.51 kg/cm^2 and 2.61 kg/m^3, respectively) and the lowest in 'Sayalonga' (0.17 kg/cm^2 and 1.06 kg/m^3). These yield results suggest that the last cultivar, originally from Andalusia, showed the worst tree performance in the coastal areas of Catalonia (Tables 2 and 3).

The most important disease of the carob tree was mildew, which attacks green pods and leaves during the spring in coastal areas, causing them to drop to the ground. Severe damage occured only in certain cultivars. 'Albarcara' was particularly sensitive to this fungus and, to a lesser degree, 'Aida'.

Pod and kernel characteristics. Pod weight, pod length, pulp weight, seed number/pod, seed weight, seed thickness and kernel content varied significantly among cultivars (Table 4). 'Rojal' and 'Mulata' trees produced the largest pods (average fruit weight 20.6 g and 21.4 g respectively) with low kernel content (10.2 % and 12.5 % respectively), while 'Gaucin-1' and 'Albarcara' produced the smallest fruits (weighting 13.0 g and 14.1 g respectively) with high kernel content (14.8 % and 20.6 % respectively) (Table 4). Similar results were found for pulp weight. Usually, cultivars with large pods (high pulp content) show lower kernel yield (r= - 0.66, n=57, $P \leq 0.0001$). These results are in agreement with other authors (1). In the main Mediterranean female carob cultivars, the usual average kernel yield ranges from 7 to 16 % (6, 13, 16, 23). Regarding pod

Table 4. Pod and kernel characteristics of ten Mediterranean carob cultivars in order of kernel yield. Average from 1998 to 2003[z].

Cultivar	Pod Wt. (g)	Pod. Lt. (cm)	Pulp Wt. (g)	No. seeds per pod	Seed wt. (g)	Seed thick. (cm)	Kernel cont. (%)
Albarcara	14.1 g[y]	15.7 d	9.8 e	12.0 b	0.252 a	0.422 c	20.6 a
Bugadera	15.8 e	16.6 c	11.4 cde	12.9 a	0.217 d	0.400 e	16.9 b
Gaucin-1	13.0 h	14.0 f	10.6 de	11.0 def	0.193 f	0.436 b	14.8 bc
Sayalonga	17.8 cd	16.4 c	13.7 bcd	11.6 bc	0.239 b	0.477 a	14.6 bc
Galhosa	17.3 d	14.7 e	13.0 bcde	10.8 ef	0.222 d	0.468 a	13.4 cd
A-19’	16.3 e	17.8 a	12.6 cde	11.0 def	0.204 e	0.351 g	13.1 cd
Gastor-1	14.9 f	16.5 c	11.3 cde	11.3 cde	0.179 h	0.415 cd	12.9 cd
Mulata	21.4 a	15.7 d	16.9 a	10.7 f	0.232 c	0.408 de	12.5 cd
Aida	18.2 c	17.7 a	14.0 abc	11.4 cd	0.206 e	0.422 c	12.3 cd
Rojal	20.6 b	17.2 b	16.1 ab	11.8 bc	0.186 g	0.372 f	10.2 d

[z] Each value in the table represents an average of 6 years of data (1998 to 2003) with three replications per cultivar, and 25 fruits/cultivar and replication.

[y] Means within a column followed by the same letter are not significantly different at P ≤ 0.05 by Duncan’s multiple range test.

size and length (Table 4 and Fig. 1), ‘A-19’, ‘Aida’ and ‘Rojal’ showed the longest pods (over 17 cm) while ‘Gaucin-1’ produced the smallest (14 cm). ‘Mulata’ pods had the fewest seeds (11) and ‘Bugadera’ the most (13) and this last cultivar showed the lowest aborted seed number (1, data not shown).

‘Albarcara’ trees produced the largest seeds (0.25 g), while ‘Gastor-1’ produced the smallest (0.18 g) (Table 4). Generally, the highest LBG content is found in heavy, thick and short carob kernels (1). The kernel thickness trait was significantly higher for ‘Sayalonga’ and ‘Galhosa’ (about 0.47 cm), followed by ‘Gaucin-1’, ‘Aida’ and ‘Albarcara’ (about 0.43 cm) and lower in ‘A-19’ (0.35 cm).

Conclusions. During the 14 years of this carob cultivar trial, significant differences were observed in some yield, growth and fruit characteristics. ‘Aida’, ‘Rojal’ and ‘A-19’ showed more precocity than the other seven cultivars. The average pod production per tree (10 to 13 years after budding) differed significantly among cultivars, with ‘Aida’ standing out for its high yield. ‘Albarcara’ had the greatest cumulative kernel yield, but it is very sensitive to mildew. Comparing the nine Mediterranean female cultivars tested, ‘Aida’, ‘Albarcara’, ‘Galhosa, ‘Gaucin-1’ and ‘Mulata’ showed good seed and pod yields, and only ‘Sayalonga’ showed poor seed yields compared to all the other cultivars. The ‘A-19’ hermaphroditic type was of interest as a pollinizer tree for orchard design.

Acknowledgement

This research was partially funded by the INIA (project no. RFP2004-00011-00-00) and DAR institutions. The authors wish to thank the owner of the orchard at “Mas Blanquet” for the facilities provided to carry out this work.

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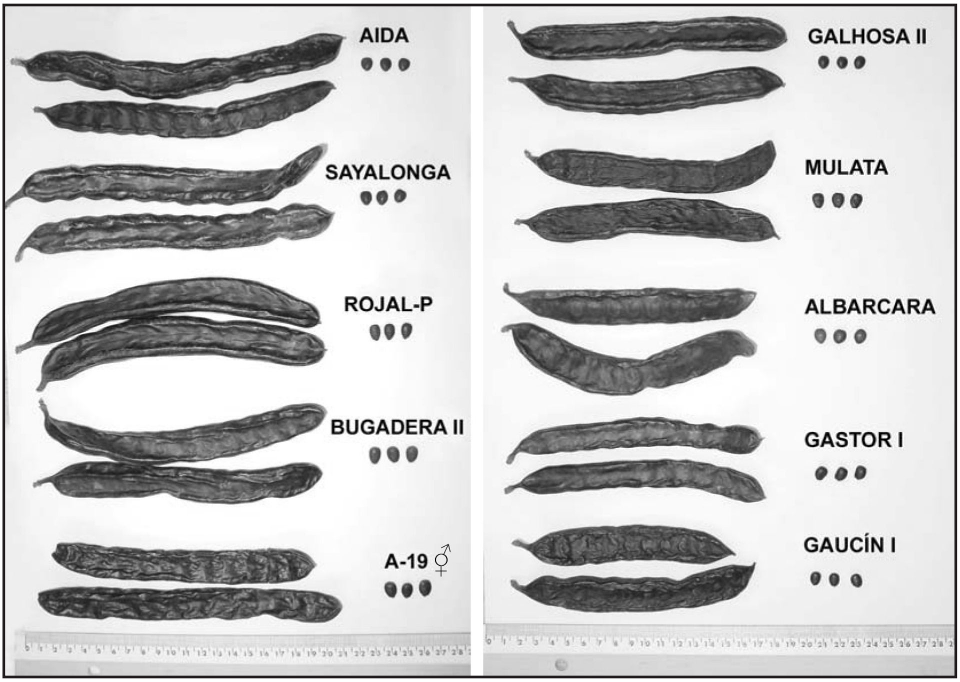

Figure 1. Photographs of representative pods and kernels of the ten Mediterranean carob cultivars included in this study (scale is in cm).

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BIOCONTROL AGENTS AND HOT WATER CAN CONTROL ROTS IN PEAR

The potential of using the biocontrol agent *Rhodotorula glutinis* alone or in combination with hot water for the control of post-harvest blue mold of pear fruit, and their effects on postharvest quality of fruit were investigated. Both hot water and *R. glutinis*, as stand-alone treatments, reduced the incidence of blue mold decay, but complete control was not achieved by either treatment. However, in combination, they completely controlled decay of inoculated fruit. In addition, the combination reduced decay on naturally infected, intact fruit. None of the treatments impaired fruit quality. Hence, the combination of hot water and *R. glutinis* could be an alternative to synthetic fungicides for the control of postharvest blue mold on pears. Paraphrased from Zhang et al. 2008. Postharvest Biology and Technology 49(2):308-313.

SHEPARD AWARD WINNER

The winner of the Shepard Award for the best paper published in the Journal of the American Pomological Society in 2007 was announced at the July 2008 annual meeting in Orlando, Florida. Congratulations to the authors, R. H. Uva and T. H. Whitlow, for their paper entitled, "Cultural Methods for Beach Plum (*Prunus maritima*) Fruit Production", published in J. Amer. Pom. Soc. 61(1):3-13.

EFFECT OF TILLAGE ON INSECTS IN VINEYARDS

Tillage can influence the abundance of insects through factors such as habitat change and food availability. The effects of tillage on the composition and abundance of invertebrates were examined in a vineyard near Mildura in Victoria, Australia, focusing particularly on groups that might act as natural enemies in vineyards. The same genera of ants occurred with and without tillage, but the abundance of several genera was reduced. Several beetles, including predators, increased in tilled areas, while spiders, millipedes, centipedes, earwigs and several parasitoids decreased in abundance after tillage. Paraphrased from Sharley et al. 2008. Agricultural and Forest Entomology 10(3):233-243.