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ECONOMIC EFFICIENCY REGARDING CASTOR BEAN (*Ricinus communis* L.) CULTIVATION IN PEDOCLIMATIC CONDITIONS IN THE CENTER OF MOLDOVA, ROMANIA

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Abstract

In Romania, castor bean (Ricinus communis L.*) is not cultivated on large areas, offering beneficial perspectives to those who want to set up a business in the agricultural field. The expansion of surfaces with this species is limited by climatic conditions, and in particular by the fall of early autumn broths, which can compromise the entire production of secondary colds. Climate change in recent years has led to the expansion of the castor cultivation area, which has obtained satisfactory production in the central area of Moldova if all technological links are respected. The research aimed to identify the genotype with the highest adaptability to the pedoclimatic conditions in the area of influence in order to establish the optimal sowing age and the distance between rows on the production and quality of seeds, implicitly in obtaining a net profit. The results obtained from 2018-2020 showed that the best option of cultivation and obtaining high net profit for the pedoclimatic conditions in the center of Moldova is the one for the variety Teleorman sown in second age and 70 cm distance between rows (12,046 lei·ha^{-1} for a production of 1,607 Mg·ha^{-1}).*

Key words: *seed production, sowing age, genotype, net profit*

INTRODUCTION

Castor bean or ricin (*Ricinus communis* L.), one of the most important crops in the *Euphorbiaceae* family, is grown worldwide for its oilseeds that produce the much prized castor oil. Due to its unique chemical properties, castor seed oil has several uses and therefore makes castor an industrially important crop [3].

Ricin is generally spread in the tropical, subtropical and warm temperate regions of the world. It is very common on marginal land, in rural and urban areas, and also at altitudes between 400 and 2,700 m. The probable origin center for castor is North East Africa, that is Ethiopia and Somalia [1] and has four diversity centers, namely, Ethiopia-East Africa, and, North-West and South-West Asia and the Arab Peninsula, the subcontinent of India and China [5, 8, 10, 14, 23]. It is now naturalized on the African continent, Red Sea (on Atlantic coast), Tunisia, South Africa and the islands from the Indian Ocean. It is also cultivated and naturalised cultivated throughout the world, especially in the tropical and subtropical areas of America, Asia and in Europe, in temperate areas [9,11, 16, 21].

In our country, for some reason, both cultivated areas and realized productions have been reduced. Because castor is originally a shrub with a high branching capacity, and Romania is at the northern limit of its culture area, it is necessary to obtain genetic forms with a shorter vegetation period, a lower branching degree, ensuring the stability and constancy of high harvest levels.

The use of castor oil for the production of biodiesel is difficult due to refining costs and high viscosity of the oil. However, because to its high oil content, distinct fatty acid composition (ricinoleic acid), and wide range of tolerance to drought and saline conditions, castor has enormous promise as a source of bioenergy and industrial raw material. [26].

Worldwide, castor oil has been used for medicinal purposes for a long time. Many illnesses and health issues can be treated with it externally, but also as an ally of the beauty of hair and skin. It has a high concentration of unsaturated fatty acids and has strong antioxidant and anti-inflammatory properties. Castor oil helps heal wounds, scratches and bruises, as well as insect stings.

The benefits of castor oil come from its concentration of unsaturated fatty acids. It is used in various cosmetic beauty treatments, but also to prevent, combat or correct various body conditions [4, 24].

High-purity derivatives may be produced from castor seeds due to their high ricinoleic acid content. In ricinoleic acid, the hydroxyl group is a unique and significant chemical reaction site that balances the carboxyl group and double bond. [19, 20].

Castor oil's high solubility in alcohols at room temperature, which also speeds up a number of chemical processes, is another crucial characteristic. [7]. Castor's high viscosity over a wide temperature range makes it a valuable ingredient in lubricants. For the chemical and polymer industries, castor oil is considered one of the most promising renewable raw materials because of its many applications and a range of well-established industrial processes that yield a diverse range of renewable platform chemicals, according to several researchers papers. [18].

At this time, in our country, the production of castor seed obtained from reduced surfaces cannot be used for industrial processing. The vast majority of growers market their seeds for the cultivation of castor as an ornamental plant. The key element for obtaining high castor production and implicitly obtaining a high profit is the observance of all technological links. The optimal sowing age plays an important role in the growth and development of castor in relation to the desired environmental conditions, which leads to a maximum yield [25]. In-depth research is also required to determine the optimal sowing age in a particular geographical area to optimise the quantitative and qualitative seed production of oil plants. Ricin is recommended to be sown until the first decade of May, about the same period as corn [12,13, 22].

Scientific study ought to incorporate the adaptation of agricultural strategies aimed at optimizing castor's productive potential. Adapting an optimum spacing, which is the space between two rows and which, when applied properly, may result in improved soil conservation and increased output, and, more efficient use of soil water and high profit. In addition to providing these advantages, mechanical work can be carried out in the field in order to destroy weeds [2, 15, 17].

It is mandatory to know both the genotypes that have a greater adaptability to the area conditions and the technological elements that lead to the improvement of the culture technology. Finding these technological parameters at castor is of great importance for the quantitative and qualitative increase of production, as well as for the improvement of culture technology. Thus, the results obtained from 2018 to 2020 on these aspects are presented in this paper.

MATERIALS AND METHODS

The research was carried out within the "Moldoveni" Agricultural Society from Neamt county, on a phaeozioma type soil with a medium texture, characterized as being well supplied with phosphorus (77.2 ppm P_{AL}), calcium (13.3 meq·100^{-1}·g soil), magnesium (1.6 meq·100^{-1}·g soil), medium supplied with nitrogen (16.3 ppm $N\text{-}NO_3$) and poorly supplied with potassium (124.3 ppm K_2O). Supply in active humus was medium (2.42%), and the soil reaction was slightly acidic (a pH of 5.96) (STRS, 2015).

For the study of climatic conditions, meteorological data collected from the Secuieni Neamt Agricultural Research and Development Station, were used. In the 2017-2020 agricultural years the average annual temperature was 8.9°C, and the annual precipitation amount was 544.3 mm. The multi-annual averages recorded in the period under review were 526.0 mm (2017/2018), 430.3 mm (2018/2019) and 376.0 mm (2019/2020). Deviations from the multi-annual average ranged from - 22 mm to - 172 mm, thus indicating an uneven distribution of rainfall during the growing season.

In the spring of 2018 an experience was placed in the experimental field of the "Moldoveni" Agricultural Society, Neamt with three factors of 4×4×3 type, arranged according to the subdivided plots method, in three repetitions and aimed to the identification of the genotype with the highest adaptability to the climatic conditions in the area of influence and the establishment of the optimal sowing age and the optimal nutrition space.

Studied factors

Factor A: Genotype, with 4 graduations:
- a_1 - Dragon;
- a_2 - Rivlas;
- a_3 - Christian;
- a_4 - Teleorman.

Factor B: Age of sowing, with 4 graduations:
- b_1 - sown in the Ist decade of April;
- b_2 - sown in the IInd decade of April;
- b_3 - sown in the IIIrddecade of April;
- b_4 - sown in the Ist decade of May.

Factor C: Rows spacing with 3 graduations:
- c_1 - 50 cm between rows;
- c_2 - 70 cm between rows;
- c_3 - 100 cm between rows.

The sown area of the experimental plot was 16.8 m^2, of which 8 m^2 were harvested.

Methyl-esterification of the samples used in the analysis was performed by the BF3-MeOH method, which occurs after alkaline hydrolysis. For 20 mg of the oil sample was added 2 mL 0.5 $mol·L^{-1}$ solution of methanol, and the mixture was brought to the temperature of 100°C and heated for 7 min. Once it has reached ambient temperature were added 3 mL of BF3-MeOH with 14% concentration, and then the container was heated again to 100°C for 14% 5 min.

After cooling, 2 mL of hexane and 7 mL of NaCl saturated solution were added, then the solution was put to the extract. The resulting hexane layer (2 mL) was used as a sample solution for GC.

The FAME (fatty acid methyl ester) analysis was performed based on GC-MS QP 2010 using a Shimandzu system equipped with an automatic injector with and without splitting the split/splitless mobile phase flow. The separation was made using a Zebron ZB-FFAP capillary column (60 m × 0.25 mm ID, 0.25 µm film thickness). Helium (He) gas, with a division ratio of 1:10, was used as a carrier with a 1.99 mL/min flow rate.

The injector had a temperature of 250°C, and the furnace temperature was set at 140°C for 10 min, and increased to 250°C at a rate of 7°C/min, then maintaining the final temperature for 10 min. To control the GC-MS operation, the software provided by LabSolution was used [6].

For the analysis of the economic efficiency of the factors studied at castor, the production costs, the gross profit and the net profit were calculated [27].

RESULTS AND DISCUSSIONS

The average of the three years indicates that the Teleorman variety has the highest adaptability to the conditions of the area. Compared to the control variant (average experience) this variety has achieved a distinctly significant production increase (48 $Mg·ha^{-1}$) (Table 1).

The second sowing era has positively influenced seed production, and its level has been influenced by climatic conditions recorded in the period under review.

During the period under study (2018-2020), the highest production increases (38 $Mg·ha^{-1}$, respectively 127 $Mg·ha^{-1}$), compared to the witness were obtained at the various sowns in the first and second ages, it follows that castor is favorable for sowing until the second half of April (Table 2).

At the variant sown in the the I[st] decade of May, a production deficit of 157 Mg·ha^{-1} was obtained very significant, compared to the experience witness, what we deduce is that it is necessary to sow castor no later than the second decade of April, because the seeds do not reach maturity (Table 2).

Table 1. Genotype influence on seed production at *Ricinus communis* L. (2018 - 2020 years average)

Genotype	Production (Mg·ha^{-1})	Difference		Signi-ficance
		%	Mg·ha^{-1}	
Dragon	1,343	100.75	10	
Rivlas	1,240	93.02	-93	ooo
Cristian	1,368	102.63	35	*
Teleorman	1,381	103.60	48	**
Average	1,333	100	Control	
LSD 5% = 23.49 Mg·ha^{-1}; LSD 1% = 35.57Mg·ha^{-1}; LSD 0.1% = 57.14 Mg·ha^{-1}.				

Source: Own results.

Table 2. Sowing age influence on seed production at *Ricinus communis* L. (2018 - 2020 years average)

Sowingage	Production (Mg·ha^{-1})	Difference		Signi-ficance
		%	Mg·ha^{-1}	
I[st] decade of April	1,371	102.85	38	*
II[nd] decade of April	1,460	109.53	127	***
III[rd] decade of April	1,325	99.40	-8	
I[st] decade of May	1,176	88.22	-157	ooo
Average	1,333	100	Control	
LSD 5% = 34.89Mg·ha^{-1}; LSD 1% = 46.55Mg·ha^{-1}; LSD 0.1% = 60.84Mg·ha^{-1}.				

Source: Own results.

Table 3. Rows spacing influence on seed production at *Ricinus communis* L. (2018 - 2020 years average)

Rows spacing	Production (Mg·ha^{-1})	Difference		Signi-ficance
		%	Mg·ha^{-1}	
50 cm	1,368	102.65	35	*
70 cm	1,423	106.78	90	***
100 cm	1,238	92.85	-95	ooo
Average	1,333	100	Control	
LSD 5% = 28.30Mg·ha^{-1}; LSD 1% = 40.96Mg·ha^{-1}; LSD 0.1% = 61.66Mg·ha^{-1}.				

Source: Own results.

Analyzing the influence of the distance between rows to castor, it follows that at greater distances production deficits are obtained. Thus, when the plant nutrition surface is increased, the branching is stronger, the, and production from the main racem decreases, instead increasing the production of secondary racemes. The density must be such that the production of secondary racemes, which do not always reach maturity, is greatly reduced.

Over the course of three years of experimentation, the average results registered indicate that the highest production was obtained at the variant sown at 70 cm between rows (1,423 Mg·ha^{-1}), which denotes that castor responds favorably to this distance as recommended in the literature (Table 3).

Among the factors that led to the superiority of the variant sown at 70 cm between the rows in the period taken in the study, it should be remembered the following: the possibility of performing mechanical slingshots up to advanced vegetation without affecting the roots and foliar apparatus, creating the possibilities of access of sunlight up to the lower floors of the leaves, earlier capsule harvesting and their uniform maturation.

Comparing with the production obtained at the control variant (average experience) it is noted that at the distance of 100 cm between the rows was obtained production deficit (-95 Mg·ha^{-1}) very significant (Table 3).

The technological factors studied had both positive and negative influences on the chemical composition of castor seeds. Thus, the production of ricinoleic acid ranged from 461.66 kg·ha^{-1} (Rivlas × sown in the I[st] decade of May × 100 cm between rows) to 767.05 kg·ha^{-1} (Teleorman × sown in the II[nd] decade of April × 70 cmbetween rows) (Table 4).

Compared to the control variant, production increases of ricinoleic acid statistically ensured as very significant were obtained from variants sown in the second age of Cristian varieties (126.82 kg·ha^{-1}) and Teleorman (146.09 kg·ha^{-1}). Also at the second age of sowing, at the varieties Dragon (98.83 kg·ha^{-1}) and Rivlas (70.91 kg·ha^{-1}) sown at the 70 cm between rows, distinct significant differences were obtained (Table 4.).

For all the varieties studied, sown in III[rd] decade of April and I[st] decade of May, negative production differences ranging between 86.63 kg·ha^{-1} and 159.3 kg·ha^{-1} have been obtained, very significant, distinctly significant and significant (Table 4).

As regards palmitic acid production, it ranged from 3.23 kg·ha^{-1} (Dragon × sown in the Ist decade of May × 100 cm between rows) to 9.94 kg·ha^{-1} (Teleorman × sown in the IInd decade of April × 70 cm between rows). The results showed that the highest amounts of palmitic acid were obtained at the Teleorman variety at almost all the interactions studied (Table 4).\

Table 4. Influence of genotype × sowing age × distance between rowson theproduction of ricinoleic acid andpalmitic acid at *Ricinuscommunis* L. (2018 - 2020 years average)

A - genotype	B - sowing age	C - distance between rows	Seed production (Mg·ha^{-1})	Ricinoleic acid (kg·ha^{-1})	Palmitic acid (kg·ha^{-1})
a_1 - Dragon	b_1 - Ist decade of April	c_1 - 50 cm	1,368	629.32	4.14°
		c_2 - 70 cm	1,410	652.94	4.30°
		c_3 - 100 cm	1,293	602.30	3.97°°
	b_2-IInd decade of April	c_1 - 50 cm	1,464	676.59	4.45°
		c_2 - 70 cm	1,548	719.79**	4.74
		c_3 - 100 cm	1,352	632.63	4.16°
	b_3-IIIrd decade of April	c_1 - 50 cm	1,320	604.48	3.98°°
		c_2 - 70 cm	1,403	646.51	4.26°
		c_3 - 100 cm	1,210	560.91	3.69°°
	b_4 - Ist decade of May	c_1 - 50 cm	1,171	534.33°	3.52°°
		c_2 - 70 cm	1,254	575.60	3.79°°
		c_3 - 100 cm	1,061	490.17°°°	3.23°°°
a_2 - Rivlas	b_1 - Ist decade of April	c_1 - 50 cm	1,267	597.94	5.11
		c_2 - 70 cm	1,320	626.48	5.35
		c_3 - 100 cm	1,201	573.60	4.90
	b_2 - IInd decade of April	c_1 - 50 cm	1,356	642.62	5.49
		c_2 - 70 cm	1,451	691.87*	5.91
		c_3 - 100 cm	1,252	600.88	5.13
	b_3 - IIIrd decade of April	c_1 - 50 cm	1,212	569.45	4.86
		c_2 - 70 cm	1,305	616.93	5.27
		c_3 - 100 cm	1,110	527.80°°	4.51°
	b_4 - Ist decade of May	c_1 - 50 cm	1,078	504.34°°°	4.31°
		c_2 - 70 cm	1,170	550.57°	4.70
		c_3 - 100 cm	975	461.66°°°	3.94°°
a_3 - Cristian	b_1 - Ist decade of April	c_1 - 50 cm	1,392	656.75	7.27
		c_2 - 70 cm	1,440	683.26	7.56
		c_3 - 100 cm	1,317	628.71	6.96
	b_2 - IInd decade of April	c_1 - 50 cm	1,482	702.31*	7.77*
		c_2 - 70 cm	1,568	747.78**	8.28**
		c_3 - 100 cm	1,370	657.30	7.28
	b_3 - IIIrd decade of April	c_1 - 50 cm	1,349	633.59	7.01
		c_2 - 70 cm	1,438	679.67	7.52
		c_3 - 100 cm	1,245	592.12	6.55
	b_4 - Ist decade of May	c_1 - 50 cm	1,215	568.24	6.29
		c_2 - 70 cm	1,294	608.86	6.74
		c_3 - 100 cm	1,103	522.30°°	5.78
a_4 - Teleorman	b_1 - Ist decade of April	c_1 - 50 cm	1,345	670.95	8.70**
		c_2 - 70 cm	1,392	698.82*	9.06***
		c_3 - 100 cm	1,269	640.99	8.31**
	b_2 - IInd decade of April	c_1 - 50 cm	1,434	718.56***	9.32***
		c_2 - 70 cm	1,521	767.05***	9.94***
		c_3 - 100 cm	1,323	671.03	8.70**
	b_3 - IIIrd decade of April	c_1 - 50 cm	1,301	646.04	8.38**
		c_2 - 70 cm	1,391	695.11*	9.01***
		c_3 - 100 cm	1,197	602.08	7.81*
	b_4 - Ist decade of May	c_1 - 50 cm	1,167	577.12	7.48
		c_2 - 70 cm	1,245	619.70	8.03*
		c_3 - 100 cm	1,055	528.16°°	6.85
		Average (control)	1,300	701	165
Ricinoleic acid - LSD 5% = 63.4 kg·ha^{-1}; LSD 1% = 88.3 kg·ha^{-1}; LSD 0.1% = 105.8 kg·ha^{-1}. Palmitic acid- LSD 5% = 1.53kg·ha^{-1}; LSD 1% = 2.04kg·ha^{-1};LSD 0.1% = 2.85kg·ha^{-1}.					

Source: Own results.

Compared to the experience control variant, very significant production increases were recorded at the interactions between the Teleorman variety × sown in the Ist decade of April × 70 cm between rows (2.93 kg·ha^{-1}), Teleorman variety × sown in the IInd decade of April at 50 between rows between rows (3.19 kg·ha^{-1}), Teleorman variety × sown in

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the IInd decade of April at 70 cm between rows (3.81 kg·ha^{-1}) and Teleorman variety × sown in the IIIrd decade of April × 70 cm between rows (2.88 kg·ha^{-1}).

Very significant negative difference was obtained at Dragon × sown in the Ist decade of May× 100 cm between rows (2.90 kg·ha^{-1}) (Table 4).

The net profit realized in the analyzed period varied in wide limits from 7,016 lei·ha^{-1} (Dragon × sown in the Ist decade of May × 100 cm between rows) to 12,046 lei·ha^{-1} (Teleorman variety × sown in the IInd decade of April × 70 cm between rows) (Table 5).

Table 5. Economic efficiency of production results2018 - 2020 (years average)

A- Genotype	B - Sowing age	C - Distance between rows	Seed production (kg·ha^{-1})	Production value (lei·ha^{-1})	Total costs (lei·ha^{-1})	Production costs (lei·kg^{-1})	Raw profit (lei·ha^{-1})	Net profit (lei·ha^{-1})
a_1 - Dragon	b_1 - Ist decade of April	50 cm	1,390	14,817	2,680	1.928	12,137	10,195
		70 cm	1,436	15,308	2,770	1.929	12,538	10,532
		100 cm	1,316	14,029	2,860	2.173	11,169	9,382
	b_2 - IInd decade of April	50 cm	1,479	15,766	2,950	1.995	12,816	10,766
		70 cm	1,568	16,715	2,790	1.779	13,925	11,697
		100 cm	1,365	14,551	2,900	2.125	11,651	9,787
	b_3 - IIIrd decade of April	50 cm	1,344	14,327	3,010	2.240	11,317	9,506
		70 cm	1,433	15,276	3,120	2.177	12,156	10,211
		100 cm	1,230	13,112	2,830	2.301	10,282	8,637
	b_4 - Ist decade of May	50 cm	1,193	12,717	2,940	2.464	9,777	8,213
		70 cm	1,283	13,677	3,050	2.377	10,627	8,926
		100 cm	1,080	11,513	3,160	2.926	8,353	7,016
a_2 - Rivlas	b_1 - Ist decade of April	50 cm	1,288	13,730	2,680	2.081	11,050	9,282
		70 cm	1,334	14,220	2,770	2.076	11,450	9,618
		100 cm	1,213	12,931	2,860	2.358	10,071	8,459
	b_2 - IInd decade of April	50 cm	1,376	14,668	2,950	2.144	11,718	9,843
		70 cm	1,465	15,617	2,790	1.904	12,827	10,775
		100 cm	1,263	13,464	2,900	2.296	10,564	8,873
	b_3 - IIIrd decade of April	50 cm	1,241	13,229	3,010	2.425	10,219	8,584
		70 cm	1,330	14,178	3,120	2.346	11,058	9,289
		100 cm	1,128	12,024	2,830	2.509	9,194	7,723
	b_4 - Ist decade of May	50 cm	1,091	11,630	2,940	2.695	8,690	7,300
		70 cm	1,180	12,579	3,050	2.585	9,529	8,004
		100 cm	977	10,415	3,160	3.234	7,255	6,094
a_3 - Cristian	b_1 - Ist decade of April	50 cm	1,415	15,084	2,680	1.894	12,404	10,419
		70 cm	1,461	15,574	2,770	1.896	12,804	10,756
		100 cm	1,341	14,295	2,860	2.133	11,435	9,605
	b_2 - IInd decade of April	50 cm	1,504	16,033	2,950	1.961	13,083	10,989
		70 cm	1,593	16,981	2,790	1.751	14,191	11,921
		100 cm	1,390	14,817	2,900	2.086	11,917	10,011
	b_3 - IIIrd decade of April	50 cm	1,369	14,594	3,010	2.199	11,584	9,730
		70 cm	1,458	15,542	3,120	2.140	12,422	10,435
		100 cm	1,255	13,378	2,830	2.255	10,548	8,861
	b_4 - Ist decade of May	50 cm	1,218	12,984	2,940	2.414	10,044	8,437
		70 cm	1,308	13,943	3,050	2.332	10,893	9,150
		100 cm	1,105	11,779	3,160	2.860	8,619	7,240
Teleorman	b_1 - Ist decade of April	50 cm	1,429	15,233	2,680	1.875	12,553	10,545
		70 cm	1,475	15,724	2,770	1.878	12,954	10,881
		100 cm	1,355	14,444	2,860	2.111	11,584	9,731
	b_2 - IInd decade of April	50 cm	1,518	16,182	2,950	1.943	13,232	11,115
		70 cm	1,607	17,131	2,790	1.736	14,341	12,046
		100 cm	1,404	14,967	2,900	2.066	12,067	10,136
	b_3 - IIIrd decade of April	50 cm	1,383	14,743	3,010	2.176	11,733	9,856
		70 cm	1,472	15,692	3,120	2.120	12,572	10,560
		100 cm	1,269	13,528	2,830	2.230	10,698	8,986
	b_4 - Ist decade of May	50 cm	1,232	13,133	2,940	2.386	10,193	8,562
		70 cm	1,322	14,093	3,050	2.307	11,043	9,276
		100 cm	1,119	11,929	3,160	2.824	8,769	7,366
Selling price: 10.66 lei·kg^{-1}								

Source: Own results.

The results obtained in the three agricultural years showed that the Teleorman variety, sown at the second epoch and at the distance of 70 cm between the rows, it realized the highest net profit (12,046 lei·ha^{-1}), where the highest seed production was obtained (1,607 lei·ha^{-1}) (Table 5).

CONCLUSIONS

Castor bean seeds have over 200 uses in the medical, pharmaceutical and cosmetic fields.

Studied production factors, respectively genotype, sowing ageand distance between rowshave a special importance onthe production of ricinoleic and palmitic acid.

In Romania *Ricinus communis* L. is cultivated on small areas, which automatically means weak competition and a strong argument in favor of starting a business in the field.

Ricinus communis L. is a productive species, unpretentious to soil fertility, drought and involves not very high expenses for cultivation.

Sowing castor bean seeds at the optimal age has numerous advantages over achieving a significant increase in production.

It is recommended to sow castor bean under the pedoclimatic conditions of the Center of Moldova of the earliest Romanian variety Teleorman, since during the period under study it has achieved the highest seed production. To increase seed production, we recommend sowing castor seeds by mid-April (second sowing age).

Following the researches it is recommend sowing castor bean at a distance of 70 cm between rows, because at greater or smaller distances than this, lower net profits was obtained.

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