

OIL PRODUCTION OF DIVERSE MEDITERRANEAN CASTOR GENOTYPES

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ABSTRACT: Castor (*Ricinus communis* L.) is a member of the Euphorbiaceae family that is found across all the tropical and semi-tropical regions of the world. Castor is considered to be one of the most promising nonedible oil crop, due to its high annual seed production and yield, and adaptability to semiarid climate and adverse growing conditions. Castor plant is an important renewable resource that has a high potential for use as a biorefining feedstock. Castor oil can be used for biodiesel production, while the main by-products generated in the castor oil production (capsule husks and meal) and the residual biomass, are potentially applicable as feedstocks for advanced ethanol and biogas.

Field experiments were conducted over the period 2019-2020 at the Experimental farm of the University of Catania to compare 28 genotypes of Castor (*Ricinus communis* L.) breed from native perennial plants in the Mediterranean basin in terms of seed and oil yield. The total seed yield ranged between 2985 and 1747 kg ha⁻¹. Oil content in castor seeds was on average 42.7 % and 46.1 % for the primary and secondary racemes, respectively. Oil yield reflected the changes in seed yield obtaining on average 1140 kg ha⁻¹.

Keywords: *Ricinus communis* L., seed yield, oil yield, Mediterranean environment.

1 INTRODUCTION

Castor bean (*Ricinus communis* L.) is a non-edible multipurpose oilseed species cultivated worldwide from tropic to arid areas. It belongs to the Euphorbiaceae family, originated from Eastern Africa and most probably from Ethiopia, as in this country are found the higher number of wild and semi-cultivated types worldwide [1,2].

All parts of castor plant are toxic to humans and animals due to the presence of toxins as ricinine, a toxic alkaloid, and Ricinus communis agglutinin, while the seeds are toxic because of the presence of ricin, a highly poison ribosome-inactivating lectin [3]. Castor oil does not contain ricin because this protein is insoluble in oil, and any residual ricin is eliminated in the refining process but is retained in the meal [4].

Castor is an industrial crop cultivated for the oil found in its seed that ranges between 28% and 59% according to germplasm or accessions [5]. This inedible oil contains ricinoleic acid, which constitutes 79% to 92% of the fatty acid content in the seed-oil. Castor oil is considered a high-value oil for the agriculture, medicine, and cosmetic sectors because ricinoleic acid can be chemically transformed to obtain various commercial products of interest, such as lubricants, inks, paints, coatings, biopolymers, and biodiesel [2,6].

Moreover, it is considered as a second-generation raw material for the production of bioenergy or industrial purposes [7].

Seed yield and oil content of castor plants are dependent on many factors including genotype, environmental conditions, agronomic practices and harvesting practices [8].

Seed yield depends on the number of racemes per plant, the number of capsules per raceme and the thousand seed weight. Under natural conditions, the castor plant has many racemes, depending on the number of branches, that develop progressively over the life of the plant [9].

The number of capsules per raceme depends on the number of female flowers on the raceme. Castor plants are normally monoecious, with male flowers on the upper

portion of the raceme and female on the lower. Flowers of both types can also be interspersed along the length of the raceme.

The proportion of male and female flowers on each raceme varies and can be influenced by the environment.

High temperatures, above 35°C, and water stress during the flowering and oil formation can reduce the seed oil content [10].

Racemes appear in the apex of stems. The primary stem ends in a raceme after producing a given number of leaves. Lateral branches can potentially grow from any leaf axil. Secondary branches are those originated from the primary stem, and tertiary are those developed from a secondary branch.

A primary raceme is that developing in the primary stem, secondary racemes are in the apex of secondary branches, and so on. Developing new branches and racemes can continue indefinitely due to the indeterminate nature of castor. This classification is an indirect way to track the time that racemes developed. This approach assumes that primary racemes initiate and mature before secondary racemes, and tertiary racemes appear and mature later than the secondary ones. Differences found among racemes of increasing orders are likely to be associated with environmental and physiological conditions that changed along the growing season [11].

The present study compared 28 genotypes of castor (*Ricinus communis* L.) breed from native perennial plants collected across the semiarid Mediterranean basin.

2 MATERIAL AND METHODS

2.1 Field trial description

Field experiments were conducted over the period 2019-2020 at the Experimental farm of the University of Catania, Italy (10 m a.s.l., 37°25' N lat., 15° 03' E long.) in a typical xerofluent soil.

The seeds of 28 genotypes were collected from plants in a site of Gafsa, in southwest Tunisia.

The soil of the experimental area was ploughed

before sowing and fertilized with 70 kg/ha N as ammonium nitrate and 60 kg/ha P₂O₅ as mineral perphosphate. Sowing was carried out in July 2019.

Castor seed were sown at 4 to 5 cm depth to 1 m intervals within row and 1.5 m apart (sowing density 0.66 m² plants). The plants were irrigated periodically until maturity according to the maximum available soil water content in a 0.6 m soil depth where root system is predominantly developed. Irrigation was scheduled when the sum of daily maximum crop evapotranspiration (ET_m) corresponded to the volume, subtracting rainfall events from the calculation.

The experiment was arranged in a randomized block design with four replicates and genotypes were randomly distributed.

2.2 Measurements and calculations

During the growing season, for each genotype, the main phenological phases (seedling emergence, flowering, brown full capsule, seed physiological maturity) were monitored. The complete browning of capsules was considered as stage of physiological maturity.

The first harvest was carried out in December 2019 on primary racemes, while fruits of racemes of higher orders were collected in the next harvests according to the different flowering time.

At the harvest the insertion height and the length of the first raceme were measured. Thereafter, the number of capsules per raceme was measured. The first raceme and the other racemes were separately collected for seed yield.

The seeds were separated from capsule residue to obtain clean seeds. A knife mill (GM200, Retsch) was used to crush seed into paste (cake) in preparation for oil extraction.

The oil content was determined according to Randall method by the use of a solvent extractor SER 148 Velp Scientific.

2.3 Statistical analysis

Data were subjected to one-way analysis of variance (ANOVA) with genotypes as main effect and according to the experimental layout. The mean separation was tested by the SNK test per P<0.05.

In order to group the studied genotypes a hierarchical cluster analysis was performed using complete linkage method adopting a measure of dissimilarity based on the Euclidean distance metric and considering the length of sowing maturity period, the oil content (%) of both primary and secondary racemes, the seed yield of both the first and secondary racemes, the height of first raceme, the length of the first raceme (R software).

3 RESULTS AND DISCUSSIONS

Physiological maturity is reached on average after 147 days from sowing (Figure 1).

The latest maturity genotype was #28 (160 days), while the earliest was the #13 (132 days).

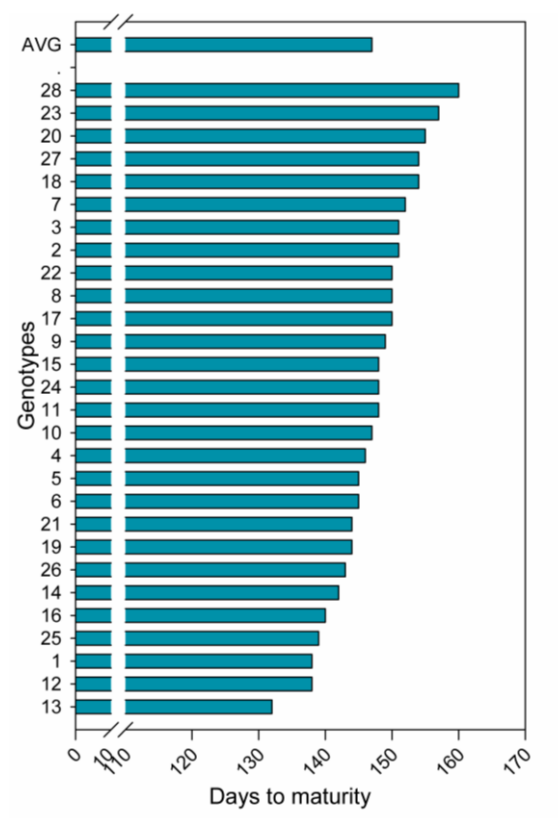


Figure 1: Phenological stage “sowing to physiological seed maturity” of 28 castor genotypes.

The cluster analysis based on complete linkage method divided genotypes into 6 groups (Figure 2). Group 1 had lower mean values for insertion height of primary raceme (cm), seed yield of primary and secondary racemes (kg ha⁻¹) and maturity date but had the largest value for seed oil content of primary raceme. Group 3 had the largest mean values for insertion height and length (cm) of primary raceme and seed yield of primary raceme (kg ha⁻¹). Group 4 had the largest mean values for seed yield of secondary racemes (kg ha⁻¹) but the lower for seed yield of primary raceme (kg ha⁻¹). Group 6 had the largest mean values for seed yield of secondary racemes (kg ha⁻¹) (Table 1). This analysis, performed on yield components and the cycle length, allowed to define the genotypes to use for the next breeding program.

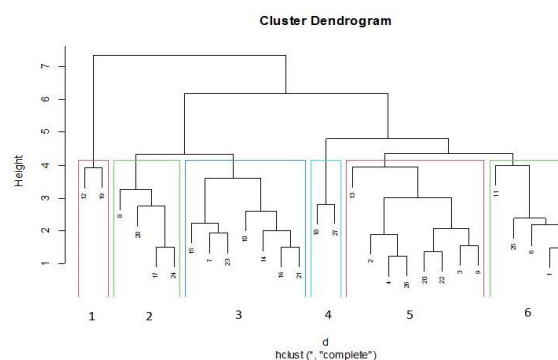


Figure 2: Graphical representation of the genetic divergence among the 28 genotypes of castor generated using complete linkage method adopting a measure of dissimilarity based on the Euclidean distance metric.

Table I: Mean of the descriptors for each of the 6 groups formed by analyzing the 28 of castor beans.

Group	Insertion height primary raceme (cm)	Length primary raceme (cm)	Maturity (days)	Seed yield primary raceme (kg ha ⁻¹)	Seed yield secondary racemes (kg ha ⁻¹)	Seed oil content primary raceme (%)	Seed oil content secondary racemes (%)
1	59.66	29.99	141	480.31	1551.03	45	43
2	70.54	31.69	152	550.49	1731.25	41	45
3	73.87	32.93	147	597.04	2087.18	43	47
4	65.97	27.97	154	419.62	2350.72	43	47
5	69.30	28.50	147	517.40	1915.60	42	47
6	70.78	31.99	143	554.93	2117.33	43	44

The seed yield was 542 and 1993 kg ha⁻¹, on average, for primary and secondary racemes, respectively (Figure 3). The total seed yield was mainly affected by yield of secondary racemes with a percentage that ranged between 68 and 85%, according to several studies the contribution of primary racemes to the total seed varies from 14 to 69% [9]. The total seed yield ranged between 3022 (genotype 27) and 1735 (genotype 12) kg ha⁻¹, which were statistically different.

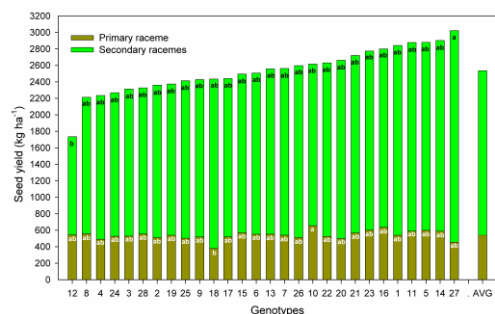


Figure 3: Seed yield of 28 castor genotypes.

Seed characteristics are not determined by the raceme order, but by an interaction of environmental conditions and genetic factors.

The percentage of oil content in castor seeds ranged between 40.4 (genotype 28) and 46.1% (genotype 12), with an average of 42.7% for the primary raceme and between 43.2 (genotype 12) and 48.1% (genotype 10), with an average of 46.1% for the secondary racemes (Figure 4).

In accordance with study of Souza et al. [12] a lower seed oil content was found in the primary than in the secondary racemes.

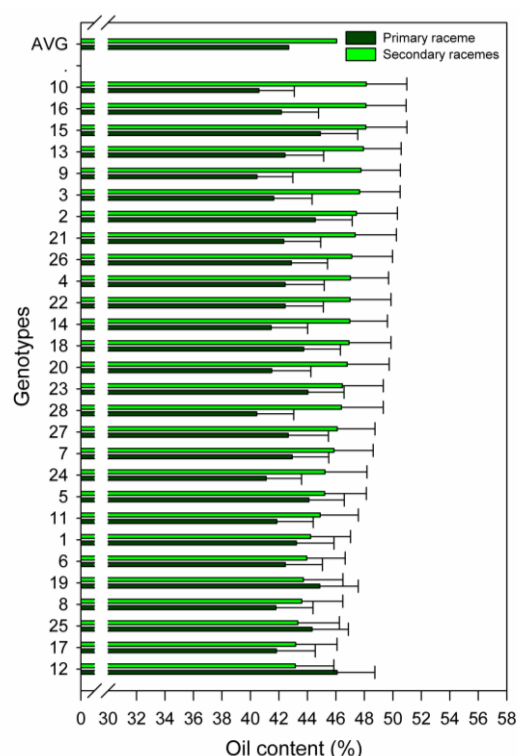


Figure 4: Seed oil content (%) of 28 castor genotypes

The main contribution to the total oil yield is given by the seed yield as reported by Koutroubas et al. [13].

Oil yield varied from 166 (genotype 18) to 270 (genotype 16) kg ha⁻¹ with an average of 231 kg ha⁻¹ for the primary raceme. The oil yield was from 518 (genotype 12) to 1206 (genotype 27) kg ha⁻¹ with an average of 918 kg ha⁻¹ for the secondary racemes.

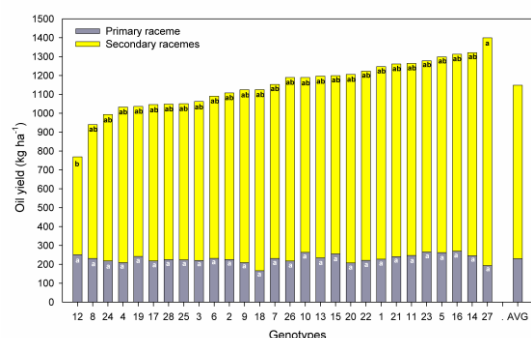


Figure 5: Oil yield (kg ha⁻¹) of 28 castor genotypes

4 CONCLUSIONS

These results suggest that investigated genotypes are suitable to the Mediterranean climate as reported by preliminary field experiments carried out in southern Sicily and in Tunisia that shown the possibility of exploiting the perennial habit of this species [14,15,16]. A great variability exists among tested genotypes, which were collected from wild semiarid environment of the Mediterranean basin. Besides seed yield and oil content, this preliminary study allows to select other traits, such as physiological, morphological and phenological, which are

currently under study, to be selected for breeding improved castor lines suitable to drought prone environment of southern Europe.

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