CASTOR BEAN CULTIVATION IN ROMANIA: A CASE OF STUDY

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ABSTRACT: The growing demand for renewable substitute for oil-derived products is a valid opportunity for farmers who cultivate oilseed species. Castor bean oil is gaining interest during the last decades not only for cosmetics purposes but also as source of biofuel or raw material for the production of lubricants and oleo-chemical products. In order to produce castor oil, the mechanical harvesting is a problem that has to be addressed. Conventional combine harvesters fail to process the considerable amount of biomass produced by castor plant, while geneticists are involved in the selection of dwarf hybrids, further investigation on the castor chain supply is fundamental for developing a reliable mechanical harvesting system. The goal of the study is to assess the possibility to extend the use of conventional machinery, currently applied for cereal crops, to the harvest of castor beans in new selected cultivars.

Keywords: Castor beans, oilseeds, mechanical harvesting, dwarf castor hybrid

1 INTRODUCTION

The traditional sources of bioenergy could not be enough to meet the growing energy demand and the new stringent targets for climate and energy policies [1]. Therefore the participation of bioenergy sources from forestry and agricultural sectors is becoming more and more solid. Among them, the production of vegetable oils as new source of biofuel is gaining interest. Many are the species of plants that are currently exploited for vegetable oil production, (e.g. cotton seeds, soya, corn, peanut, rapeseed, canola, sunflower, coconut, palm etc.) but castor oil is high versatile product. Castor (*Ricinus communis* L.) belongs to the *Euphorbiaceae* family and it exhibits interesting capacity to tolerate salinity, drought and it is a promising candidate for phytoremediation of contaminated sites (metals, metaloids and persistent organic pollutants) with additional benefits of multi-purpose oilseed production [2]. The use of castor bean oil has been know from Egyptian times [3] and the particular structure of the castor oil made of 90% ricinoleic, 4% linoleic, 3% oleic, 1% stearic, and less than 1% linolenic fatty acids, makes it suitable for various industrial applications, ranging from energy to chemical ones. In facts, studies confirm the suitability for the production of soaps and waxes [4], or the possibility to produce totally vegetable lubricants as reported by Dwivedi & Sapre (2002) since it is possible to produce both the lubricant fraction and the gellan fraction. Besides, their study also reports a simultaneous reaction scheme to form sodium and lithium greases using castor oil.

The extraction of the oil from seeds can be performed in either cold or warm pressing or via chemical extraction by using organic solvents. Although, the capacity of oil extraction may differ among the methods, during the extraction, the ricin isoforms and alkaloid ricinine are not transferred in the oil but they remain in the seed cake [4].

The production of castor oil accounts only for the 0.15% of the total vegetable oil produced all over the world [6] and the world production of castor oil seed increased from 1.19 Mt in 1998 to 1.4 Mt in 2018, with a pick of 2.74 Mt in 2011 [7] highlighting a constant growing interest in its cultivation. In the world, the most productive country is India (more than 80% of the worldwide production) along with Mozambique, China, Brazil, Myanmar, Ethiopia, Paraguay and Vietnam. This mainly because the low costs of labour. In fact, the main problem with the cultivation of castor beans is the harvesting, that since the lack in the possibility to harvest the seeds mechanically, it is usually performed manually. The mechanization is still an unsolved problem that makes the cultivation of castor plant not possible in the developed countries, mainly for non-pharmaceutical purposes where the price per tonne must be as low as possible. Traditional varieties are tall, up to 12 m in Ethiopia [8] where it grows as perennial species. Brighnam [9] reported for normal internode types an average height ranging between 1.8 m 3.7 m and seed yields of irrigated castor ranging from 2.2 t ha^{-1} to 3.4 t ha^{-1} up to 4 t ha^{-1} under particular favourable conditions. Breeders around the world are struggling to produce hybrids of castor with the same productivity but shorter and with homogeneous ripening of the capsules, but still many problems are faced. Auld et al., (2003) [10] suggested the height of 30–125 cm as acceptable for mechanical harvesting with conventional machineries.

In the framework of the European project MAGIC "Marginal lands for Growing Industrial Crops", the present study aims to increase the knowledge on the current supply chain of castor oil in Romania, where local varieties are cultivated for the production of pharmaceutical castor oil. Farmers are interested in the possibility to expand the cultivation of castor plants and produce vegetable oil for industrial applications. In order to do that, the harvesting has to be performed mechanically and further investigations on the current supply chain and morphological traits of dwarf hybrids are fundamental for future proposals.

2 MATERIALS AND METHODS

The test was performed in two phases: in the first part focused on the mechanical removal of the husk from the seeds and the cold extraction of the vegetable oil using the seeds collected the year before from local varieties; the second part was performed in the field focusing on the characteristics of the dwarf cultivars of castor plants in order to collect data needed for the setting of the combine harvester in possible future applications.

2.1 Dehusking machine and cold mechanical press

The dehusking of the seeds was performed on the capsules collected the previous year from local cultivar of castor plants. The capsules were collected at the moisture content below 10% stored in the storehouse at room temperature. The dehusking machine was a Longer 630-B (Zhengzhou Longer Machinery Co. Ltd) (Figure 1) equipped with a trashing cylinder made of 4 beaters longitudinally fixed on drum (60 cm long – diam. 40 cm) and a mechanical system to adjust the distance between the trashing cylinder and concave. Pre-tests were performed in order to finely regulate that distance in order to have seeds clean and unbroken. The distance of 2.5 cm was the best compromise. The uncleaned seeds were automatically separated in a 80 cm x 55 cm sieve with 12 mm wide holes and conveyed back to threshing cylinder and reprocessed. Clean seeds were collected into a basket, whereas the capsules were blown apart and collected afterward. The machine was driven by a 7.7 kW diesel engine. Before starting with the test, the machine was preloaded and make running for 5 minutes. Seeds and capsules obtained were not include in the calculation.

The fuel tank was refilled with fuel, then engine was started and 10 kg of capsules previously weighted were loaded in the tank of the dehusking machine. After 60 sec the engine was stop and both clean seeds and capsules were weighted. The fuel tank was refilled and volume of fuel was recorder for fuel consumption calculation. The test was repeated for 3 time for mean and standard deviation values. From each run, approximately 200 g of seeds were collected and shipped to the CREA laboratory for the damaged seeds assessment.

The extraction of the oil from seeds was performed locally by using an hydraulic press equipped with electric motor driving the oil pump. The maximum pressure of the hydraulic oil was 81 MPa and the flow rate was regulated manually in order to make the piston move constantly into the canister. Approximately 15 kg of previously dehusked seeds were loaded into the canister per single run. The canister was made of steel, 4 mm thick, and heavenly pierced to permit the oil flow outside during the extraction. The oil was collected into a basket at the base of the press, then weighted. In total five runs were performed recording the amount of seeds loaded, the time needed for the extraction and the weight of the oil collected. A hanging scale mod. CH15K20 (KERN & SOHN GmbH) was used to weight the beans and oil.

2.2 Dwarf cultivars: growth analysis and seeds yield

In November 2018, 3 experimental fields of 0.4 ha were selected in Geacca 100 km east of Cluj Napoca, Romania. Cow manure was applied at the quantity 6 t ha^{-1} before plowing (20-30 cm in depth) and harrowing. After receiving the seeds of the new castor dwarf cultivars (C1008, C856 and C1030) from the breeder company KAIIMA,(Kaiima Bio Agritech, Ltd) sowing took place during the first week of June 2019 using a precision sowing machines at the sowing density of 3.6 plants m^{-2} and sowing depth of 8cm. Irrigation was not provided from sowing to harvesting. As the cultivation is organic, no chemicals were used for weed control which was performed manually. In October 2019, 4 plots of 3 m^2 per cultivar were selected randomly. Plants within the plot were counted, measured in height then cut at the ground level and brought outside the field for further measurements. Plants were dissected stems, leaves and capsules and the fresh weight was recorded using a precision scale mod. CH15K20 (KERN & SOHN GmbH). A representative sample of each section was put in plastic sealed bag and shipped to CREA laboratory for dry weight and seed yield assessment. Four replication per cultivars were obtained. In the laboratory, seeds were removed manually from the capsules and weighted for fresh weight. The water content of stems, leave, capsules and seeds was determined via gravimetric analysis in an oven at 105 ± 2 °C, until constant weight. Hundred fresh seeds were taken apart for 100-seeds weight and the measurement of the beans size. Beans were measured in length and two opposite diameter using an electronic caliber.

2.3 Statistical analysis

All data were subjected to the analysis of variance (ANOVA), using the R 3.6.1 software to separate statistically different means ($P \leq 0.05$) [11]. Tukey's HSD post-hoc test was performed to calculate the statistical differences between the means [12].

3 RESULTS AND DISCUSSIONS

3.1 Stationary threshing machine

In order to extract the oil contained in the castor seeds, the external part of the capsule have to be removed. The husk can be easily cracked but the hull of the seeds can be damaged if too much pressure is applied. Therefore, the regulations of the machines aimed to clean the seeds properly but with as less damaged seeds as possible. The machines could process approximately 600 kg fresh matter (F.M.) of capsules hourly with a fuel consumption 1.67 l t^{-1} of capsules. As shown in Table I, from the starting quantity of 10 kg of dried capsules, approximately 10% of the seeds processed are damaged. This is an undesired condition since the internal part of the cracked seeds is exposed to aerial oxygen that could reduce the quality of the final oil produced [13]. On the other hand, according to literature, undamaged seeds can be stored for long time. In fact, the key factor is temperature that, associated with the length of storage time, can affect negatively the quality of the beans and the extracts. This effect is accentuate as the storage period increased from 15 to 35 °C and storage duration increase from 45 days to 180 days. The highest grade commercial quality oil is only achieve when beans were stored at 15 °C for up to 180 days [14].

Therefore, the oil extraction is to be performed shortly after dehusking.

Table I: Quantity of seeds and capsules collected after the dehusking as well as the fuel consumption of the machine and the percentage of broken seeds found

Clean seeds	Capsules	Damaged seeds	Fuel consuption
Kg fw	Kg fw	$\%_{w/w}$	l h^{-1}
7.62 ± 0.3	2.41 ± 0.25	10.2 ± 1.68	0.72 ± 0.05

Figure 1: Dehusking machine (left) and the seeds obtained (right) after the fine regulations.

All the seeds were collected and used in the cold press for the oil extraction.

3.2 Cold press and oil extraction

The extraction of the oil followed the dehusking process. The average value of castor oil extract was 4.96 kg (±0.4) corresponding to 30% w/w. Oil content in castor seeds ranges between 40% and 60% w/w depending on the cultivar [15]. As predicted by local farmers, the modest quantity of broken seeds did not caused clogging in the canister of the press. However, according to their experience, higher value can trigger unexpected clogs in holes of the canister, that can reduce the performances of the press. After the cold extraction, the oil is usually decanted for 48 hours, then filtered twice and bottled. The remaining cake produced after the extraction is collected and spread on fields as natural fertilizer. However, the cake is still rich in oil and ricinin after the extraction and in case of higher production, the environmental sustainability of this practice should be investigated.

Although the cold press extraction cannot extract the whole oil within the seeds, is still preferred when the oil is meant for pharmaceutical purposes. Conventional methods require the use of organic solvent and high temperature in order to extract as much oil as possible but this may alter the fine properties of the oil [16]. This is preferable in case of industrial uses as for the production of lubricants or biofuels. Comparative analysis showed that the values of viscosity, density, thermal conductivity, and pour point for castor oil were higher than the values of a standard lubricant (SAE 40 engine oil) [17].

3.3 Growth characteristics of dwarf hybrids

Data collected from the experimental fields of the dwarf hybrids provided by KAIIMA, revealed interesting traits that make them more suitable for mechanical harvesting in comparison with local cultivars. The average height of the new hybrids was 93.9 cm with an above ground fresh biomass produced of 190 g excluding the capsules. The seed yield was 2.8 t F.M. ha^{-1}(Table II). According to Auld et al. 2003 [10] the average plant height recorded is within the upper limit of the suggested range (30–125 cm) for mechanical cultivation. However, differences found within the hybrids suggest possible different working speeds that the combine harvester can effort in order to avoid clogging. Although, all hybrids are valid candidates for further mechanical harvesting test, different effective field capacity of the combine may be noticed.

Table II: Morphological traits and fresh weight of aerial biomass and seed yield. Different letters indicate statistical difference. Same letters within column are not significantly different by Tukey's HSD multiple comparison at P < 0.05.

Cultivar	Plant height	Number of racemes	Stem and leaves	Stem and leaves humidity	Seed yield
	cm	n plant^{-1}	g pianta^{-1}	%	t ha^{-1}
C1008	94.6 b	3.3 a	191.1 b	77.97 b	2.7 a
C856	74.4 c	2.6 b	115.4 c	78.97 b	2.8 a
C1030	112.8 a	2.5 b	263.2 a	80.70 a	2.8 a

First raceme was found at 30.3 cm and 30.2 from the ground in C1008 and C856 respectively. In C1030 the first raceme was positioned at 54.9 cm from the ground. Nodal position of the first raceme is important when considering varieties better suited for mechanical cultivation to ensure the combine is built and set to an appropriate height to effectively harvest and capture most, if not all, of the seeds.

The size of the seeds shown in Table III provide precious insight on the setting of the cleaning shoe of a combine harvester. In fact, once the husk is removed, the seeds are sieved within the cleaning shoe in order to remove even the smallest part of the capsule that could have remained stack after the dehusking. Here, the size of the holes present on the sieves plays an important role in the quality of the seeds harvested. The weight of seeds, provided an important clue regarding the rotation speed of the fan that blows the residues outside the cleaning shoe of the combine harvester.

Table III: Dimensions and fresh weight of seeds produced by dwarf cultivar. Different letters indicate statistical difference. Same letters within column are not significantly different by Tukey's HSD multiple comparison at P < 0.05.

Cultivar	Length	$Width_1$	$Width_2$	100-seeds weight
	mm	mm	mm	g F.M.
C1008	13.3 b	8.9 b	6.7 b	30.1 b
C856	12.7 b	9.2 b	6.4 b	33.0 b
C1030	16.2 a	10.1 a	7.2 a	45.3 a

4 CONCLUSIONS

The present study suggests that the new dwarf hybrids proposed by KAIIMA produce low quantity of aerial biomass but high quantity of seeds, 2.8 t F.M. ha^{-1} on average in organic farming conditions. Furthermore, the mean plant height is suitable for mechanical harvesting with conventional combine harvester. The specific tests performed with stationary thresher revealed the optimal range of regulation of the cleaning shoes of the combine harvester although 10 % of the seeds can be damaged but, that, did not compromised the efficiency of the cold extraction.

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