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Research of the Influence of Some Technological Sequences on Different *Ricinus communis* L. Genotypes, Under the Influence of Pedoclimatic Conditions from the Center of the Moldova Region, Romania

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ABSTRACT

Castor oil plant (castor bean) has been widely accepted as an agricultural solution for all subtropical and tropical areas that need low-cost commercial crops and at the same time provide traditional agriculture with stable income, obtained from current unproductive lands. In Romania, this plant is almost not cultivated at all, it offers important perspectives to those who want to lay the foundations of a business in the agricultural field. In Romania, castor oil plant is mainly grown in the south of the country. The growth of areas with this plant is limited by climatic conditions and especially by the fall of the first hoar-frost in autumn, which can compromise the production of plants secondary racemes. The increasingly climate change has led to the widening of the castor bean cultivation area, which is producing good production in the central area of Moldova if all the technological stages are carried out in optimal conditions.

The research aimed to identify the genotype with the greatest adaptability to the pedoclimatic conditions in the area in order to establish the optimal sowing epoch and the optimal nutrition space to obtain the largest production and the best quality seeds.

Results obtained during the research period (2018-2020) highlight that the best cultivation option for soil and climatic conditions in central Moldova is the characteristic for the interaction between the Telorman variety sown in the second decade of April at a distance of 70 cm between rows (1607 Mg·ha^{-1}).

Keywords: castor oil plant genotype, sowing epoch, distance between rows, production and seeds quality.

INTRODUCTION

The *Euphorbiaceae* family includes 218 genera and 6745 species distributed worldwide. The genus *Ricinus* is considered monotypic with the species *Ricinus communis* L. and is included in the subfamily *Acalyphoidae* which covers 99 genera and 1865 species. Some are tall perennials, others behave like ancient dwarf species. Color differences in leaves, stems and inflorescences have led to the selection of these varieties as ornamental plants. However, attempts to classify such subspecies are botanically inaccurate.

In most countries, the "red" and "white" types are distinguished based on the color of young shoots. Within them, hybrids or varieties are recognized on the basis of seed characteristics. However, there are varieties and hybrids of castor oil plants with a limited degree of branching or even monoracemal forms of great importance for the cultivation areas of our country. The strain represents 40-41% of the total dry matter produced by the castor plant (Bîlteanu, 2001).

In temperate climates, castor oil behaves as an annual plant. In Africa and Asia, in the tropical and subtropical zone, castor is a

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perennial plant, 10-12 m high and with a crown reaching 4-5 m in diameter.

Castor oil adapts easily and is found in the dry areas of many tropical and subtropical countries. It was grown in Egypt 6000 years ago and from there it spread through the Mediterranean Sea, the Middle East, Asia, the Far East and India at one time (Aboelsoud, 2010; Lim, 2012). Deacon (1986) summarizes the evidence for the very early introduction of this species in South Africa, with a series of archaeological records dating back to the Stone Age.

Temperature is an important factor that influences the growth and development of castor plants. For this reason, plant growth and development must be associated with temperatures more than with chronological time (Melucă et al., 2021). It is based on the assumption that plant development ceases below a certain temperature (basic temperature) and that their development in optimal conditions takes place with increasing active thermal degrees (Yang et al., 1995).

The sowing of castor oil in the optimal time, along with other technological elements, is the key for obtaining the maximum production. Determining the optimal sowing epoch plays an important role in plant growth and development in relation to the desired environmental conditions, leading to a maximum yield (Siadata and Hemayatib, 2009). Therefore, research is needed to determine the optimal sowing time in a given area to optimize the quantitative and qualitative production of seeds in oilseeds.

Castor oil should be sown by the first decade of May, at about the same time as corn. Plants will rise between 10 and 21 days. For example, despite being an important crop, castor oil has never been treated as a commercial crop in Turkey and is not grown. The optimal sowing time and the effects of the sowing epoch on castor oil production in Anatolia are unknown (Koutroubas et al., 2000; Öztürk et al., 2014).

The epoch of sowing may influence the quantity and quality of castor seeds. If the sowing of castor is delayed, the production of seeds and oil per unit area decreases. By sowing castor oil earlier, plants have the opportunity to fully benefit from soil moisture and nutrients during the growing season, allowing seeds (Öztürk et al., 2014).

Due to the high demand for castor oil in the chemical and biodiesel production industry, there is an increase in areas cultivated with castor oil, for instance, in Brazil. However, in order for this expansion of the cultivated area to be economically viable, it is necessary for local farmers to implement new technologies with low costs for castor cultivation, for the purpose of greater verticalization of the entire production chain (Azevedo et al., 2001; César and Batalha, 2010; Oliveira, 2014).

Adapting agricultural practices that promote maximizing the productive potential of castor should be included in scientific research. Establishing an ideal distance, defined as the distance between two rows and which, if used correctly, can lead to an increase in production, better soil conservation and more efficient use of soil water. In addition to ensuring these advantages, mechanical works in the field can be performed in order to destroy the weeds (Beltrão and Vale, 2007; Magalhães et al., 2013; Akwasi et al., 2021; Raj et al., 2022).

Castor oil is originally a shrub with a high branching capacity, and Romania is at the northern limit of its cultivation area. It is necessary to obtain genetic forms with a shorter vegetation period, a lower degree of branching, ensuring the stability and consistency of high crop levels.

Also, it is necessary to know both the genotypes that have a greater adaptability to the zonal conditions and the technological parameters that lead to the improvement of the culture technology. Establishing these technological parameters in castor oil is of particular importance for the quantitative and qualitative growth of production, as well as for the improvement of culture technology. Thus, in this paper are presented the results obtained from 2018 to 2020 on these aspects.

MATERIAL AND METHODS

The research took place within the Moldoveni Agricultural Company from

Neamț County, on a kambic phaeosium soil type, with medium texture, characterized as well supplied with phosphorus (77.2 ppm P_{AL}), calcium (13.3 meq·100^{-1}·g of soil), magnesium (1.6 meq·100^{-1}·g of soil), medium supplied with nitrogen (16.3 ppm $N\text{-}NO_3$) and poorly supplied with potassium (124.3 ppm K_2O). The supply in active humus is medium (2.42 %), and the soil reaction is slightly acidic (pH=5.96) (STRS, 2015).

For the study of climatic conditions, meteorological data recorded at the ARDS Secuieni have been analysed. The average annual temperature was 8.9°C, and the multiannual averages amount of precipitation was 544.3 mm during the 2017-2020 agricultural period. The recorded total amount of precipitation per agricultural year were 526 mm for 2017-2018, 430.3 mm for 2018-2019 and 376 mm for 2019-2020. Deviations from the multiannual average ranged from 22 mm to 172 mm, thus indicating a non-uniform distribution of precipitation during the growing season.

The purpose of the research was to identify the genotype with the highest adaptability to climatic conditions in the area of influence and to establish the optimal sowing epoch and the optimal nutrition space.

In the spring of 2018, an experience with three factors of 4x4x3 type, according to the method of the subdivided plots into three repetitions, was located in the experimental field of the Moldoveni Neamt Agricultural Company. The biological material used in the research was procured from ARDS Teleorman. The Dragon, Rivlas and Cristian genotypes were approved in 2004, and the Teleorman variety in 1987.

A factor: ***genotype***, with 4 graduations:
a_1 - Dragon;
a_2 - Rivlas;
a_3 - Cristian;
a_4 - Teleorman.

B factor: ***sowing epoch***, with 4 graduations:
b_1 - sown in the first decade of April;
b_2 - sown in the second decade of April;
b_3 - sown in the third decade of April;
b_4 - sown in the first decade of May.

C factor: ***distance between rows***, with 3 graduations:
c_1 - 50 cm between rows;
c_2 - 70 cm between rows;
c_3 - 100 cm between rows.

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

The castor seed was hand sown at a depth of 6-8 cm. During the growing season, manual hoeings were carried out one by one to control the weeds.

Seeds germination samples were analysed in the germination chamber at temperatures between 7°C and 18°C.

With the help of the Soxlet method and the Det Gras N6p equipment with six positions, we determined the contents of the castor seeds in oil.

The dry matter content was determined in an air-forced oven SLW 53 heating to 105ºC.

With the help of the Soxlet method and the Det Gras N6p equipment with six positions, we determined the contents of the castor seeds in oil. The dry matter content was determined in an air-forced oven SLW 53 heating to 105ºC.

The protein content was determined by the Kjeldahl method, and the mineralization was performed in a Turbotherm TT 265 unit connected with a Turbosorg Tur / K scrubber. A Vapodest 30S unit was used for distillation, and finally a classic titration with a 25 ml class A burette was made.

RESULTS AND DISCUSSION

The experimental results obtained at castor oil in the period 2018-2020 indicate a significant differentiation of seed production according to the cultivated genotype, the sowing epoch, the distance between rows and climatic conditions.

In laboratory conditions, at temperatures below 10°C a very slow emergence was obtained with a very high percentage of gaps. When castor seeds were germinated at temperatures above 10°C, a much faster germination was obtained. Thus, at a temperature of 14°C, it took 8 days to achieve 83.6% of germinated seeds. The increase in germination temperature by another 4ºC above this temperature (18ºC) caused the castor seeds to germinate in 5 days, obtaining a uniform germination and with a very small percentage of ungerminated seeds (Figure 1 and Figure 2).

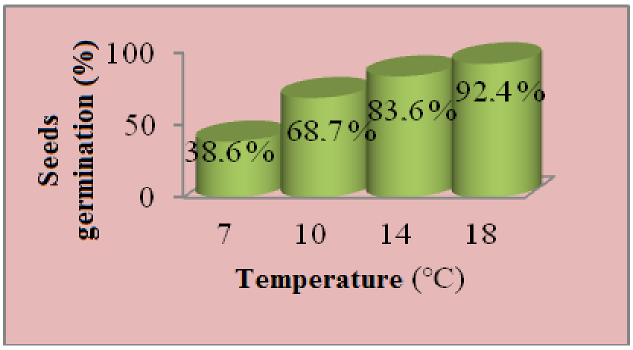

Figure 1. The influence of temperature on the germination of seeds *Ricinus communis* L.

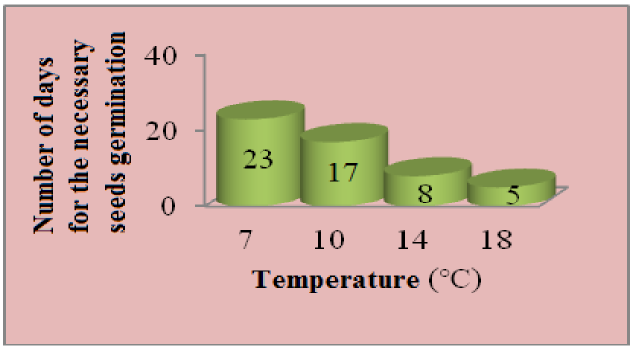

Figure 2. The influence of temperature on the number of days necessary for the *Ricinus communis* L. seeds germination

From the results obtained (Figure 3) for all experienced varieties, it is observed that there is a direct correlation between the number of capsules per plant and the number of seeds per plant, the coefficients being statistically assured and interpreted as very significant.

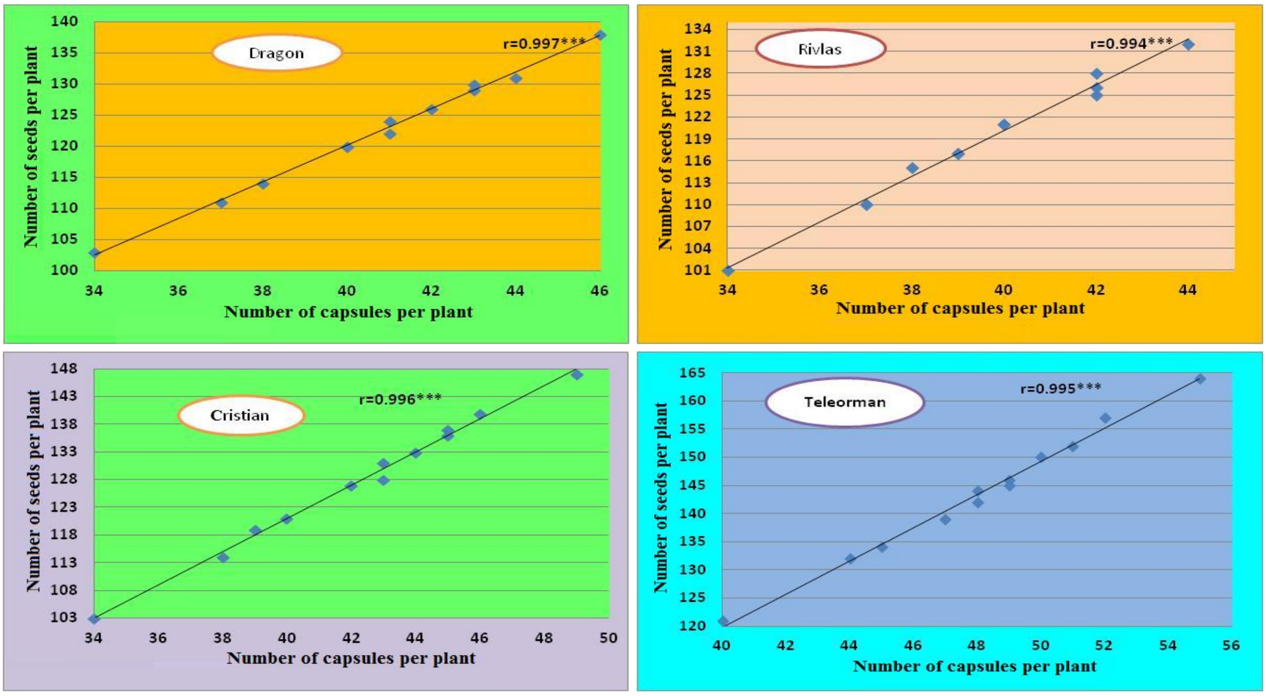

Figure 3. Correlations between the number of capsules per plant and the number of seeds per plant for the genotypes studied in the period 2018-2020

The average productions obtained during the experimentation period (2018-2020) were directly influenced by the experienced technological factors. They varied within limits between 977 Mg·ha^{-1} ($a_2b_4c_3$ - Rivlas genotype, sown in the first decade of May, at 100 cm between rows) and 1607 Mg·ha^{-1} ($a_4b_2c_2$ - Teleorman genotype, sown in the second decade of May, at 70 cm between rows). The production spores obtained from variants sown in the second epoch and at a distance of 70 cm between the rows were between 57-274 Mg·ha^{-1}, statistically assured and interpreted as significant and very significant (Table 1).

According to data obtained in the period 2018-2020, it results that castor oil plant is a species that reacts well to sowing in the second decade of May and at a distance of 70 cm between rows.

Table 1. Results obtained on the influence of the interaction between genotype x sowing epoch x distance between rows on seed production at castor oil plants (2018-2020 average)

A - genotype	B - sowing epoch	C - distance between rows	Seed production ($Mg \cdot ha^{-1}$)	Differences		Significance
				%	$Mg \cdot ha^{-1}$	
a_1 - Dragon	b_1 - sown in the first decade of April	c_1 - 50 cm	1390	104.30	57	*
		c_2 - 70 cm	1436	107.75	103	***
		c_3 - 100 cm	1316	98.72	-17	
	b_2 - sown in the second decade of April	c_1 - 50 cm	1479	110.93	146	***
		c_2 - 70 cm	1568	117.63	235	***
		c_3 - 100 cm	1365	102.43	32	
	b_3 - sown in the third decade of April	c_1 - 50 cm	1344	100.80	11	
		c_2 - 70 cm	1433	107.50	100	***
		c_3 - 100 cm	1230	92.30	-103	ooo
	b_4 - sown in the first decade of May	c_1 - 50 cm	1193	89.52	-140	ooo
		c_2 - 70 cm	1283	96.22	-50	o
		c_3 - 100 cm	1080	81.02	-253	ooo
a_2 - Rivlas	b_1 - sown in the first decade of April	c_1 - 50 cm	1288	96.59	-45	o
		c_2 - 70 cm	1334	100.04	1	
		c_3 - 100 cm	1213	91.01	-120	ooo
	b_2 - sown in the second decade of April	c_1 - 50 cm	1376	103.22	43	*
		c_2 - 70 cm	1465	109.92	132	***
		c_3 - 100 cm	1263	94.72	-70	oo
	b_3 - sown in the third decade of April	c_1 - 50 cm	1241	93.09	-92	ooo
		c_2 - 70 cm	1330	99.79	-3	
		c_3 - 100 cm	1128	84.59	-205	ooo
	b_4 - sown in the first decade of May	c_1 - 50 cm	1091	81.81	-242	ooo
		c_2 - 70 cm	1180	88.51	-153	ooo
		c_3 - 100 cm	977	73.31	-356	ooo
a_3 - Cristian	b_1 - sown in the first decade of April	c_1 - 50 cm	1415	106.17	82	***
		c_2 - 70 cm	1461	109.62	128	***
		c_3 - 100 cm	1341	100.59	8	
	b_2 - sown in the second decade of April	c_1 - 50 cm	1504	112.79	171	***
		c_2 - 70 cm	1593	119.50	260	***
		c_3 - 100 cm	1390	104.29	57	*
	b_3 - sown in the third decade of April	c_1 - 50 cm	1369	102.67	36	
		c_2 - 70 cm	1458	109.37	125	***
		c_3 - 100 cm	1255	94.17	-78	oo
	b_4 - sown in the first decade of May	c_1 - 50 cm	1218	91.39	-115	ooo
		c_2 - 70 cm	1308	98.09	-25	
		c_3 - 100 cm	1105	82.89	-228	ooo
a_4 - Teleorman	b_1 - sown in the first decade of April	c_1 - 50 cm	1429	107.22	96	***
		c_2 - 70 cm	1475	110.67	142	***
		c_3 - 100 cm	1355	101.64	22	
	b_2 - sown in the second decade of April	c_1 - 50 cm	1518	113.85	185	***
		c_2 - 70 cm	1607	120.55	274	***
		c_3 - 100 cm	1404	105.34	71	**
	b_3 - sown in the third decade of April	c_1 - 50 cm	1383	103.72	50	*
		c_2 - 70 cm	1472	110.42	139	***
		c_3 - 100 cm	1269	95.22	-64	oo
	b_4 - sown in the first decade of May	c_1 - 50 cm	1232	92.44	-101	ooo
		c_2 - 70 cm	1322	99.14	-11	
		c_3 - 100 cm	1119	83.94	-214	ooo
Average (control)			1333	100	Control	
LSD A × B × C ($Mg \cdot ha^{-1}$)				0.5	41.32	
				0.1	57.18	
				0.01	79.90	

Table 2. Results obtained on the influence of the studied factors on the production of oil and protein at *Ricinus communis* L.

A - genotype	B - sowing epoch	C - distance between rows	Dry matter production ($Mg \cdot ha^{-1}$)	Oil production ($l \cdot ha^{-1}$)	Crude protein production (kg/ha)
a_1 - Dragon	b_1 - sown in the first decade of April	c_1 - 50 cm	1368	735	174
		c_2 - 70 cm	1410	763	181
		c_3 - 100 cm	1293	704	164
	b_2 - sown in the second decade of April	c_1 - 50 cm	1464	791^{**}	189^{*}
		c_2 - 70 cm	1548	841^{***}	210^{***}
		c_3 - 100 cm	1352	739	172
	b_3 - sown in the third decade of April	c_1 - 50 cm	1320	706	164
		c_2 - 70 cm	1403	756	176
		c_3 - 100 cm	1210	656	150
	b_4 - sown in the first decade of May	c_1 - 50 cm	1171	624^{o}	139^{o}
		c_2 - 70 cm	1254	673	150
		c_3 - 100 cm	1061	573^{ooo}	125
a_2 - Rivlas	b_1 - sown in the first decade of April	c_1 - 50 cm	1267	672	164
		c_2 - 70 cm	1320	704	172
		c_3 - 100 cm	1201	645	155
	b_2 - sown in the second decade of April	c_1 - 50 cm	1356	722	177
		c_2 - 70 cm	1451	778^{*}	199^{**}
		c_3 - 100 cm	1252	675	162
	b_3 - sown in the third decade of April	c_1 - 50 cm	1212	640	153
		c_2 - 70 cm	1305	693	166
		c_3 - 100 cm	1110	593^{ooo}	139^{o}
	b_4 - sown in the first decade of May	c_1 - 50 cm	1078	567^{ooo}	129^{oo}
		c_2 - 70 cm	1170	619^{o}	142^{o}
		c_3 - 100 cm	975	519^{ooo}	116^{ooo}
a_3 - Cristian	b_1 - sown in the first decade of April	c_1 - 50 cm	1392	749	185^{*}
		c_2 - 70 cm	1440	780^{*}	193^{**}
		c_3 - 100 cm	1317	717	174
	b_2 - sown in the second decade of April	c_1 - 50 cm	1482	801^{**}	199^{**}
		c_2 - 70 cm	1568	853^{***}	221^{***}
		c_3 - 100 cm	1370	750	182
	b_3 - sown in the third decade of April	c_1 - 50 cm	1349	723	175
		c_2 - 70 cm	1438	776^{*}	188^{*}
		c_3 - 100 cm	1245	676	161
	b_4 - sown in the first decade of May	c_1 - 50 cm	1215	648	150
		c_2 - 70 cm	1294	695	161
		c_3 - 100 cm	1103	596^{ooo}	136^{oo}
a_4 - Teleorman	b_1 - sown in the first decade of April	c_1 - 50 cm	1345	727	166
		c_2 - 70 cm	1392	757	173
		c_3 - 100 cm	1269	694	156
	b_2 - sown in the second decade of April	c_1 - 50 cm	1434	779^{*}	179
		c_2 - 70 cm	1521	831^{***}	200^{**}
		c_3 - 100 cm	1323	727	163
	b_3 - sown in the third decade of April	c_1 - 50 cm	1301	700	157
		c_2 - 70 cm	1391	753	169
		c_3 - 100 cm	1197	652	144^{o}
	b_4 - sown in the first decade of May	c_1 - 50 cm	1167	625	135^{oo}
		c_2 - 70 cm	1245	671^{o}	145^{o}
		c_3 - 100 cm	1055	572^{ooo}	121^{ooo}
Average (control)			1300	701	165
LSD A × B × C ($l \cdot ha^{-1}$, $Mg \cdot ha^{-1}$)			0.5 0.1 0.01	66.1 86.3 103.6	18.3 27.2 40.6

The interaction of the studied factors influenced the oil production at castor oil plants. Thus, oil production varied from 519 $l \cdot ha^{-1}$ ($a_2b_4c_3$ - Rivlas genotype, sown in the first decade of May, at 100 cm between rows) to 853 $l \cdot ha^{-1}$ ($a_3b_2c_2$ - Cristian genotype, sown in the second decade of May, at 70 cm between rows) (Table 2).

Compared to the production obtained by the control variant (average), production increases statistically assured in oil production are obtained in the four varieties in the second sowing era, which means that castor is good to sow until the second half of April.

Most production differences were found in interactions with the sown in the first decade of May, significant and very significant negatives (Table 2).

Protein production was influenced by the sowing epoch, its values were between 116 Mg·ha^{-1} ($a_2b_4c_3$ - Rivlas genotype, sown in the first decade of May, at 100 cm between rows) and 221 Mg·ha^{-1} ($a_3b_2c_2$ - Cristian genotype, sown in the second decade of May, at 70 cm between rows). Compared to the control variant (average), very significant production increases (45-56 Mg·ha^{-1}) were obtained in variants sown with the Dragon and Cristian varieties in the second era at a distance of 70 cm between rows (Table 2).

Other distinctly significant increases were recorded in the Rivlas, Cristian and Teleorman varieties at the second sowing epoch and at a distance of 70 cm between the rows (28-35 Mg·ha^{-1}).

The third and fourth sowing epochs variants of sowing obtained significant negative production differences, distinctly significant and very significant in most interactions.

CONCLUSIONS

In the pedoclimatic conditions in the Center of Moldova it is recommended to sow the earliest Romanian variety Teleorman, because during the period considered in the study it achieved the highest seed production. To increase seed production, we recommend sowing castor oil by mid-April (second epoch studied).

We recommend sowing at a distance of 70 cm between rows, because at distances smaller than this lower the possibility of performing mechanical hoeings in advanced stages of vegetation without affecting the roots and foliar apparatus, creating the possibilities for access to sunlight to the lower floors of the leaves.

At longer distances between rows production deficits are obtained. Thus, when the nutrient surface of the plants increases, the branching is stronger, and production from the main racem decreases, increasing instead the production of secondary racecams. The density must be established in such a way as to greatly reduce the production of secondary racems, which do not always reach maturity.

REFERENCES

Aboelsoud, N.H., 2010. *Herbal medicine in ancient Egypt*. Journal of Medicinal Plant Research, 4: 82-86.

Akwasi, Y., Sheng, Y., Jiannong, L., Yu, X., Hanna, A.D., Miao, C., Xuegui, Y., 2021. *Castor oil (Ricinus communis): a review on the chemical composition and physicochemical properties.* Food Sci. Technol., 41(2): 399-413.

Azevedo, D.M.P., Nóbrega, L.B., Lima, E.F., Batista, F.A.S., Beltrão, N.E.M., 2001. *Manejo Cultura. The agrobusiness of castor oil in Brazil*: 121-160.

Beltrão, N.E.M., and Vale, L.S., 2007. *Oil crops and their characteristics*. Revista Biodiesel, 1: 34-35.

Bîlteanu, Gh., 2001. *Fitotehnie - vol II*. Edit. Ceres, Bucureşti.

César, A.S., and Batalha, M.O., 2010. *Biodiesel production from castor oil in Brazil: A difficult reality*. Energy Policy, 38: 4031-4039.

Deacon, J., 1986. *Human settlement in South Africa and archaeological evidence for alien plants and animals.* In: Macdonald, I.A.W., Kruger, F.J., Ferrar, A.A. (eds.), The Ecology and Management of Biological Invasions in Southern Africa. Oxford University Press, Cape Town, South Africa: 3-19.

Koutroubas, S.D., Papakosta, D.K., Doitsinis, A., 2000. Water *Requirements for Castor Oil Crop (Ricinus communis L.) in a Mediterranean Climate*. Journal of Agronomy and Crop Science, 184(1): 33-40.

Lim, T.K., 2012. *Ricinus communis. In a book Edible medicinal and non-medicinal plants*. Fruits, 2: 484-502.

Magalhães, I.D., Soares, C.S., Costa, F.E., Almeida, A.E.S., Oliveira, A.B., Vale, L.S., 2013. *Viability of castor bean x sesame intercrop in Paraiba, brazilian semiarid: Influence of different planting dates.* Revista Brasileira de Agroecologia, 8: 57-65.

Melucă, C., Strurzu, R., Ion, V., 2021. *Sowing time at castor bean in south Romania in the context of actual climatic condition.* Scientific Papers, Series A, Agronomy, 64(1): 444-452.

Oliveira, A.B., 2014. *Emergence and stablishment of physic nut seedlingsas a function of positions and sowing depths*. Agrária, 9: 483-488.

Öztürk, Ö., Gerem, G.P., Yenici, A., Haspolat, B., 2014. *Effects of Different Sowing Dates on Oil Yield of Castor (Ricinus communis L.)*. World Academy of Science, Engineering and Technology International Journal of Agricultural and Biosystems Engineering, 8(2): 184-188.

Raj, S.P., Solomon, P.R., Thangaraj, B., 2022. *Euphorbiaceae. In: Biodiesel from flowering plants*. Springer, Singapore.

Siadata, S.A., and Hemayatib, S.S., 2009. *Effect of sowing date on yield and yield components of three oilseed rape varieties*. Plant Ecophysiology, 1: 31-35.

Yang, S., Logan, J., Coffey, D.L., 1995. *Mathematical formulae for calculating the base temperature for growing degree days*. Agricultural and Forest Meteorology, 74: 61-74.