

Review

Castor: A Renewed Oil Crop for the Mediterranean Environment

Valeria Cafaro ^{1,†}, Giorgio Testa ²  and Cristina Patanè ^{1,*} 

¹ CNR-Istituto per la BioEconomia (IBE), Sede Secondaria di Catania, Via P. Gaifami 18, 95126 Catania, Italy; valeria.cafaro@ibe.cnr.it

² Dipartimento di Agricoltura, Alimentazione e Ambiente, Università degli Studi di Catania, Via Valdisavoia 5, 95123 Catania, Italy; gtesta@unict.it

* Correspondence: cristinamaria.patane@cnr.it

[†] This work was part of the Ph.D. thesis of the first author Valeria Cafaro; PhD program in Agricultural, Food and Environmental Science at the University of Catania, Italy.

Abstract: Castor (*Ricinus communis* L.) is a plant belonging to the *Euphorbiaceae* family originated from Asia or Africa and well adapted to the Mediterranean environment. As an oilseed crop with a high oil content (35–65%), it is nowadays used for biofuels production, with a large potential for applications in chemical and pharmaceutical sectors as well. As for other oilseed crops, the interest towards this crop has grown exponentially in the past decades because of the necessity of limiting fossil fuels, obtaining clean energy, and use of a renewable energy source as required by RED (Renewable Energy Directive) within the European Union. Moreover, castor has a great adaptability in different soil and climate conditions, and it is known as a low-key maintenance crop. These characteristics, together with the necessity of increasing renewable energy sources, with the possibility of re-evaluating marginal lands, make castor the ideal plant to be exploited in the years to come. This review aims at giving useful information regarding its cultivation and soil and climate requirements, providing an overview on its spread on the market.

Keywords: castor management; renewable energy crop; marginal land; biofuels crop



Academic Editor: Yingpeng Han

Received: 8 May 2025

Revised: 28 May 2025

Accepted: 4 June 2025

Published: 6 June 2025

Citation: Cafaro, V.; Testa, G.; Patanè, C. Castor: A Renewed Oil Crop for the Mediterranean Environment. *Agronomy* **2025**, *15*, 1402. <https://doi.org/10.3390/agronomy15061402>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The production and consumption of renewable energies are experiencing consistent growth, driven by policies adopted in numerous countries. These policies aim to enhance energy autonomy, contribute to the reduction of carbon dioxide emissions, and support agricultural initiatives [1]. It is expected that the global energy demand will increase by approximately 50% in 2050. In alignment with the Kyoto Protocol, the Agenda 2030, and the Conference of the Parties, the European Union has introduced a series of directives aimed at counteracting greenhouse gas emissions into the atmosphere (GHG). The objective is to achieve a reduction in these emissions of 80–95% by 2050 [2].

Trying to cope with the exponential increase in oil and coal consumption around 2050, renewable energies fit perfectly into this scenario as the only possibility to guarantee energy sources continuously and constantly over time. Although the transition to renewable energy may present challenges, it is clear that the demand for “clean energy” is essential for the future. Scientific research and technological innovation will, therefore, be essential for the realization of these ambitious goals.

Biofuels, including biodiesel and bioethanol, produced from oil-bearing and starchy plants, have the potential to fully satisfy these needs [3]. Their production would also

exploit those marginal lands where no-food crops could be easily introduced, thereby preserving essential farmland for food production purposes.

Since the economic boom, a great interest in the vegetable oil sector began to grow. Palm oil has experienced a great expansion from 2008 to 2017, as the most requested vegetable oil in the market, with countries such as Indonesia and Malaysia as the main players in production and export [4]. The exponential growth of palm oil, given its extreme versatility of application in both food and industry sectors, has been roughly stopped because of its social and environmental negative impact [5]. The European Union has, therefore, promoted a sustainable biofuel industry, through the adoption of the Directive 2018/2001/UE (RED-Renewable Energy Directive) [6], which established the requirements for the sustainable and environmentally friendly production of biofuels by setting out different criteria [7]. This policy, by declaring palm oil as a high-risk product, has encouraged research towards sunflower, soybean, and rapeseed, proving them the main future alternative crops. In addition, the growing unavailability of arable land due to constant climate change should also be taken into consideration. The utilization of marginal lands, characterized by fragile and disadvantaged soils in arid and semi-arid regions, presents a viable alternative. This approach has the potential to minimize competition for agricultural use while simultaneously mitigating greenhouse gas emissions and limiting biodiversity loss [8].

Castor (*Ricinus communis* L.) becomes the protagonist of this new reality, being a warm oilseed crop, adapted to different environments and with a wide range of applications [9]. Thus, the aim of this review is to focus on the available knowledge of castor, highlighting the inclusion and adaptability of castor in the semi-arid regions in order to improve its cultivation and productivity in the Mediterranean area.

2. Establishing Castor as an Advantageous Oil Crop in Europe: Economic Overview

2.1. Oil World Scenario

The annual production of lubricants is around 30 and 40 million tons [10]. Lubricants, which are 95% oil-based, have wide industrial applications such as reducing friction and heat, protecting against corrosion, transmitting energy, and other activities [11]. However, they have uncontested environmental consequences and about 50–70% of production is poured into the environment [12].

Last decades faced a substantial increase in biofuel production, considered the main source of energy that can be produced even in geographical areas with limited resources [13]. Thus, the scientific community is projected to develop new products with higher biodegradability and lower toxicity.

Bio-based sources have significantly grown since 2002 [14]. The vegetable market for industrial oil was valued at USD 29.220.6 million in 2020, and it is expected to increase by 4.13% around 2021–2026 [15]. In this picture, Italy holds a significant position in Europe, ranking third, after Germany and France, in terms of energy consumption from RES (21.9 Mtep) and total energy consumption (107.6 Mtep). According to the Italian Energy Services Operator (GSE), the share of energy consumption in Italy from renewable energy sources is 20.4%, exceeding the target set for 2020 [16].

The current increase in the vegetable oil market plays a relevant role in Europe and the past twenty years have seen the introduction of several crops with wide energy potentiality [17].

After the adoption of the U.S. Renewable Fuel Standard in 2005, which established requirements for a minimum volume of renewable fuels that must be transported and sold in the US, a significant increase in the use of first-generation biofuels occurred. Their market introduction offered both economic opportunities and an environmentally friendly

approach. However, the increased use of crops such as sugarcane and corn as sources of first-generation biofuels, adversely influenced the global food system [18], shifting the interest towards crops for second-generation biofuels, more suitable for marginal land [13].

This new scenario contributed to a renewed interest in castor.

2.1.1. Castor Insights

Castor (*Ricinus communis* L.) is an oilseed crop that offers a wide range of industrial applications. Its oil content is 35–65% [19], which is really high when compared with that of other oilseed crops such as soybean, sunflower, rapeseed, and palm (Table 1) [20]. The oil content range of variation in castor depends on the genetic difference among cultivars [21]. The oil contains 85–90% ricinoleic acid (RA, 12-hydroxyl-cis-9-octadecenoic acid), an oleic acid derivate used in many industrial applications as a source of unique fatty acid. The RA content makes castor the only natural crop with such a high concentration [22].

Table 1. Oil content of major oilseed crops.

Crop	Oil Content (%)
Castor bean	35–65
Palm	30–60
Rapeseed	30–50
Sunflower	25–48
Soybean	15–22

The increasing use of castor has led to a significant rise in the market volume, which is expected to reach USD 1.54 billion by 2026. In 2018, castor oil was ranked 751st among the most-traded products, with a total trade of \$1,72 M. In the same year, the top exporting countries were Mexico (\$1.54 M), Egypt (\$83.5 K), the Philippines (\$46.3 K), Kenya (\$18.5 K), and Ukraine (\$17.9 K). While the most importers were the United States (\$1.57 m), Croatia (\$62.5 K), Uganda (\$17.5 K), and Kyrgyzstan (\$9.86 K), ranking castor 10th as the most imported product [23].

Nowadays, China, USA, and Europe are the key players in the current market, with China being the main importer with an import value of 41%. India is ranked 1st as the main exporter with a value of export of 87% equal to \$1.1 B, followed by some European countries such as the Netherlands (4%), France (2.96%), and Germany (2.14%) [24].

Castor is emerging as a promising crop for cultivation in Mediterranean regions due to its strong economic potential compared to other oilseed crops (i.e., sunflower, rapeseed, and soybean). Castor seed yield ranges between 1.8 and 4.75 t ha^{−1}, with an oil content ranging from 35% to 65% [25,26]. Production costs for castor are moderate, estimated to be between €500 and €800 ha^{−1}. However, the market price for castor oil is significantly higher than that of edible oils, reaching 1200–2000 € ton^{−1} [27].

In contrast, sunflower and rapeseed oil yield is 0.9 to 1.7 t ha^{−1}, and this oil is sold at lower prices, ranging from €800 to €1000 t^{−1} [28,29]. Soybean seed yields are even lower.

2.1.2. Castor Challenges Towards the Market

Despite several industrial applications of its oil, the cultivation of castor in Europe is still limited [30]. The presence of toxins like ricin, ricinine, and some allergens makes castor not widely used and exploited [31]. Ricin is a powerful toxic protein synthesized in the endosperm of the seed, which can lead to death, even in small quantities [32]. Ricin is considered one of the most poisonous substances existing [33]. Ricin content ranges from 1% to 5% of the defatted seed cake by weight, corresponding to approximately 1–2 mg of ricin per seed, depending on cultivar and environmental conditions. Nevertheless, the

oil of castor can also be used for human purposes because ricin is insoluble in the oil and the residuals are discarded by the refining process [34]. Even though studies have proved that high temperatures can denature this protein, the concern is still widely spread, emphasized by numerous cases of poisoning by voluntary or involuntary ingestion of ricin [32]. Another toxic protein in castor oil is RCA (*Ricinus communis* agglutinin), which causes the coagulation of red blood cells [35].

Castor oil diffusion in the market is limited also by its high hygroscopicity, which causes high water retention and leads to algae growth, filtration, and corrosion problems [22]. Moreover, difficulties during extraction and injection caused by its high viscosity and higher compressibility [36] lead to incomplete combustion, atomization, deposition of carbon on the injector, cocking, higher engine deposits, and engine problems during winter seasons [37].

Another impacting factor is related to the enormous handy work required during seed harvest [9]. Castor seed ripening is not simultaneous, thus limiting the mechanical harvesting, mainly carried out manually. Manual harvest increases costs for production and relative by-products [38]. Nonsimultaneity in seed ripening also causes problems of seed loss for shattering [39].

3. Origin and Distribution of the *Palmus Christi*

The history of castor is ancient. The first literary appearances are in the Book of Jonah (Jonah 4: 6–7) [40]. The Talmudists make it back up to the “oil of kik”, which is the same “kikajon” described by Jonah.

However, it seems castor roots are even more ancient. Egyptians were used to keep a “Medical Papyri”, also known as “The Papyrus Ebers”, in which all the recipes and medical uses were collected by sages and philosophers [41].

Numerous sources indicate that castor oil was used as medicine during the early medieval period. Reports suggest that Albert the Great, Bishop of Regensburg, cultivated castor in the mid-thirteenth century, but its cultivation declined afterward. It remained popular as an ornamental plant until the 18th century in Europe, where it was also grown for medicinal purposes [41].

The etymology of the name ‘*Ricinus communis*’ is noteworthy. The term ‘*Ricinus*’ derives from the Latin name “tick”, because the seeds have a resemblance to the tick bodies, meanwhile *communis* is the Latin word for “common”. This nomenclature was introduced by Linnaeus. Prior to the 18th century, *Ricinus* was commonly referred as “Christ Palm” or “*Palma Christi*” because the leaves give resemblance to the Hand of Christ [42].

The term castor can be misleading as it is associated with *Castor Canadensis*, the North American beaver. Additionally, castor is also the name of one of the two bright stars of the Gemini constellation—Castor and Pollux also known as ‘Gemini twins’ [42].

As well as for the name, the center of origin was not easily identified. In fact, the identification of the center of origin takes two distinct and separate factions. Some researchers are of the opinion that it is indigenous to Africa [42]. Other researchers claim that it is native to India [43]. One of the reasons why identifying castor origins is so difficult is because castor has four centers of diversity, based on morphological variation: (a) Ethiopian-East African; (b) North-West and South-West Asia and Arabian Peninsula; (c) Subcontinent of India; and (d) China. Anyway, Ethiopian-East Africa is considered the most probable site of origin because of the higher diversity present in it [44]. Moreover, given that the genetic material distributed in Eastern Africa has an arboreal phenotype, with a single elongated trunk, a dehiscence capsule, and small seeds, it is suggested that this represents the wild relative of the domesticated castor bean [45]. Once established, it spreads quickly, which is why it is considered an invasive crop in several countries [9].

Nowadays, castor easily grows in the African continent (221,130 ha), through the Atlantic coast to the Red Sea, Tunisia to South Africa. It is also cultivated in the tropical and subtropical regions of America (162,203 ha) and Asia (1,151,200 ha) and in most of Europe [46].

Germplasm studies reveal low levels of genetic variation and a lack of geographically structured genetic populations in castor. Therefore, seeking to broaden knowledge on the genetic diversity of castor, the study of the genetic alterations that occurred during domestication is essential. Xu [47], through a genome assembly study at the de novo chromosome level of the progenitor of castor, by sequencing and analyzing 505 accessions worldwide, confirmed that the accessions found in East Africa are the wild progenitors of castor and domestication dates back to 3200 years ago. In addition, a notable climatic event that occurred about 7000 years ago in Turkana could be the cause of the genetic bottleneck that led to significant genetic differences between populations in Kenya and Ethiopia.

Other researchers suggested that a large amount of genetic variation is present in the genome of castor, contradicting what has been said so far about low genetic diversity [48]. Further studies on wild germplasm are required in the future.

4. Biological and Genetic Features

Despite the common name (castor bean), castor (*Ricinus communis*) L. does not belong to the Fabaceae family, but it belongs to the Euphorbiaceae family. It is a non-edible oilseed plant. Castor ($2n = 2x = 20$) is generally a cross-pollinated diploid plant but actually, it has a mixed pollination system that favors also self-pollination by geitonogamy [49]. Cross-pollination occurs for anemophilia or entomophilia [50]. The cross-pollination rate is 50–80%, which depends on genotype and environmental conditions. In some dwarf cultivars, it may exceed 90%.

Castor is a monoecious plant; however, it may have both pistillate and staminate flowers interspersed in the rachis, thus favoring self-pollination [42].

The genus *Ricinus* includes approximately 91 species, which are easily intercrossable and produce fertile intermediates. Despite researchers evidence of its variability, this last is not so high, but it is mostly due to wild and semi-wild castor plants, widespread in the world [51].

4.1. Botanical Features

Castor is an annual herb or a perennial shrub, 1–7 m high, depending on climate and soil. Swetman [52] described the plant as perennial in semi-tropical environments, but in temperate ones, frosts and low temperatures may cause plant death, therefore it is preferable to grow castor as an annual crop [53].

Leaves are petiolate, stipulate and alternate, except in the first node, which has two opposite leaves. The color is normally green and varies from light to dark depending on the level of anthocyanin pigmentation [53].

Root system is a well-developed taproot that can reach considerable depth, up to 5 m underground, with lateral roots.

Kole and Rabinowicz [42] described the stem as erect, cylindrical, and branched, often fragile, glabrous, and glaucous. The main stem ends with an inflorescence. Once the main inflorescence is settled, from the first node below, the sympodial succession of ramifications begins, and each branch ends with a secondary raceme that can originate other racemes. Plant height ranges from 60 cm (dwarf varieties) to 5 m.

The inflorescence is an erect monoecious raceme, 10–40 cm long, depending on the cultivar. Female flowers have petals with a deciduous calyx of 3–5 sepals. Male flowers consist of numerous branched stamens, with a small yellow anther (Figure 1A). Flowering

occurs early, after 40–70 days after sowing [54]. African spontaneous castor blooms later (140 days from sowing) [55]. After pollination, the dry stamens fall off and leave the pistillate flowers on, which become a spiny or spine-less capsule [56] (Figure 1B). Fruit set up and ripening lasts approximately 45 days, but further 25 days are required for full ripening (Figure 1C). The fruit is a spiny capsule, equipped with a white, orange, red, or brown caruncle, depending on the variety, which can contain three ovoid seeds. The size of the seeds varies from 7 to 25 mm in length and from 5 to 15 mm wide. Seeds contain 40–60% oil, 20% substances like albuminoids, cellulose, rubber, resins, and salts, as well as a glycoprotein, ricin, and an alkaloid, ricinin, which is highly toxic. Seeds may have a dormancy of a few months or even several years [56]. Severino [31] evidenced the crucial role of the seed coat in the germination process. Its mechanical resistance significantly influences germination speed; a thicker seed coat can delay germination, while a thinner one facilitates it.

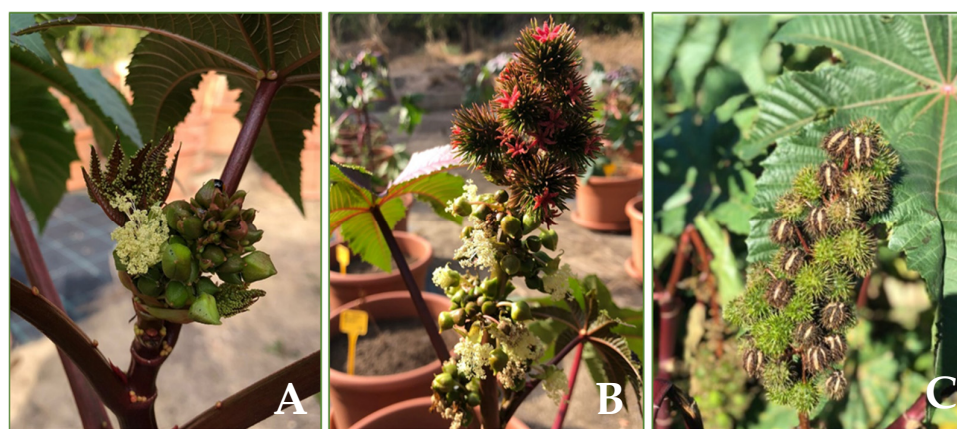


Figure 1. Developmental stages of castor capsule: (A) Beginning of the flowering (female flowers and yellow stamens are visible); (B) Spiny fruits appearance; (C) Fully ripened capsules.

Capsules ripening on raceme proceeds gradually, starting from the bottom to the top. When ripen, capsules become darker and open (dehiscence) or fall, especially in the wild types [42]. The seeds size varies from 7 to 25 mm in length and 5 to 15 mm in width.

4.2. Phenology

Gervasio [57] recognized 4 main development stages and 15 sub-intermediate stages (Figure 2). Stage 1 corresponds to the initial slow growth and includes three sub-stages following sowing: Emergence (V_e), approximately 15 days after the formation of the cotyledons; Seedlings (V_m) with the formation of two complete leaves, after about 38 days from sowing; Differentiation (V_o), approximately 85 days after sowing, which represents the end of the first phase of growth [58] (Figure 3). Stage 2 of exponential growth includes five sub-stages: Inflorescence appearing (F1) and Anthesis (A1) on the main raceme; Inflorescence appearing (F2) on secondary racemes; Fruit set (G1) on the main raceme; Anthesis (A2) on secondary racemes. Stage 3 includes six sub-stages: Inflorescence appearing (F3) on tertiary racemes; Fruit set (G2) on secondary racemes; Anthesis (A3) on tertiary racemes; Ripening (M1) on the main raceme; Fruit set (G3), on tertiary racemes; Ripening (M2) on secondary racemes. Stage 4 includes only Maturation on tertiary racemes (M3).

5.3. Soil Requirements

Castor grows in different types of soils, for this reason, it is considered an ideal plant to be introduced in marginal land [61]. However, it benefits from fairly deep, well-drained, and fertile soils with acidic conditions (pH 5.0–6.5), and little tolerates clayey, poor drainage, and marshy soils [42]. Extremely fertile soils are undesirable as they favor vegetative growth depressing seed growth [62].

5.4. Water Requirements

Water availability is a key environmental factor affecting plant growth and yield, with its role varying across developmental stages. Since castor produces racemes sequentially, water must be prioritized during critical phases (phenological stages G1, G2, G3) to support seed formation and overall productivity [63]. Castor growing season in tropics and subtropics occurs during the rainy season (ideal rainfall 750–1000 mm); however, overall satisfactory yields may be obtained even with 375–500 mm water [64]. When grown annually, at least 100 mm of water is needed during the growth, with seed germination and flowering as the main critical stages [65]. Nevertheless, in marginal areas, castor can adapt to long periods of drought [66].

5.5. Nutrients Requirements

For optimal seed yields ranging between 1.8 and 2.0 t/ha, castor plants uptake approximately 60–80 kg/ha of nitrogen (N), 10–32 kg/ha of potassium oxide (K_2O), 10–18 kg/ha of phosphorus pentoxide (P_2O_5), 5–13 kg/ha of calcium oxide (CaO), and 6–10 kg/ha of magnesium oxide (MgO) from the soil [67]. Nutritional demands peak during the capsule formation stage, underscoring the importance of timely nutrient availability [42].

Nitrogen is a critical component of chlorophyll and amino acids, directly influencing photosynthetic efficiency and overall plant vigor. Phosphorus is vital for root development, enhancing the plant's capacity to absorb water and nutrients. Its application along planting rows is recommended to optimize root growth. Potassium is essential for flower and fruit development; deficiencies can significantly compromise yield [68].

6. Breeding and Variety Development

During the last decades, castor breeding programs focused on the selection of new cultivars with reduced plant height and stem size adapted to mechanical harvesting, higher yields, and lack of capsule shattering.

6.1. Dwarf Varieties

One of the main concerns for mechanical harvest in castor is the extreme plant height [27]. Manual harvest is the current alternative, which, however, involves high production costs.

Seeds must be harvested quickly after ripening, to avoid drop and losses. However, the plant habitus (presence of lateral branches and consequent non-simultaneousness in seed ripening) [69] makes it necessary to select for genotypes with desired traits (e.g., low height, contemporaneity in seed ripening) and adapt to mechanical harvest [9].

Baldanzi [70] compared 69 normal with 22 dwarf genotypes of castor. Dwarf types had reduced height (approximately 65 cm) and smaller branches, both useful traits for mechanical harvest.

In a second study, dwarf lines of castor were selected for high grain yield and high oil content. Some of them provided up to 1.4 t/ha yield seeds, thus having both morphological and productive desirable traits [71].

Dwarf hybrids of castor provided by Kaiima Company (Campinas–SP, Brazil) were evaluated in north Italy (Bologna, 44°33' N, 11°23' E) and in central Greece (Aliartos 38°22' N, 23°6' E). The results from this study evidenced the high adaptability of these types to Mediterranean environmental conditions, providing high seed yield (2 t/ha) and oil content (54%) [72]. These results were confirmed by Cafaro et al. [26] who reported up to 2.3 t/ha seed yields for the same hybrids of castor.

As an alternative to dwarf types, the adoption of plant growth regulators (PGR) has been proposed to reduce plant growth. PGR act on the hormone concentration, specifically inhibiting gibberellin and auxin transport [73]. Oswalt et al. [74], studying the effects of the application of two growth retardants: Stance® (Bayer CropScience, Research Triangle Park, NC, USA) and Pix® (BASF Corporation, Research Triangle Park, NC, USA), reported how the effectiveness of PGRs on castor may largely vary with castor type.

6.2. Breeding Improvement

A deep knowledge of the available germplasm is a starting point for undertaking successful breeding programs. Auld [75] and Bertozzo [76] used mass selection to obtain high-quality and heritable traits, such as those introduced in the “NES” line, having a higher frequency of pistils.

In a further study, a local genotype of castor was selected from a wild Tunisian population through mass selection, for adaptation to the Mediterranean environment. This genotype was also assessed for the best sowing date (from April to July). Early spring sowing in April resulted in the highest seed yield (2 t/ha) [26].

Through crossing, a new genetic variability has been exploited. Cultivars like Dawn, Hale, Bakers 296, Cimmaron, Campinas, and Lynn were obtained and used in new breeding programs [51].

Service et al. [77], through intercrossing obtained an open-pollinated population of castor (TTU-LRC), selected for reduced levels of ricin and *R. communis* agglutinin, and for the dwarf internode trait.

From selection within the available germplasm of castor, a natural mutant of castor (OLE-1) was developed, having low levels of ricinoleic acid (approx. times lower than wild cultivars). Besides low ricinoleic acid, the mutant had high oleic acid (approx. 19 times higher than common varieties) [78]. High levels of oleic acid result in high oxidative stability, with positive implications in the industrial sector [79].

550Gy r-rays gamma irradiation was used on seeds to induce mutations in a particular pistillate line of castor, DPC-9, susceptible to leafhopper. Wilt-resistant pistillate lines were generated [80].

Currently, most of the studies are focusing on molecular adaptation mechanisms. Indeed, protoplasts are studied to understand the overall functions of genes and proteins. Bai et al. [81] used cultivar Tongbi 5 for protoplast isolation for studying gene expression. Xu et al. [82] studied plant-specific GRAS (GAI, RGA, SCR) gene families through a genome-wide study, to identify genes related to root tip tissue and root development.

Plant development is also controlled by transcriptional factors that involve epigenetic mechanisms of regulation [9]. DNA methylation, histone modifications, gene expressions, and cellular and physiological traits are frequently changed by epigenetics. Through a complex analysis of the transcriptome sequencing, Han et al. [83] provided an overall knowledge of seed-specific genes and the molecular basis for seed development, in particular, DMV'S (DNA methylation valleys) are highly conserved and associated with evolutionary processes of seed and leaves formation in many crops.

Several castor varieties shown their suitability for cultivation in the Mediterranean environment, which often require early maturation and tolerance to cooler temperatures.

The ‘Hale’ variety, which was developed in the United States, is recognized for its significant production of seeds and oil [35]. Additionally, this variety demonstrated strong adaptability to shorter growing seasons. The ‘DCH-177’ and ‘Vijaya’ varieties, originating from India, exhibit early maturation and demonstrate resilience to drought conditions, making them suitable for Mediterranean-type climates [84]. Brazilian varieties such as ‘BRS Nordestina’ and ‘E24’ are distinguished by their ability to endure variable temperatures and arid conditions [85]. Dwarf hybrid genotypes like ‘C1012’, ‘C1019’, and ‘C1020’ have been tested in Mediterranean climates showing positive results at high temperatures, which make them suitable for late sowing [26].

6.3. Castor Response to Abiotic Stresses

Plants act mechanisms of tolerance to survive and escape from hostile environments and to keep on with growth [86].

Among abiotic stresses, drought is one of the most significant constraints on crop productivity. Although sensitive to drought during its early developmental stages, including germination, and seedling emergence [57,82], castor is reported as a drought-tolerant plant [31]. At the cellular level, castor exhibits both morphological and biochemical adaptation to low soil water availability, such as maintaining turgor pressure, increasing cell wall elasticity, reducing cell size, preserving the photosynthetic apparatus, and closing stomata [87]. Castor plants have been demonstrated to be able to fully recover photosynthetic activity within 24 h after rewatering [88]. One of the key physiological traits conferring drought tolerance in castor is osmotic adjustment (OA), which enables cells to retain water and maintain function under stress. Genotypes with high OA (HOA) accumulate greater levels of proline, total soluble sugars (TSS), free amino acids (FAA), and potassium compared to low OA (LOA) genotypes, and consistently achieve higher seed yields under water deficit [88]. The selection of drought-tolerant genotype is also an important aspect of the scientific panorama of improving crop resilience to water scarcity. Salt (NaCl) stress impairs water uptake by increasing osmotic activity, which delays germination and negatively affects seedling establishment, growth, and final yield [89,90]. While castor has been described as moderately salt-tolerant in some studies [86,91], most research has focused on agronomic traits like seed yield and oil content rather than early growth responses [92]. Salt stress limits water absorption by lowering soil water potential, particularly around the root zone, thereby inducing osmotic stress and water deficit [93]. Plants generally tolerate osmotic stress through reduced cell expansion in roots and leaves and lower stomatal conductance to save water [94]. Salt stress also exerts ionic effects. The accumulation of Na^+ under high salinity delays and reduces seed germination by interfering with K^+ uptake, causing ionic imbalance and disrupting key cellular functions. In a study where seed germination performance under different salt concentrations of imbibition solution was assessed in castor, low levels of salinity (-0.3 , -0.6 MPa) slightly delayed germination, with final rates comparable to those of non-stressed seeds. However, at higher levels of salinity (ψ down to -0.9 MPa), germination was significantly delayed and reduced, indicating a high sensitivity of the species to salinity, at least during germination [86]. At -1.2 MPa, germination was completely inhibited. These findings were consistent with those of Han [95] who reported a 65% reduction in castor seed germination at 150 mM NaHCO_3 , underscoring the crop limited tolerance to osmotic stress.

Castor has a wide range of physiological, metabolic, and molecular responses to temperature stress. Low temperatures inhibit germination, which does not occur at 8°C [96]. Conversely, high temperatures ($>35^\circ\text{C}$) stimulate shoots and cotyledon growth while decreasing root biomass, leading to a shift in resource allocation toward the aerial parts of the plant [97]. Some genotypes, such as MPA11, exhibit improved root growth under heat

stress, indicating genetic variability in heat tolerance. Heat stress triggers the mobilization of starch reserves in cotyledons, leading to increased levels of sugars like glucose and fructose to meet the plant energy demands [98]. Additionally, amino acids such as methionine and tryptophan accumulate in response to heat, indicating a shift toward nitrogen metabolism to regulate growth. Furthermore, heat stress stimulates the production of osmoprotectants and antioxidants, such as galactinol and tocopherols, which help mitigate oxidative damage caused by elevated temperatures [98]. Additionally, stress response genes are upregulated against oxidative stress [99].

7. Agronomic Management in the Mediterranean Environment

7.1. Sowing

Sowing time in castor strictly depends on its thermal requirements. Castor seeds require a minimum soil temperature of approximately 15 °C for germination [100]. As a result, spring sowings (March–April) are generally recommended to fulfill thermal requirements for germination. In spring sowings, castor seeds can take 6 days only to emerge. Sowings from June to September are also feasible; however, they result in lower seed yields. Winter sowings (e.g., in November) can be adopted in some areas (Southern Russia, Central U.S., China); however, they may extend the growing season up 240 days, significantly delaying seedling emergence [100].

It has been reported that dwarf hybrids perform better with late spring sowings (May and June), whereas local genotypes adapted to Mediterranean conditions prefer early spring sowings [26].

Sowing is typically performed manually or using seeding machines [9]. For annual cultivation, plant spacing is generally 100 cm between rows and 30–50 cm within rows, targeting a plant density of 20,000–30,000 plants/ha, with a seed rate of 8–18 kg/ha. In perennial castor, spacing increases to 1.5–2.5 m within rows and 2–3 m between rows, with a seed rate of 1.1–2.7 kg/ha. Seeding depth ranges from 5 to 9 cm.

7.2. Irrigation

Although castor is drought-tolerant, water stress reduces yield. The crop consumes about 400 L of water per kg of dry matter. While 500 mm of rainfall may suffice for dwarf varieties, optimal yields require 600–700 mm, though production can occur with as little as 375–500 mm annually [101].

Irrigation timing significantly affects the crop cycle. Full irrigation from flowering to main raceme maturation extended the cycle to ~87.4 days, while irrigation only until flowering shortened it to ~84.3 days, and sowing-only irrigation reduced it to ~78.3 days [101]. Water stress during raceme development can impact both raceme formation and growth duration.

Water volume is closely linked to yield. Calcagno [102] found that yield increased by 50% when irrigation volume rose from 1700 to 3200 m³/ha, primarily due to more racemes per plant. Water stress during seed filling reduces seed number and weight, lowering overall yield. Full irrigation resulted in yields of 2600.33 kg/ha, while water stress yielded 1839.75 kg/ha [103].

Efficient water use (WUE) is critical for growth. Soil properties, such as clay content and organic matter, affect water retention. Castor has higher water needs early in development, with water demand decreasing at physiological maturity. Root system efficiency, seen in cultivars like EBDA MPA 11 and BRES, also improves water uptake [104].

7.3. Fertilization

Under rainfed conditions, the recommended doses of fertilizers are 40 kg/ha of N, 40 kg/ha P_2O_5 , and 20 kg/ha of K_2O . Under irrigation, are 60 kg/ha of N, 30 kg/ha P_2O_5 , and 30 kg/ha of K_2O [105].

The use of binary and ternary compound fertilizers has been found to be more effective and cost-efficient compared to simple mineral fertilizers [68]. Castor meal (CM) as an organic fertilizer is also utilized to improve soil fertility [106]. CM contains approximately 4.2–7.5% N and 0.7–1.0% K, with a C/N ratio of about 12:1, which facilitates rapid mineralization and nutrient release. Optimal application rates for CM have been identified as 100–150 kg per 0.1 ha, balancing crop productivity [106].

7.4. Weed Management

Castor exhibits slow vegetative growth during its early development stages, making it highly vulnerable to weed competition, which can significantly reduce both yield and the efficiency of mechanical harvesting. According to Costa [107], yield losses due to weed may reach up to 86% during the first year of cultivation, when grown as perennial. However, once the crop is fully established (2nd year), it becomes more competitive and can suppress weed growth effectively. The level of weed competition is influenced by several factors, including weed species, density, and distribution. However, crop agronomic management (e.g., cultivar, fertilization, plant spacing) may greatly affect the level of weed completion. Studies have identified a critical period for weed control (critical period for preventing interference-CPPI), which in castor spans from 9 to 41 days after emergence (DAE), depending on sowing time [108].

Weeding in castor is commonly made through mechanical and chemical methods, although agronomic practices such as soil preparation, crop rotation, intercropping, and optimized plant spacing can also contribute to weed control. The use of dwarf genotypes can help weed control through higher planting densities and narrower spacing. Chemical weed control in castor is limited due to the lack of highly selective compounds. Therefore, mechanical control remains the most widely used approach, although it is economically feasible only for small-scale cultivation.

7.5. Pests and Diseases

Climate change and intensive agriculture have increased pest and disease pressures in crop production. Castor tolerates different pests (approximately 107 insect species) and diseases (approximately 150 among fungi and bacteria).

Most pests originate from the Eastern Hemisphere and damage the crop throughout its life cycle [109]. They are typically classified by habitat, plant part attacked, and nature of damage [110]. Soil-dwelling pests such as *Holotrichia consanguinea* (Coleoptera), commonly known as the sugarcane white grub, and *Odontotermes obesus* (Blattodea), a subterranean termite, are prevalent in sandy soils and damage roots, impairing seedling emergence [110]. Sap-sucking pests include the rose jassid (*Empoasca flavescens*, Rhynchota), which injects toxins during feeding, leading to leaf curling and abscission, and the whitefly (*Trialeurodes ricini*, Hemiptera), which causes stunted growth by extracting leaf sap. Defoliators such as semilooper (*Achaea janata*, Lepidoptera) are common from July to November, causing severe defoliation [109]. The castor shoot borer (*Dichocrosis punctiferalis*, Lepidoptera) is particularly damaging in rainfed areas from flowering to maturity stages. Other pests include the serpentine leaf miner (*Liriomyza trifolii*, Diptera), which causes leaf drop by tunneling through leaf tissue, and the tobacco caterpillar (*Spodoptera litura*, Lepidoptera), which skeletonizes leaves [110].

Castor is a crop relatively tolerant to diseases. However, high humidity, moderate temperatures ($\sim 25^{\circ}\text{C}$), and frequent rainfall may favor gray mold, caused by *Botryotinia ricini* or *Amphobotrys ricini*, which may lead to capsule collapse [111]. Vascular wilt, caused by *Fusarium oxysporum* f. sp. *ricini*, is particularly severe under water stress during flowering, potentially reducing yield by up to 85% [111]. Charcoal rot, caused by *Macrophomina phaseolina*, thrives in hot, dry conditions and causes stem and root rot, as well as seedling blight [112,113].

Plant protection in castor cultivation involves the use of regulated chemical agents, with active substances specifically designed to target particular pest complexes. Insecticides such as imidacloprid, thiamethoxam, emamectin benzoate, and spinosad are commonly employed to manage sucking and defoliating pests [114]. Fungicides like mancozeb, carbendazim, and metalaxyl are utilized to control key pathogens [115]. The effectiveness of these agents is maximized when they are integrated within Integrated Pest Management (IPM) [109].

7.6. Harvest

The crop is harvested when all capsules are totally dried and leaves start to fall (stages M1 and M2) [57]. All racemes maturation is not simultaneous, therefore a single harvest is not practicable, increasing the production costs of oil and sub-products [38]. Non-simultaneousness of racemes also makes mechanical harvesting difficult. Therefore, manual harvest is still commonly adopted. A delayed harvest can lead to seed losses by shattering [39]. A combined sunflower harvester with headers has been proposed for the mechanical harvest of castor [38]. Another approach involves the use of a vibrating system, to collect only the capsules [112].

8. The Wide Potentiality of Castor

Mutlu and Meier [106] stated that “Castor oil is considered as one of the most promising renewable raw materials for the chemical and polymer industries because of its manifold uses and to different series of well-established industrial procedures that yield a variety of different renewable platform chemicals”.

Mubofu [111] testified how the increase in production of castor witnessed in the past centuries, is due to its very wide range of applications and the possibility of using it in various sectors.

Already in the past, castor was strongly used mainly for its oil, which was considered a strong laxative. Nowadays, the oil has a wide range of applications ranging from agricultural uses to the pharmaceutical industry, but also textile, paper, rubber, cosmetics, paints, inks, additives, and especially lubricants and the production of biofuels [114].

8.1. Potential Feedstock

8.1.1. Castor Oil

Like other vegetable oils, castor oil is composed of triglycerides of various fatty acids and about 10% glycerin. The fatty acids present are approximately 80–90% ricinoleic, 3–6% linoleic, 2–4% oleic, and 1–5% saturated fatty acids [9]. The high content of ricinoleic acid involves a great versatility of uses of the oil. This monounsaturated, hydroxylated fatty acid has unique chemical reactivity and functional versatility. Due to the high presence of ricinoleic acid, the oil results particularly viscous as well as poisonous due to the presence of ricin and ricinin. Toxicity is a positive factor in the competition of use of the oil itself, between food and industrial uses. The oil also has good stability and shelf life. Its hydroxyl group contributes to oxidative stability, making it suitable for long-term storage. Although castor oil has considerable toxicity, its fields of uses are broader than most other vegetable oils [31]. The oil is used for many industrial chemical products due to its unique composition structure. Applications include lubricants, coatings, plastics, and cosmetics.

The production of castor oil generates two important by-products, the extraction cake and the residues of the capsules and racemes. For every ton of oil, 1.31 t of residues and 1.13 t of deoiled cake are produced. The extraction cake is the most important by-product, rich in N and P, which finds its main use as a fertilizer. The N content of castor cake (7.54%) is similar to cotton cake (8.21%) [106]. The oil extraction cake can also be used, after detoxification, as a protein supplement in the diet of some ruminants. Detoxification processes typically involve heat treatment or chemical methods to deactivate ricin.

The oil can be extracted through three methods: (a) mechanical pressing, (b) solvent extraction, and (c) a combination of mechanical pressing and solvent extraction. Prior to the extraction process, the seeds must be cleaned using shaking sieves and air blowing to eliminate contaminants such as sand, stones, wood, plant residues, and metals. After that, the seeds are dried to facilitate the splitting of the hull, which can subsequently be removed either manually or by utilizing a dehuller [22].

Mechanical pressing involves the introduction of cleaned and dehulled castor seeds into a screw press, which exerts high pressure to extract oil from the seed tissues. This method is noted for its simplicity and environmentally friendly attributes; however, it is not viable when scaled up for large-scale production [115].

Solvent extraction method is a process that involves treating raw materials with hexane or petroleum ether to extract oil. This method separates oil from a mixture known as ‘miscella’, which consists of oil and solvent, through distillation. Residual solvent in the solid by-product, or cake, is then recovered via evaporation and condensation, allowing for reuse in future extractions. A key aspect of this method is the high solubility of oils and fats in hexane or petroleum ether, which has a boiling point of 67 °C. After extraction, a rotary evaporator is utilized to gently evaporate solvents from the samples [116]. However, this method requires significant energy and investment; additionally, the most commonly used solvent, hexane, is hazardous and can cause health issues with prolonged exposure.

The combined method of mechanical pressing and solvent extraction is usually the most efficient for producing oil at industrial scale, balancing environmental sustainability and high efficiency, making it the best option when both oil yield and resource use are important [117].

8.1.2. Biofuels

In the forthcoming years, biodiesel derived from vegetable oils will become an alternative to petroleum-based diesel fuels. The current global context necessitates production methods with reduced environmental impact and viable substitutes for conventional fossil fuels [118]. Utilizing natural and renewable raw materials mitigates the environmental footprint of fossil fuels by decreasing greenhouse gas emissions, hydrocarbons, and atmospheric particulates [119]. Biodiesel is non-toxic, lacks aromatic compounds, and, when produced from castor oil, exhibits a cetane number (CN) of 43.7, which is lower than that of conventional diesel (CN 51) [120]. Additionally, castor biodiesel possesses high miscibility, low iodine content, and a low freezing point of −14 °C [121]. Its elevated oxygen content (>10%) enhances the combustion process, facilitating cleaner burning. Moreover, the absence of sulfur in castor biodiesel prevents the formation of sulfur oxides, compounds known for their detrimental environmental effects [122].

However, certain physicochemical properties of pure castor biodiesel do not align with European standards. Albuquerque [123] reported that the specific gravity of castor biodiesel is approximately 0.920, exceeding the European specification range of 0.860–0.900. Furthermore, its kinematic viscosity at 40 °C is about 13.5 mm²/s, exceeding the acceptable range of 3.5–5.5 mm²/s [123]. To address these discrepancies, blending castor biodiesel with other vegetable oils has been explored. For instance, incorporating up to 60% by

volume of soybean oil into castor biodiesel results in a blend that meets the European specific gravity requirements. Conversely, blends with a 60% volume of cottonseed or canola oils still exceed the specified limits. Regarding viscosity, blending castor biodiesel with 20% by weight (200 g/kg) of cottonseed or soybean biodiesel brings the kinematic viscosity within the acceptable European range [123].

The production of castor biodiesel involves extracting oil from castor seeds, employing mechanical pressing, solvent extraction, or a combination of both methods. While vegetable oil-derived fuels can be utilized without refining, their high viscosity necessitates further processing. Viscosity influences the fuel's mixing capabilities [124], spray quality [125], and the formation of new reactants [126]. To reduce viscosity, several techniques are employed, including microemulsification [127], thermal cracking, blending with diesel [128], and, most commonly, transesterification. This process, also known as alcoholysis, involves a chemical reaction between an ester and an alcohol in the presence of a catalyst, yielding esters and glycerol. The catalyst accelerates the reaction, thereby reducing processing time, although it may increase overall production cost [129].

8.1.3. Organic Fertilizer

Although castor is primarily cultivated for oil production, the resulting by-products are extensively utilized across various sectors of the industrial chain. The two main by-products generated during oil extraction are husks and meal. Specifically, the capsule husks constitute the outer residual layer that encloses the fruit, while the meal is the solid residue obtained following oil extraction [106]. Due to its high nitrogen content, castor meal has been evaluated by several researchers as a potential substitute in animal feed formulations [130]. However, beyond its application in livestock nutrition, there is growing industrial interest in the utilization of castor meal as an organic fertilizer, attributed to its broad applicability and agronomic benefits.

From a sustainability perspective, the valorization of castor by-products aligns with efforts to mitigate environmental impacts within the agricultural sector. Their use can contribute to enhanced soil fertility, increased crop yields, and improved nutrient cycling, thereby supporting more sustainable agricultural practices.

8.1.4. Medicinal and Pharmaceuticals

Minor uses of castor are associated with medicinal and pharmaceutical products and activities. The antibacterial activity of leaf extracts of castor has been proven against bacteria such as *Escherichia coli*, *Staphylococcus aureus*, *K. pneumoneae*, and *Streptococcus prodgens* [131,132].

The various applications within the medicinal and pharmaceuticals field range also from anti-inflammatory activity [133], central analgesic activity [134], anticancer [135], and antifertility activities [136].

8.1.5. Phytoremediation

The demographic expansion followed by the Industrial Revolution has increased the heavy metal pollution within the environment through the direct discharge of pollutants into water and soil [137]. The use of pesticides, commercial fertilizers, industrial and, in general, all kinds of human practices are strictly responsible for the high amount of polluted land, over 75% of the worldwide land surface [138].

In this contest, phytoremediation represents a valid alternative for restoring these degraded and contaminated lands. The use of oil crops in the phytoremediation process is outrageously beneficial because of the double possibility of decontaminating the soil by using crops that are not fated for the food industry and that can still be productive [121].

Recently studies have proved the consistent validity of castor as a crop able to extract heavy metals and tolerate their high concentration [132]. The ability to grow in wasteland

soil, its perennial attitude, and its tolerance to salinity, drought, and heavy metals keeping its oil yield make castor more suitable for the process more than other crops [139].

9. Final Remarks and Future Perspective

Renewable energy production is expected to grow exponentially by 2050, leading to increased interest in the vegetable oil sector, with sunflower, soybean, and rapeseed emerging as major alternative crops. Indeed, the need to identify second-generation biofuel crops adapted to marginal lands, as alternative to first-generation biofuels which negatively impact the global food system, renewed the attention towards castor. Meanwhile, the European Union has introduced Directive 2018/2001/EU (RED—Renewable Energy Directive) which outlines strict sustainability criteria for biofuel production. UE policy encourages non-food, low-impact oil crops, making castor a particularly attractive alternative to unsustainable palm oil.

Castor is a promising renewable resource known for its high oil yield and unique physicochemical properties. These characteristics make castor highly desirable for a wide range of non-food industrial applications, including bio-lubricants, coatings, bioplastics, and medicinal products. Its adaptability strengthens its value chain and increases its economic potential in a future circular bioeconomy.

This review explored the origin and global distribution of castor, emphasizing its domestication and adaptability. The Mediterranean climate supports castor cultivation, with autumn sowing favored by mild winters and seasonal rainfall, avoiding summer drought. However, in colder areas, spring sowing is an alternative but may need irrigation. Castor presents strategic opportunities in the Mediterranean basin in light of increasing climate variability, water scarcity, and land degradation. Integrating castor into European cropping systems could open new industrial opportunities, support degraded land development, and contribute to energy diversification, aligning with EU sustainability requirements (e.g., reducing greenhouse gas emissions through renewable energy production).

Advancements in breeding (e.g., development of high-yielding and stress-tolerant varieties) and improvement of agronomic and harvesting technologies are essential to enhance castor agronomic potential. Moreover, research on castor mechanical harvesting is crucial to enhance labor efficiency, reduce production costs, and facilitate crop expansion at commercial scales.

To fully realize castor role in a diversified and sustainable energy future, ongoing research, technological innovation, and supportive policies are essential.

Author Contributions: Conceptualization, methodology, formal analysis, writing—original draft preparation, writing—review and editing: V.C. and C.P.; data curation, investigation, resources, V.C.; validation, G.T. and C.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: No new data were created or analyzed in this study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bhattarai, H. Renewable Energy and Energy Storage Systems. In *Energy Conversion: Methods, Technology and Future Directions*; Delve Publishing: New York, NY, USA, 2022; pp. 269–289. [\[CrossRef\]](#)
2. Cozzi, L.; Gould, T. *World Energy Outlook 2021*; International Energy Agency (IEA): Paris, France, 2021; pp. 1–386.
3. Osorio-González, C.S.; Gómez-Falcon, N.; Sandoval-Salas, F.; Saini, R.; Brar, S.K.; Ramírez, A.A. Production of Biodiesel from Castor Oil: A Review. *Energies* **2020**, *13*, 2467. [\[CrossRef\]](#)
4. Alamsyah, Z.; Ratnasari, D.; Elwamendri, E.; Fauzia, G. The Influence of EU Renewable Energy Directive Policy to Indonesian Palm Oil Exports to Some EU Countries. *IOP Conf. Ser. Earth Environ. Sci.* **2024**, *1302*, 012149. [\[CrossRef\]](#)

5. Meijaard, E.; Brooks, T.M.; Carlson, K.M.; Slade, E.M.; Garcia-Ulloa, J.; Gaveau, D.L.A.; Lee, J.S.H.; Santika, T.; Juffe-Bignoli, D.; Struebig, M.J.; et al. The Environmental Impacts of Palm Oil in Context. *Nat. Plants* **2020**, *6*, 1418–1426. [\[CrossRef\]](#) [\[PubMed\]](#)
6. European Commission. DIRETTIVA (UE) 2018/2001 DEL PARLAMENTO EUROPEO E DEL CONSIGLIO Dell'11 Dicembre 2018 Sulla Promozione Dell'uso Dell'energia Da Fonti Rinnovabili. *Gazz. Uff. dell'Unione Eur.* **2018**, *2018*, 128.
7. Dusser, P. The European Energy Policy for 2020–2030 RED II: What Future for Vegetable Oil as a Source of Bioenergy? *OCL* **2019**, *26*, 51. [\[CrossRef\]](#)
8. Mellor, P.; Lord, R.A.; João, E.; Thomas, R.; Hursthouse, A. Identifying Non-Agricultural Marginal Lands as a Route to Sustainable Bioenergy Provision—A Review and Holistic Definition. *Renew. Sustain. Energy Rev.* **2021**, *135*, 110220. [\[CrossRef\]](#)
9. Cafaro, V. Selection of a *Ricinus communis* L. Genotype and Improvement of the Agronomic Management in Semi-Arid Mediterranean Environment. Ph.D. Thesis, University of Catania, Sicily, Italy, 2023.
10. Syahir, A.Z.; Zulkifli, N.W.M.; Masjuki, H.H.; Kalam, M.A.; Alabdulkarem, A.; Gulzar, M.; Khuong, L.S.; Harith, M.H. A Review on Bio-Based Lubricants and Their Applications. *J. Clean. Prod.* **2017**, *168*, 997–1016. [\[CrossRef\]](#)
11. Cecilia, J.A.; Ballesteros Plata, D.; Alves Saboya, R.M.; Tavares De Luna, F.M.; Cavalcante, C.L.; Rodríguez-Castellón, E. An Overview of the Biolubricant Production Process: Challenges and Future Perspectives. *Processes* **2020**, *8*, 257. [\[CrossRef\]](#)
12. Quaranta, E. Lubricant Oil Consumption and Opportunities for Oil-Free Turbines in the Hydropower Sector: A European Assessment. *Energies* **2023**, *16*, 834. [\[CrossRef\]](#)
13. Cavelius, P.; Engelhart-Straub, S.; Mehlmer, N.; Lercher, J.; Awad, D.; Brück, T. The Potential of Biofuels from First to Fourth Generation. *PLoS Biol.* **2023**, *21*, e3002063. [\[CrossRef\]](#)
14. Rutz, D.; Janssen, R.; van den Berg, N.; Spekreijse, J.; Reumerman, P.; Matschegg, D.; Bacovsky, D.; Gröngroft, A.; Karampinis, E.; Kourkoupas, D.; et al. Summary Paper for Policy Makers: Retrofitting Europe's Industry with Bioenergy. 2019, 24. Available online: https://www.biofit-h2020.eu/files/pdfs/D2.6_BIOFIT%20Summary_2019-11-25b.pdf (accessed on 25 February 2025).
15. Industry reports Europe Vegetable Oil Market (2016–2026) 2021. Available online: https://agriculture.ec.europa.eu/system/files/2019-10/agricultural-outlook-report-2016_en_0.pdf (accessed on 25 February 2025).
16. Administration, U.S.E.I. *Crude Oil Prices Briefly Traded Below \$9 in Spring 2020 But Have Since Been Mostly Flat*; U.S. Energy Information Administration (EIA): Washington, DC, USA, 2024.
17. Gasparatos, A.; Stromberg, P.; Takeuchi, K. Sustainability Impacts of First-Generation Biofuels. *Anim. Front.* **2013**, *3*, 12–26. [\[CrossRef\]](#)
18. European Environment Agency. Agriculture Contributes to Climate Change. *Agric. Clim. Change* **2015**, *19*, 1–9. Available online: <https://www.eea.europa.eu/en/analysis/maps-and-charts/climate-change-and-agriculture> (accessed on 25 January 2025).
19. Deng, X.; Ma, Y.; Cheng, S.; Jin, Z.; Shi, C.; Liu, J.; Lin, J.; Yan, X. Castor Plant Adaptation to Salinity Stress during Early Seedling Stage by Physiological and Transcriptomic Methods. *Agronomy* **2023**, *13*, 693. [\[CrossRef\]](#)
20. Bunting, E. Oilseed Crops. In *Experimental Agriculture*; Cambridge University Press: Cambridge, UK, 1983; Volume 20, p. 660.
21. Yadav, P.; Anjani, K. Assessment of Variation in Castor Genetic Resources for Oil Characteristics. *JAOCs J. Am. Oil Chem. Soc.* **2017**, *94*, 611–617. [\[CrossRef\]](#)
22. Singh, S.; Sharma, S.; Sarma, S.J.; Brar, S.K. A Comprehensive Review of Castor Oil-Derived Renewable and Sustainable Industrial Products. *Environ. Prog. Sustain. Energy* **2023**, *42*, e14008. [\[CrossRef\]](#)
23. Alola, A.A.; Özkan, O.; Obekpa, H.O. Examining the Patterns of Disaggregate Energy Security Risk and Crude Oil Price: The USA Scenario over 1970–2040. *Resour. Policy* **2023**, *82*, 103514. [\[CrossRef\]](#)
24. FAOSTAT Food and Agriculture Organization of the United Nations. Available online: <http://www.fao.org/faostat/en/#data> (accessed on 3 November 2024).
25. Anastasi, U.; Sortino, O.; Cosentino, S.L.; Patanè, C. Seed Yield and Oil Quality of Perennial Castor Bean in a Mediterranean Environment. *Int. J. Plant Prod.* **2014**, *9*, 99–116.
26. Cafaro, V.; Calcagno, S.; Patanè, C.; Cosentino, S.L. Effects of Sowing Dates and Genotypes of Castor (*Ricinus communis* L.) on Seed Yield and Oil Content in the South Mediterranean Basin. *Agronomy* **2023**, *13*, 2167. [\[CrossRef\]](#)
27. Suardi, A.; Stefanoni, W.; Latterini, F.; Pari, R.; Lazar, S.; Fernando, A.L.; Palmieri, N. The Economic and Environmental Assessment of Castor Oil Supply Chain. *Eur. Biomass Conf. Exhib. Proc.* **2021**, 1184–1188.
28. Chen, X.; Zhang, H.; Teng, A.; Zhang, C.; Lei, L.; Ba, Y.; Wang, Z. Photosynthetic Characteristics, Yield and Quality of Sunflower Response to Deficit Irrigation in a Cold and Arid Environment. *Front. Plant Sci.* **2023**, *14*, 1280347. [\[CrossRef\]](#)
29. Izgi, M.N.; Çil, A.; Çil, A.N. Yield and Quality Characteristics of Sunflower (*Helianthus annuus* L.) Cultivars by Different Sowing Dates. *J. Appl. Life Sci. Environ.* **2024**, *57*, 371–394. [\[CrossRef\]](#)
30. Ravneet, K.; Thallada, B. Potential of Castor Plant (*Ricinus communis*) for Production of Biofuels, Chemicals, and Value-Added Products. In *Waste Biorefinery*; Thallada, B., Ashok, P., Eldon, R., Rene, D.C.W.T., Eds.; Springer: Singapore, 2020; pp. 269–310.
31. Severino, L.S.; Auld, D.L.; Baldanzi, M.; Cândido, M.J.D.; Chen, G.; Crosby, W.; Tan, D.; He, X.; Lakshamma, P.; Lavanya, C.; et al. A Review on the Challenges for Increased Production of Castor. *Agron. J.* **2012**, *104*, 853–880. [\[CrossRef\]](#)
32. Rasetti-Escargueil, C.; Avril, A. Medical Countermeasures against Ricin Intoxication. *Toxins* **2023**, *15*, 100. [\[CrossRef\]](#) [\[PubMed\]](#)

33. Abbes, M.; Montana, M.; Curti, C.; Vanelle, P. Ricin Poisoning: A Review on Contamination Source, Diagnosis, Treatment, Prevention and Reporting of Ricin Poisoning. *Toxicon* **2021**, *195*, 86–92. [CrossRef]
34. Greenfield, R.A.; Brown, B.R.; Hutchins, J.B.; Iandolo, J.J.; Jackson, R.; Slater, L.N.; Bronze, M.S. Microbiological, Biological, and Chemical Weapons of Warfare and Terrorism. *Am. J. Med. Sci.* **2002**, *323*, 326–340. [CrossRef]
35. Landoni, M.; Bertagnon, G.; Ghidoli, M.; Cassani, E.; Adani, F.; Pili, R. Opportunities and Challenges of Castor Bean (*Ricinus communis* L.) Genetic Improvement. *Agronomy* **2023**, *13*, 2076. [CrossRef]
36. Scholz, V.; da Silva, J.N. Prospects and Risks of the Use of Castor Oil as a Fuel. *Biomass Bioenergy* **2008**, *32*, 95–100. [CrossRef]
37. Thomas, T.P.; Birney, D.M.; Auld, D.L. Viscosity Reduction of Castor Oil Esters by the Addition of Diesel, Safflower Oil Esters and Additives. *Ind. Crops Prod.* **2012**, *36*, 267–270. [CrossRef]
38. González, R.; Kumar Patel, A.; Stefanoni, W.; Latterini, F.; Malkogiannidis, V.; Salpiggidis, V.; Alexopoulou, E.; Pari, L. Mechanical Harvesting of Castor Bean (*Ricinus communis* L.) with a Combine Harvester Equipped with Two Different Headers: A Comparison of Working Performance. *Energies* **2022**, *15*, 2999. [CrossRef]
39. Pari, L.; Latterini, F.; Stefanoni, W. Herbaceous Oil Crops, a Review on Mechanical Harvesting State of the Art. *Agriculture* **2020**, *10*, 309. [CrossRef]
40. The Holy Bible, Book of Jonah 4:6-7 *Book of Jonah*; New International Version. Available online: <https://www.biblegateway.com/passage/?search=Jonah+4:6-7&version=NIV> (accessed on 21 April 2023).
41. Dawson, W.R. Studies in Medical History: (A) The Origin of the Herbal. (b) Castor-Oil in Antiquity. *Aegyptus* **1929**, *10*, 47–72.
42. Kole, C.; Rabinowicz, P. *Compendium of Plant Genomes the Castor Bean Genome*; Springer: Cham, Switzerland, 2018; ISBN 9783319972794.
43. Watt, G. *The Dictionary of the Economic Products of India: Horticultural Index*; Government of India: Calcutta, India, 1896.
44. Gusamo, B.K.; Jimbudo, M. Tree-Borne Oilseed Crops: *Jatropha Curcas*, *Ricinus communis*, *Anacardium Occidentale* and Some Native Trees for Oil Production for Bio-Energy Source in Papua New Guinea. *J. Agric. Environ. Sci.* **2015**, *4*, 113–123. [CrossRef]
45. Purseglove, J.W. *Castor, Sesame & Safflower* By E. A. Weiss London: Leonard Hill Books (1971), pp. 901, £16.00. *Exp. Agric.* **1972**, *8*, 282. [CrossRef]
46. Chakrabarty, S.; Kalam Mohammad Aminul Islam, A.; Yaakob, Z.; Kalam Mohammad Mominul Islam, A. Castor (*Ricinus communis*): An Underutilized Oil Crop in the South East Asia. In *Agroecosystems—Very Complex Environmental Systems*; Springer: Singapore, 2021.
47. Xu, W.; Wu, D.; Yang, T.; Sun, C.; Wang, Z.; Han, B.; Wu, S.; Yu, A.; Chapman, M.A.; Muraguri, S.; et al. Genomic Insights into the Origin, Domestication and Genetic Basis of Agronomic Traits of Castor Bean. *Genome. Biol.* **2021**, *22*, 113. [CrossRef]
48. Xu, W.; Yang, T.; Qiu, L.; Chapman, M.A.; Li, D.Z.; Liu, A. Genomic Analysis Reveals Rich Genetic Variation and Potential Targets of Selection during Domestication of Castor Bean from Perennial Woody Tree to Annual Semi-Woody Crop. *Plant Direct* **2019**, *3*, e00173. [CrossRef]
49. Cheema, N.M.; Azim Malik, M.; Qadir, G.; Zubair Rafique, M.; Nawaz, N. Influence of Temperature and Osmotic Stress on Germination Induction of Different Castor Bean Cultivars. *Pakistan J. Bot.* **2010**, *42*, 4035–4041.
50. Rizzardo, R.A.G.; Milfont, M.O.; Da Silva, E.M.S.; Freitas, B.M. Apis Mellifera Pollination Improves Agronomic Productivity of Anemophilous Castor Bean (*Ricinus communis*). *An. Acad. Bras. Cienc.* **2012**, *84*, 1137–1145. [CrossRef]
51. Anjani, K. Castor Genetic Resources: A Primary Gene Pool for Exploitation. *Ind. Crops Prod.* **2012**, *35*, 1–14. [CrossRef]
52. Swetman, A. *Oilseed Crops*, 2nd ed.; Weiss, E.A., Ed.; ix 364 Pp; Blackwell Science (1999): Oxford, UK, 2000.
53. Bunting, E.S. *Oilseed Crops*. By E. A. Weiss. London: Longman (1983), pp. 660, £35. *Exp. Agric.* **1984**, *20*, 267–268. [CrossRef]
54. Simmonds, N.W.; Purseglove, J.W. *Tropical Crops. Dicotyledons*. *J. Ecol.* **1969**, *57*, 846–847. [CrossRef]
55. Van der Vossen, H.A.M.; Umail, B.E. *Plant Resources of South-East Asia*; Backhuys Publishers: Leiden, The Netherlands, 2001.
56. Campbell, D.N. Determining the Agronomic and Physiological Characteristics Of the Castor Plant (*Ricinus communis* L.): Developing a Sustainable Cropping System for Florida. Master's Thesis, University of Florida, Gainesville, FL, USA, 2013. Available online: https://ufdcimages.uflib.ufl.edu/UF/E0/04/55/14/00001/CAMPBELL_D.pdf (accessed on 12 March 2023).
57. Rios, G.F.; de Carvalho, L.G.; da Silva Junior, J.J.; Neto, P.C.; Fraga, A.C. Method and Phenological Characterization of the Stadiums and Phases of the Development of Castor Bean Plants. *Afr. J. Agric. Res.* **2016**, *11*, 4488–4497. [CrossRef]
58. Marin, F.R.; Angelocci, L.R.; Nassif, D.S.P.; Vianna, M.S.; Pilau, F.G.; da Silva, E.H.F.M.; Sobenko, L.R.; Gonçalves, A.O.; Pereira, R.A.A.; Carvalho, K.S. Revisiting the Crop Coefficient–Reference Evapotranspiration Procedure for Improving Irrigation Management. *Theor. Appl. Climatol.* **2019**, *138*, 1785–1793. [CrossRef]
59. Weiss, E.A. *Oilseed Crops*, 2nd ed.; Blackwell Science: Oxford, UK, 1999; ISBN 0-632-05259-7.
60. Messina, C.D.; Rotundo, J.; Hammer, G.L.; Gho, C.; Reyes, A.; Fang, Y.; van Oosterom, E.; Borrás, L.; Cooper, M. Radiation Use Efficiency Increased over a Century of Maize (*Zea Mays* L.) Breeding in the US Corn Belt. *J. Exp. Bot.* **2022**, *73*, 5503–5513. [CrossRef] [PubMed]
61. Carrino, L.; Visconti, D.; Fiorentino, N.; Fagnano, M. Biofuel Production with Castor Bean: A Win-Win Strategy for Marginal Land. *Agronomy* **2020**, *10*, 1690. [CrossRef]

62. Salihu, B.Z.; Gana, A.K.; Apuyor, B.O. Castor Oil Plant (*Ricinus communis* L.): Botany, Ecology and Uses. *Int. J. Sci. Res.* **2014**, *3*, 1333–1341.
63. Severino, L.S.; Auld, D.L. Seed Yield and Yield Components of Castor Influenced by Irrigation. *Ind. Crops Prod.* **2013**, *49*, 52–60. [\[CrossRef\]](#)
64. Falasca, S.L.; Ulberich, A.C.; Ulberich, E. Developing an Agro-Climatic Zoning Model to Determine Potential Production Areas for Castor Bean (*Ricinus communis* L.). *Ind. Crops Prod.* **2012**, *40*, 185–191. [\[CrossRef\]](#)
65. De Lima, G.S.; Gheyi, H.R.; Nobre, R.G.; Xavier, D.A.; Dos Anjos Soares, L.A.; Cavalcante, L.F.; Dos Santos, J.B. Emergence, Growth, and Flowering of Castor Beans as a Function of the Cationic Composition of Irrigation Water. *Semin. Agrar.* **2016**, *37*, 651–664. [\[CrossRef\]](#)
66. Papazoglou, E.G.; Alexopoulou, E.; Papadopoulos, G.K.; Economou-Antonaka, G. Tolerance to Drought and Water Stress Resistance Mechanism of Castor Bean. *Agronomy* **2020**, *10*, 1580. [\[CrossRef\]](#)
67. Koutroubas, S.D.; Papakosta, D.K.; Doitsinis, A. Water Requirements for Castor Oil Crop (*Ricinus communis* L.) in a Mediterranean Climate. *J. Agron. Crop Sci.* **2000**, *184*, 33–41. [\[CrossRef\]](#)
68. Patel, J.J.; Patel, D.M.; Patel, J.R.; Damor, R.P. Effect of Farm Yard Manure and Nitrogen on Growth, Yield and Economics of Castor (*Ricinus communis* L.). *Pharma Innov.* **2023**, *12*, 1439–1443.
69. Zhao, H.; Zhang, C. Analysis on the Research Status and Structure Characteristics of Castor Harvester. In Proceedings of the 2019 IEEE International Conference on Mechatronics and Automation (ICMA), Tianjin, China, 4–7 August 2019; pp. 415–420. [\[CrossRef\]](#)
70. Baldanzi, M.; Myczkowski, M.L.; Salvini, M.; Macchia, M. Description of 90 Inbred Lines of Castor Plant (*Ricinus communis* L.). *Euphytica* **2015**, *202*, 13–33. [\[CrossRef\]](#)
71. de Oliveira Neto, S.S.; Ramos, A.R.; da Silva Oliveira, C.E.; da Silva, E.A.A.; Zanutto, M.D. Genetic Divergence and Physiological Quality of Dwarf Castor Bean Lines Seeds. *Pesqui. Agropecu. Trop.* **2022**, *52*, 1–18. [\[CrossRef\]](#)
72. Zanetti, F.; Chieco, C.; Alexopoulou, E.; Vecchi, A.; Bertazza, G.; Monti, A. Comparison of New Castor (*Ricinus communis* L.) Genotypes in the Mediterranean Area and Possible Valorization of Residual Biomass for Insect Rearing. *Ind. Crops Prod.* **2017**, *107*, 581–587. [\[CrossRef\]](#)
73. Burton, J.D.; Pedersen, M.K.; Coble, H.D. Effect of Cyclanilide on Auxin Activity. *J. Plant Growth Regul.* **2008**, *27*, 342–352. [\[CrossRef\]](#)
74. Oswalt, J.S.; Rieff, J.M.; Severino, L.S.; Auld, D.L.; Bednarz, C.W.; Ritchie, G.L. Plant Height and Seed Yield of Castor (*Ricinus communis* L.) Sprayed with Growth Retardants and Harvest Aid Chemicals. *Ind. Crops Prod.* **2014**, *61*, 272–277. [\[CrossRef\]](#)
75. Auld, D.L.; Zanutto, M.D.; McKeon, T.; Morris, J. *Oil Crops-Handbook of Plant Breeding in Oil Crops-Handbook of Plant Breeding*; Springer: New York, NY, USA, 2009; pp. 316–332.
76. Bertozzo, F.; da Costa Lara, A.C.; Zanutto, M.D. Melhoramento Genético Da Mamona Visando Incremento de Flores Femininas. *Bragantia* **2011**, *70*, 271–277. [\[CrossRef\]](#)
77. Service, F.S.; Simpson, C.E.; Baring, M.R.; Schubert, A.M.; Melouk, H.A.; Black, M.C.; Lopez, Y.; Keim, K.A.; Texas, T. Registrations of Cultivars. *Crop Sci.* **2002**, 2298–2316. Available online: <https://www.ars.usda.gov/ARSEUserFiles/60701500/Publications/Marshall/MarshallCropSci03.pdf> (accessed on 25 February 2025).
78. Duran, A.J.F.P.; Lyra, G.P.; Campos Filho, L.E.; Martins, R.H.B.; Bueno, C.; Rossignolo, J.A.; Fiorelli, J. The Use of Castor Oil Resin on Particleboards: A Systematic Performance Review and Life Cycle Assessment. *Sustainability* **2025**, *17*, 3609. [\[CrossRef\]](#)
79. Rojas-Barros, P.; Fernández-Martínez, J.M. Fatty Acid and Tocopherol Accumulation in the Seeds of a High Oleic Acid Castor Mutant. *Ind. Crops Prod.* **2005**, *22*, 201–206. [\[CrossRef\]](#)
80. Rojas-Barros, P.; De Haro, A.; Fernández-Martínez, J.M. Inheritance of High Oleic/Low Ricinoleic Acid Content in the Seed Oil of Castor Mutant OLE-1. *Crop Sci.* **2005**, *45*, 157–162. [\[CrossRef\]](#)
81. Lavanya Cherukupalli, P.; Duraimurugan, P.; Lakshamma, T.; Manjunatha, K.T.; Ramya, M.; Santhalakshmi Prasad, M.; Senthilvel Senapathy; Vishnuvardhan Reddy, A. Development of Leafhopper and Wilt Resistant Pistillate Line in Castor through Mutation Breeding. In Proceedings of the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, Vienna, Austria, 27–31 August 2018; Available online: <https://conferences.iaea.org/event/145/contributions/5044/> (accessed on 5 June 2024).
82. Bai, L.; Cheng, Y.; She, J.; He, Z.; Liu, H.; Zhang, G.; Cao, R.; Chen, Y. Development of an Efficient Protoplast Isolation and Transfection System for Castor Bean (*Ricinus communis* L.). *Plant Cell Tissue Organ Cult.* **2020**, *143*, 457–464. [\[CrossRef\]](#)
83. Xu, W.; Chen, Z.; Ahmed, N.; Han, B.; Cui, Q.; Liu, A. Genome-Wide Identification, Evolutionary Analysis, and Stress Responses of the GRAS Gene Family in Castor Beans. *Int. J. Mol. Sci.* **2016**, *17*, 1004. [\[CrossRef\]](#) [\[PubMed\]](#)
84. Han, B.; Wu, D.; Zhang, Y.; Li, D.Z.; Xu, W.; Liu, A. Epigenetic Regulation of Seed-Specific Gene Expression by DNA Methylation Valleys in Castor Bean. *BMC Biol.* **2022**, *20*, 57. [\[CrossRef\]](#)

85. Omprakash, S. Identification of Sources, Mechanisms of Resistance and Management of Major Insect Pests on Sesame (*Sesamum indicum* L.). Master's Thesis, Professor Jayashankar Telangana State Agricultural University, Hyderabad, India, 2021. Available online: <https://krishikosh.egranth.ac.in/handle/1/5810204863> (accessed on 5 June 2023).
86. Silva, D.F.; Queiroga, V.P.; Silva, J.G.; Silva, M.G.; Nascimento, J.A. Cultivo da Mamoneira sob Diferentes Tipos de Águas Residuárias e de Abastecimento e Níveis de Água no Solo. *Rev. Caatinga* **1983**, *26*, 11–21. Available online: <https://periodicos.ufersa.edu.br/caatinga/article/view/2795> (accessed on 5 June 2024).
87. Cafaro, V.; Alexopoulou, E.; Cosentino, S.L.; Patanè, C. Assessment of Germination Response to Salinity Stress in Castor through the Hydrotime Model. *Agronomy* **2023**, *13*, 2783. [\[CrossRef\]](#)
88. Thatikunta, R. In Vitro Screening of Castor Genotypes for Stress Tolerance Seed Physiology View Project Horticulture View Project. *J. Oilseeds Res.* **2001**, *18*, 292–293.
89. Sausen, T.L.; Rosa, L.M.G. Growth and Limitations to Carbon Assimilation in *Ricinus communis* (Euphorbiaceae) under Soil Water Stress Conditions. *Acta Bot. Bras* **2010**, 648–654. [\[CrossRef\]](#)
90. de Sousa Lopes, L.; Prisco, J.T.; Gomes-Filho, E. Inducing Salt Tolerance in Castor Bean through Seed Priming. *Aust. J. Crop Sci.* **2018**, *12*, 943–953. [\[CrossRef\]](#)
91. Zheng, J.; Suhono, G.B.F.; Li, Y.; Jiang, M.Y.; Chen, Y.; Siddique, K.H.M. Salt-tolerance in Castor Bean (*Ricinus communis* L.) Is Associated with Thicker Roots and Better Tissue K^+ / Na^+ Distribution. *Agriculture* **2021**, *11*, 821. [\[CrossRef\]](#)
92. Pinheiro, H.A.; Silva, J.V.; Endres, L.; Ferreira, V.M.; de Albuquerque Câmara, C.; Cabral, F.F.; Oliveira, J.F.; de Carvalho, L.W.T.; dos Santos, J.M.; dos Santos Filho, B.G. Leaf Gas Exchange, Chloroplastic Pigments and Dry Matter Accumulation in Castor Bean (*Ricinus communis* L.) Seedlings Subjected to Salt Stress Conditions. *Ind. Crops Prod.* **2008**, *27*, 385–392. [\[CrossRef\]](#)
93. Abishek, R.; Santhi, R.; Maragatham, S.; Venkatachalam, S.R.; Uma, D.; Lakshmanan, A. Response of Hybrid Castor Under Different Fertility Gradient: Correlation Between Castor Yield and Normalized Difference Vegetation Index (NDVI) Under Inductive Cum Targeted Yield Model on an Alfisol. *Commun. Soil Sci. Plant Anal.* **2023**, *54*, 1816–1831. [\[CrossRef\]](#)
94. Thakkar, K.; Kachhwaha, S.S.; Kodgire, P. Enhanced Castor Seed Oil Extraction Assisted by the Synergistic Effect of Ultrasound and Microwave: Impact on Extraction Effectiveness and Oil Quality. *Chem. Eng. Process. Process Intensif.* **2023**, *185*, 109307. [\[CrossRef\]](#)
95. Singh, P.; Choudhary, K.K.; Chaudhary, N.; Gupta, S.; Sahu, M.; Tejaswini, B.; Sarkar, S. Salt Stress Resilience in Plants Mediated through Osmolyte Accumulation and Its Crosstalk Mechanism with Phytohormones. *Front. Plant Sci.* **2022**, *13*, 1006617. [\[CrossRef\]](#)
96. Han, P.; Li, S.; Yao, K.; Geng, H.; Liu, J.; Wang, Y.; Lin, J. Integrated Metabolomic and Transcriptomic Strategies to Reveal Adaptive Mechanisms in Castor Plant during Germination Stage under Alkali Stress. *Environ. Exp. Bot.* **2022**, *203*, 105031. [\[CrossRef\]](#)
97. Cafaro, V.; Alexopoulou, E.; Cosentino, S.L. Germination Response of Different Castor Bean Genotypes to Temperature for Early and Late Sowing Adaptation in the Mediterranean Regions. *Agriculture* **2023**, *13*, 1569. [\[CrossRef\]](#)
98. Ribeiro, P.R.; Zanotti, R.F.; Deflers, C.; Fernandez, L.G.; de Castro, R.D.; Ligterink, W.; Hilhorst, H.W. Effect of Temperature on Biomass Allocation in Seedlings of Two Contrasting Genotypes of the Oilseed Crop *Ricinus communis*. *J. Plant Physiol.* **2015**, *185*, 31–39. [\[CrossRef\]](#)
99. Ribeiro, P.R.; Fernandez, L.G.; de Castro, R.D.; Ligterink, W.; Hilhorst, H.W.M. Physiological and Biochemical Responses of *Ricinus communis* Seedlings to Different Temperatures: A Metabolomics Approach. *BMC Plant Biol.* **2014**, *14*, 223. [\[CrossRef\]](#)
100. Neto, V.G.; Ligterink, W.; Hilhorst, H.W.M.; Santos, I.D.; Teixeira, C.R.; Santos, E.E.; Loureiro, M.B.; Takahashi, D.; Fernandez, L.G.; Ribeiro, P.R.; et al. Resilience of *Ricinus communis* L. to High Temperatures during Germination and Seedling Growth Resulting from Efficient Superoxide Dismutase Modulation. *Rev. Bras. Bot.* **2024**, *47*, 311–324. [\[CrossRef\]](#)
101. Patanè, C.; Cosentino, S.L.; Corinzia, S.A.; Testa, G.; Sortino, O.; Scordia, D. Photothermal Zoning of Castor (*Ricinus communis* L.) Growing Season in the Semi-Arid Mediterranean Area. *Ind. Crops Prod.* **2019**, *142*, 111837. [\[CrossRef\]](#)
102. Sortino, O.; Cosentino, L.; Sidella, S. Ricino (*Ricinus communis* L.). In *Lo Sviluppo Delle Colture Energetiche in Italia*; Consiglio per la Ricerca e la sperimentazione in Agricoltura (CRA): Roma, Italy, 2011; pp. 89–98, ISBN 9788490225370.
103. Calcagno, S.; Piccitto, A.; Patan, C.; Cosentino, S.L. Effects of Nitrogen Fertilization and Soil Water Content on Seed and Oil Yield in Perennial Castor in a Mediterranean Environment. *Agronomy* **2023**, *13*, 1070. [\[CrossRef\]](#)
104. Reza Sadeghi-Bakhtavari, A.; Hazrati, S. Growth, Yield, and Fatty Acids as Affected by Water-Deficit and Foliar Application of Nitrogen, Phosphorus, and Sulfur in Castor Bean. *J. Plant Nutr.* **2020**, *35*, 453–468. [\[CrossRef\]](#)
105. de Araújo Nascimento, D.; dos Santos Brito, A.; da Silva, L.M.N.; Peixouto, L.S.; Cotrim, V.F. Water Use Efficiency of Castor Bean under Semi-Arid Conditions of Brazil. *Agric. Water Manag.* **2022**, *260*, 107278. [\[CrossRef\]](#)
106. Shah, S.K. Review on Foliar Application of Plant Nutrients on Castor Review on Foliar Application of Plant Nutrients On castor. *J. Food. Agric. Res.* **2023**, *3*, 85–100.
107. Lima, R.L.S.; Severino, L.S.; Sampaio, L.R.; Sofiatti, V.; Gomes, J.A.; Beltrão, N.E.M. Blends of Castor Meal and Castor Husks for Optimized Use as Organic Fertilizer. *Ind. Crops Prod.* **2011**, *33*, 364–368. [\[CrossRef\]](#)

108. Costa, A.G.F.; Sofiatti, V.; Maciel, C.D.D.G.; Poletine, J.P.; Sousa, J.I.D. Weed Management Strategies for Castor Bean Crops. *Acta Sci. Agron.* **2014**, *36*, 137–145. [\[CrossRef\]](#)
109. Vitorino, H.S.; Martins, D.; Costa, S.Í.A.; Marques, R.P.; de Souza, G.S.F.; de Campos, C.F. Eficiência de Herbicidas No Controle de Plantas Daninhas Latifoliadas Em Mamona. *Arq. Inst. Biol.* **2012**, *79*, 129–133. [\[CrossRef\]](#)
110. Reddy, V.D.; Rao, P.N.; Poduri, N.; Rao, K.V. *Pests and Pathogens: Management Strategies*; CRC Press: Boca Raton, FL, USA, 2011; ISBN 978-0-415-66576-6.
111. Gahukar, R.T. Management of Pests and Diseases of Castor (*Ricinus communis* L.) in India: Current Status and Future Perspective. *Arch. Phytopathol. Plant Prot.* **2018**, *51*, 956–978. [\[CrossRef\]](#)
112. Jos, D. Gray Mold of Castor: A Review. *Plant Pathol.* **2012**, *11*, 15–25. [\[CrossRef\]](#)
113. Mubofu, E.B. Castor Oil as a Potential Renewable Resource for the Production of Functional Materials. *Sustain. Chem. Process.* **2016**, *4*, 11. [\[CrossRef\]](#)
114. Chan, A.P.; Crabtree, J.; Zhao, Q.; Lorenzi, H.; Orvis, J.; Puiiu, D.; Melake-Berhan, A.; Jones, K.M.; Redman, J.; Chen, G.; et al. Draft Genome Sequence of the Oilseed Species *Ricinus communis*. *Nat. Biotechnol.* **2010**, *28*, 951–956. [\[CrossRef\]](#) [\[PubMed\]](#)
115. Rocha, A.C.; da Silveira Alves, F.G.; Salles, H.O.; Pompeu, R.C.F.F.; Ludke, J.V.; Severino, L.S.; Cândido, M.J.D. The Industrial Process of Solvent Extraction of Castor Oil Reduces the Toxicity of the Meal. *Ind. Crop. Prod.* **2022**, *181*, 114800. [\[CrossRef\]](#)
116. Khalaf, M.; Abdel-Fadeel, W.; Hashish, H.M.A.; Wapet, D.E.M.; Mahmoud, M.M.; Elhady, S.A.; Esmail, M.F.C. Experimental Investigation of Different Extraction Methods for Producing Biofuel from *Jatropha* Seeds and Castor Seeds. *Int. J. Energy Res.* **2023**, *2023*, 1780536. [\[CrossRef\]](#)
117. Nde, D.B.; Anuanwen, C.F. Optimization Methods for the Extraction of Vegetable Oils: A Review. *Processes* **2020**, *8*, 209. [\[CrossRef\]](#)
118. Marchetti, J.M.; Miguel, V.U.; Errazu, A.F. Possible Methods for Biodiesel Production. *Renew. Sustain. Energy Rev.* **2007**, *11*, 1300–1311. [\[CrossRef\]](#)
119. Keera, S.T.; El Sabagh, S.M.; Taman, A.R. Castor Oil Biodiesel Production and Optimization. *Egypt. J. Pet.* **2018**, *27*, 979–984. [\[CrossRef\]](#)
120. Nguyen, H.C.; Nguyen, M.L.; Su, C.H.; Ong, H.C.; Juan, H.Y.; Wu, S.J. Bio-Derived Catalysts: A Current Trend of Catalysts Used in Biodiesel Production. *Catalysts* **2021**, *11*, 812. [\[CrossRef\]](#)
121. Bauddh, K.; Singh, K.; Singh, B.; Singh, R.P. *Ricinus communis*: A Robust Plant for Bio-Energy and Phytoremediation of Toxic Metals from Contaminated Soil. *Ecol. Eng.* **2015**, *84*, 640–652. [\[CrossRef\]](#)
122. Adesanya, V.O.; Cadena, E.; Scott, S.A.; Smith, A.G. Life Cycle Assessment on Microalgal Biodiesel Production Using a Hybrid Cultivation System. *Bioresour. Technol.* **2014**, *163*, 343–355. [\[CrossRef\]](#)
123. Albuquerque, M.C.G.; Machado, Y.L.; Torres, A.E.B.; Azevedo, D.C.S.; Cavalcante, C.L.; Firmiano, L.R.; Parente, E.J.S. Properties of Biodiesel Oils Formulated Using Different Biomass Sources and Their Blends. *Renew. Energy* **2009**, *34*, 857–859. [\[CrossRef\]](#)
124. Diamante, L.M.; Lan, T. Absolute Viscosities of Vegetable Oils at Different Temperatures and Shear Rate Range of 64.5 to 4835 s⁻¹. *J. Food Process.* **2014**, *2014*, 234583. [\[CrossRef\]](#)
125. Talavera-Prieto, N.M.C.; Ferreira, A.G.M.; Portugal, A.T.G.; Egas, A.P.V. Viscosity of Cottonseed Oil and Biodiesel. *J. Chem. Eng. Data* **2019**, *64*, 1166–1176. [\[CrossRef\]](#)
126. Igbax, S.I.; Ogbu, E.A.; Fadeyi, O.A. Effect of Vegetable Oil Viscosity on Biodiesel. *Fuel* **2022**, *90*, 1751–1761.
127. Uddin, M.N.; Techato, K.; Taweekun, J.; Rahman, M.M.; Rasul, M.G.; Mahlia, T.M.I.; Ashrafur, S.M. An Overview of Recent Developments in Biomass Pyrolysis Technologies. *Energies* **2018**, *11*, 3115. [\[CrossRef\]](#)
128. Balat, M. Production of Biodiesel from Vegetable Oils: A Survey. *Energy Sources Part A Recover. Util. Environ. Eff.* **2007**, *29*, 895–913. [\[CrossRef\]](#)
129. Mahlia, T.M.I.; Syazmi, Z.A.H.S.; Mofijur, M.; Abas, A.E.P.; Bilal, M.R.; Ong, H.C.; Silitonga, A.S. Patent Landscape Review on Biodiesel Production: Technology Updates. *Renew. Sustain. Energy Rev.* **2020**, *118*, 109526. [\[CrossRef\]](#)
130. de Oliveira, A.S.; Campos, J.M.S.; Oliveira, M.R.C.; Brito, A.F.; Filho, S.C.V.; Detmann, E.; Valadares, R.F.D.; de Souza, S.M.; Machado, O.L.T. Nutrient Digestibility, Nitrogen Metabolism and Hepatic Function of Sheep Fed Diets Containing Solvent or Expeller Castorseed Meal Treated with Calcium Hydroxide. *Anim. Feed Sci. Technol.* **2010**, *158*, 15–28. [\[CrossRef\]](#)
131. Islam, T.; Bakshi, H.; Sam, S.; Sharma, E.; Hameed, B.; Rathore, B.; Gupta, A.; Ahirwar, S.; Sharma, M. Assessment of Antibacterial Potential of Leaves of *Ricinus communis* Against Pathogenic and Dermatophytic Bacteria. *Int. J. Pharma Res. Dev. Online* **2010**, *1*, 1–7.
132. Li, J.; Chen, M.; Yang, X.; Zhang, L. Effect and Mechanisms of Soil Functional Groups in Bacterial-Enhanced Cadmium Contaminated Soil Phytoremediation. *Environ. Technol. Innov.* **2024**, *33*, 103531. [\[CrossRef\]](#)
133. Ilavarasan, R.; Mallika, M.; Venkataraman, S. Anti-Inflammatory and Free Radical Scavenging Activity of *Ricinus communis* Root Extract. *J. Ethnopharmacol.* **2006**, *103*, 478–480. [\[CrossRef\]](#)
134. Almeida, R.N.; Almeida, R.N.; Navarro, D.S.; Barbosa-Filho, J.M. Plants with Central Analgesic Activity. *Phytomedicine* **2001**, *8*, 310–322. [\[CrossRef\]](#) [\[PubMed\]](#)

135. Ladda, P.L.; Magdum, C.S. Evaluation of Anti-Tubercular Activity of *Ricinus communis* Linn. By Proportion, Nra and Bact/Alert Methods. *Int. J. Pharm. Pharm. Sci.* **2012**, *4*, 474–478.
136. Reserved, A.R. Anti-Fertility Activity of Methanol Extracts of Three Different Seed Varieties of *Ricinus communis* Linn. *Niger. J. Pharm. Sci.* **2007**, *6*, 78–83.
137. Saier, M.H.; Trevors, J.T. Phytoremediation. *Water. Air. Soil Pollut.* **2010**, *205*, 61–63. [[CrossRef](#)]
138. Gibbs, H.K.; Salmon, J.M. Mapping the World's Degraded Lands. *Appl. Geogr.* **2015**, *57*, 12–21. [[CrossRef](#)]
139. Tripathi, S.; Sharma, P.; Purchase, D.; Chandra, R. Distillery Wastewater Detoxification and Management through Phytoremediation Employing *Ricinus communis* L. *Bioresour. Technol.* **2021**, *333*, 125192. [[CrossRef](#)]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.