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SOWING TIME AT CASTOR BEAN IN SOUTH ROMANIA IN THE CONTEXT OF ACTUAL CLIMATIC CONDITIONS

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Abstract

Castor bean is an important oil plant cultivated mainly for its oil which is a versatile product with a wide range of uses. In Romania, castor bean is cultivated on small areas for scientific, ornamental, industrial and medicinal purposes, but it has a real potential to develop in the future.
In the context of actual climatic conditions which are changing, researches concerning the sowing time are important in view to correlate the plant development and phenology with the evolution of the climatic condition, this being essential for the yield formation in term of quantity and quality. Starting from this necessity, the objective of this paper is to present the results of the researches performed in South Romania in view to establish the temperature threshold for sowing castor bean as the plants to grow and develop well and the first raceme to reach maturity in good conditions. Researches were performed in field conditions at the Agricultural and Development Research Station Teleorman located in South Romania, in the years 2019 and 2020 and on cambic chernozem soil conditions. Four local castor bean varieties (Teleorman, Dragon, Cristian and Rivlas) were sowed at three moments, respectively: sowing time I – temperature of 7°C at 7 o'clock and at 10 cm in the soil; sowing time II – temperature of 10°C at 7 o'clock and at 10 cm in the soil; sowing time III – temperature of 13°C at 7 o'clock and at 10 cm in the soil. The highest yields were obtained at the sowing time I, and the highest yields were obtained at Rivlas variety, which is the latest (mid-late) among the studied varieties.

Key words*: castor bean, variety, sowing time, climatic conditions, South Romania.*

INTRODUCTION

Castor bean (*Ricinus communis* L.) is an oil tropical plant, which has its origin in East Africa. Known since ancient times, the castor bean crop is now in the attention of farmers in countries located in warm and temperate areas of the globe, due to its main product, the most requested, respectively the castor oil, valuable raw material for many industries, such as textile, leather, machine building and aeronautics, paint industry, varnishes, high quality emulsions, printing industry, cosmetics industry, pharmaceutical industry, raw material for the production of sebacic acid, for obtaining synthetic fibres, and chemical industry (Sturzu et al., 2014). Castor oil is a valuable product because of its high content of ricinoleic acid which can reach 90%.
Despite the great importance of the castor oil, it contributes to only 0.15% of the vegetable oil produced in the world (Patel et al., 2016).
In Romania, currently the castor bean is cultivated on small areas for scientific, ornamental, industrial and medicinal purposes.
One possibility to reduce the economic negative effects of the actual climate change would be to introduce into cultivation or to extent the cultivation of the thermophilic plants. One such plant is castor bean. The increase in temperature in the last decades requires a new zoning of crops and the adaptation of cultivation technologies, so as to avoid periods with pedological and atmospheric drought.
The optimal sowing time of spring crops is determined by the achievement of a certain temperature at the sowing depth, depending on the species. New varieties and hybrids have shown earlier sowing requirements, at a thermal threshold 1-2°C lower than old cultivars (Sin, 2007). In most castor bean growing regions, the yield can be rapidly increased through the use of improved

agronomic practices. Key technologies include selecting the right genotype combined with the use of good quality seeds, proper sowing date, irrigation, soil fertilization, weed, pest and disease management, optimized plant density, mechanical harvesting and post-harvest management (Severino et al., 2012; Henderson et al., 2000; Tourino et al., 2002).

In the southern part of Romania, castor bean sowing can be done as early as possible, when in the soil at the sowing depth the temperature reaches 8-10°C and this has a tendency to increase, starting with the first decade of April at the latest on April 25 (Prodan and Prodan, 1993; Prodan et al., 1984).

The reduction of the vegetation period as a result of the breeding works makes possible the sowing of new varieties until May 1, because they reach maturity faster than the old varieties (Negrilă et al., 1993). But, the sowing season greatly influences the yield of the main raceme and therefore the sowing should not be delayed, in order to allow the full maturity of the main raceme before the first frost falls. Also, the date of sowing influences the number of nodes / internodes (Kittock and Williams, 1968). Practicaly, the sowing date is often used to overcome environmental constraints on crop production (Farhadi et al., 2013).

In addition to seed yield, the date of sowing also influences the oil content. Sowing on May 10 led to higher oil content (51.18%), followed by May 25 and June 10. The lowest oil content (43.67%) was observed for June 25. The oil content in the seeds of oilseeds is of enormous importance, because increasing the amount of oil offers a greater economic importance of the crop (Öztürk et al., 2014).

The objective of this paper is to present the results of the researches performed in South Romania in view to establish the temperature threshold for sowing castor bean as the plants to grow and develop well and the first raceme to reach maturity in good conditions.

MATERIALS AND METHODS

Researches were carried out in field experiments at the Agricultural and Development Research Station Teleorman (ADRS Teleorman) located in South Romania (Teleorman county) in the years 2019 and 2020.

The researches were performed under rainfed conditions on a soil of cambic chernozem type, the vertical subtype, having a loam-clay texture on the depth of the ploughed layer (0-25 cm). From the point of view of the physical and chemical properties, the soil is characterized by a clay content of 45%, humus content of 3.1%, weakly acid soil reaction (pH varies between 6.1 and 6.5), total nitrogen content of 0.166%, phosphorus mobile of 40-60 ppm, and mobile potassium of 250 ppm.

The main hydro-physical indices of the soil on the horizon 0-80 cm have the following average values: bulk density of 1.43 t/m^3, field capacity of 27.3% (310.4 mm), and permanent wilting point of 15.0% (171.0 mm).

Experimental design. The field experiments were placed according to the method of subdivided plots with 3 replications, with the following factors:

- Factor A – sowing times, with 3 graduations:
  - a_1 = sowing time I, this being represented by the soil temperature of 7°C at 7 o'clock and at a depth of 10 cm;
  - a_2 = sowing time II, this being represented by the soil temperature of 10ºC at 7 o'clock and at a depth of 10 cm;
  - a_3 = sowing time III, this being represented by the soil temperature of 13ºC at 7 o'clock and at a depth of 10 cm.
- Factor B – castor bean variety, with 4 graduations:
  - b_1 = Teleorman variety;
  - b_2 = Cristian variety;
  - b_3 = Dragon variety;
  - b_4 = Rivlas variety.
- Factor C – year, with 2 graduations:
  - c_1 = 2019;
  - c_2 = 2020.

The biological material consisted of four Romanian varieties of castor bean with different precocities but also with different degree of branching. All the four castor bean varieties (Teleorman – early variety; Cristian and Dragon - mid-early varieties; Rivlas mid-late variety) were created at ARDS Teleorman.

The ideal arrangement of plants in the planting area depends on the intrinsic characteristics of the cultivar, such as size, growth habits and architecture of the plants (Bezerra et al., 2009), as well as on the pedo-climatic conditions and the management system of the castor bean crop (Severino et al., 2006.a, 2006.d; Bizinoto et al., 2010). In our field experiments, the area of the experimental plot was of 14 m^2 (L = 5 m; l = 2.8 m), the plant density of 60,000 plants/ha, the distance between rows of 70 cm, the number of plants/plot of 84, the number of plants/row of 21, the distance between plants/row of 23.8 cm.

Crop management. The preceding crop was common winter wheat. After the preceding crop was harvested, there was performed a harrowing work, and after that the ploughing was performed at a depth of 30 cm. In the autumn, 100 kg of nitrocalcar (27% nitrogen) were applied, being incorporated with the disc harrow work. In the spring, complex chemical fertilizers of 15:15:15 type were applied, in a dose of 200 kg commercial product on ha. For the preparation of the germination bed, two perpendicular works made with a combinator were performed. After preparing the germination bed, the sowing rows were marked with the SPC-8 seed drill. The sowing was done manually with the planter at a depth of 6 cm. To ensure the number of plants on the plot, 2-3 seeds were sown in the nest. After plant emergence, the plants were thinned, leaving only one plant in the nest.

The control of the weeds was performed by the application immediately after sowing of the herbicides Dual Gold 960 EC (S-metolachlor 960 g/l) at a rate of 1.5 l/ha and Roundup (glyphosate 360 g/l) at a rate of 2.0 l/ha. For controlling in the vegetation period of the monocotyledonous weeds, the herbicide Leopard 5 EC (quizalofop-P-ethyl 50 g/l) was applied in a rate of 0.75 l/ha in the growth stage of 5-6 leaves. Unfortunately, for the control of dicotyledonous weeds there is not yet a herbicide for the castor bean crop with application in the vegetation period. As a consequence, in our field experiments the control of dicotyledonous weeds in the vegetation period was done by a mechanical weeding followed by a manual correction weeding. After the growth stage of appearance of the main raceme, the weeds are no longer a problem for the castor bean crop, because they no longer have favourable conditions for development (light, water and nutrients), the land being covered by the canopy of the castor bean plants.

During the vegetation period, no phytosanitary treatments were performed, being necessary to note the reaction of castor bean varieties to the appearance of specific diseases and pests.

Climatic data. In terms of temperature in the experimental years, castor bean benefited throughout the vegetation period from temperatures higher than the multiannual average specific for the area where the field experiments were implemented (Figure 1).

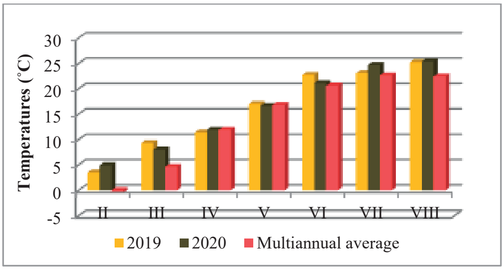

Figure 1. Average monthly temperatures at ARDS Teleorman in 2019 and 2020

In terms of water, in 2019, castor bean benefited of 376.6 mm of rainfall over the entire vegetation period, being 76.6 mm more than the crop requirements for humidity, but their distribution was unfavourable to the castor bean plants. Thus, in the first part of the vegetation period the rainfall was quantitatively higher than the multiannual average by 27.2 mm in April, 48.1 mm in May and 99.3 mm in June. During the period of the plant yield components formation, respectively in July and August, there was an accentuated water deficit of 27.1 mm in July and of 47.2 mm in August, a month in which no rainfall was registered (Figure 2).

In 2020, there were excess rainfall in May (+7.8 mm) and June (+11.6 mm), deficit rainfall in April (-21.8 mm), while in July and August there was registered a cumulative deficit of -92.9 mm, compared to the multiannual averages of the area. In July, it can be said that the drought was installed, when only 2.8 mm of rainfall was recorded, the rainfall being practically absent, and the deficit of the month being of 58.6 mm. In August, the rainfall was of 12.6 mm, of which 12.2 mm in the second decade, the deficit being of 34.4 mm.

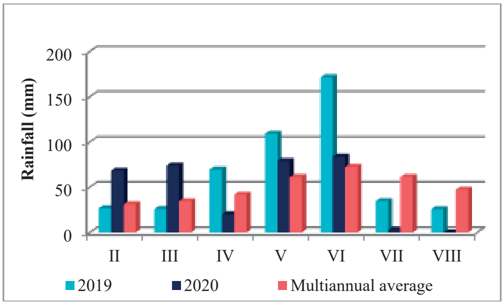

Figure 2. Sum of the monthly rainfall at ARDS Teleorman in 2019 and 2020

In 2020, the high temperatures from the end of February allowed the sowing time I on 28.02.2020. The subsequent evolution of temperatures (snow and blizzard on 8 of March) completely compromised the castor plants, this imposing the resowing later.

The sowing time I was on 20 of March in 2019 and on 28 of March in 2020, the sowing time II was on 2 of April in 2019 respectively on 7 of April in 2020, and the sowing time III was on 26 of April in 2019 respectively on 19 of April in 2020.

Determinations and data analysis. It was calculated the sum of temperature degrees and number of days from sowing to emergency and from sowing to maturity of the main raceme.

In the vegetation period it was determined the percentage of the broken plants and by the end of the vegetation period it was determined the percentage of monoracemal plants, the plant height, and the insertion height of the main raceme.

Harvesting was done manually. After harvesting, the seeds were peeled by hand on each variant and after that they were weighed. Also, it was determined the weight of 1,000 seeds, the number and the mass of seeds on the main raceme, the number of capsules on the main raceme and the length of the main raceme. The percentage of oil in the seeds was determined based on the magnetic resonance phenomenon performed on the Spinlock device.

The calculation and interpretation of the results was made based on the analysis of the variance of the experiments placed in the subdivided plots (Ceapoiu, 1968).

RESULTS AND DISCUSSIONS

On average over the years of experimentation, castor bean plants needed 365.8ºC to emerge. Teleorman variety emerged first in all years of experimentation regardless of the time in which it was sown (Figure 3). As number of days, the varieties emerged in 35 days (in average per year) in the sowing time I, in 32 days in the sowing time II, and in 20 days in the sowing time III (Figure 4).

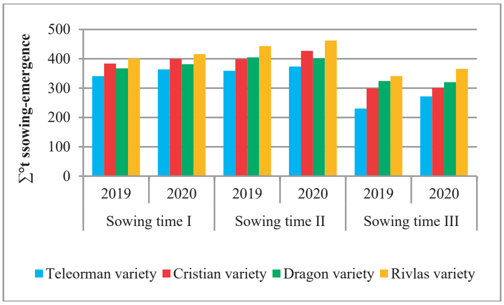

Figure 3. Sum of temperature degrees from sowing to emergence of castor bean plants, at ARDS Teleorman in 2019 and 2020

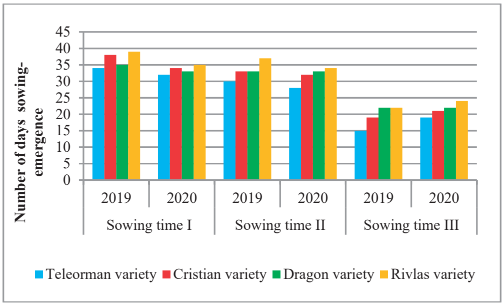

Figure 4. Number of days from sowing to emergence of castor bean plants, at ARDS Teleorman in 2019 and 2020

During the vegetation period, the differences regarding the sum of temperature degrees between sowing times were recovered. Thus, in sowing time I there were registered 2803.95°C, in sowing time II 2815.60°C, and in sowing time III 2743.96°C (Figure 5). As number of days, castor bean plants reached maturity of the main raceme in 147 days in the sowing time I, in 144 days in the sowing time II, and in 128 days in the sowing time III (Figure 6). Of the tested varieties, Teleorman variety is the earliest variety (129 days).

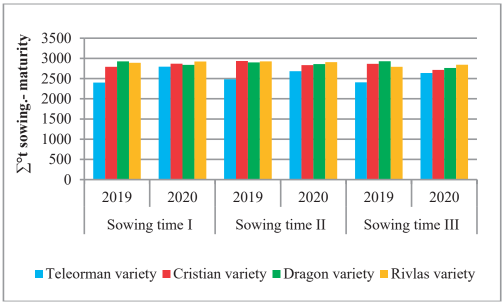

Figure 5. Sum of temperature degrees from sowing to maturity of the main raceme, at ARDS Teleorman in 2019 and 2020

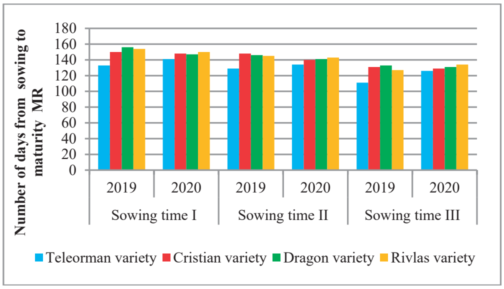

Figure 6. Number of days from sowing to maturity of the main raceme, at ARDS Teleorman in 2019 and 2020

The biomass accumulated by each genotype at the beginning of the reproduction phase is the most important factor for determining the seed yield at castor bean (Carvalho et al., 2010; Severino et al., 2006.c; Soratto et al., 2012). In indeterminate vegetative growth, meristems are very repetitive, reproducing the same or similar structure several times, and their activity can continue indefinitely (Taiz and Zeiger, 2004).

Analyzing the collected data we can say that castor bean plants when they reach the sum of degrees specific to a certain phenophase move to the next phenophase regardless of the number of days and the stage of development. Thus, delaying sowing reduces the period of plant development that directly influence the seed yield.

Due to the architecture of the castor bean plant, the breaking strength is a phenomenon that can cause significant yield losses. In 2019, in the first decade of June, when the plant yield components begin to form and the plants are vigorous in architecture, 114 mm of precipitation fell. The rains were accompanied by strong storms that broke the castor bean plants. This was due to the fistulous stem and the fact that the plant cells were turgid, but also due to the weight of the racemes, which made them prone to the breaking phenomenon. In the sowing time I there was a lower percentage of broken plants because the plants were better developed vegetatively, which brought them better resistance to breakage. On average, during the years of experimentation, the lowest percentage of broken plants had the plants in the sowing time I (9%). The best breaking resistance registered Teleorman variety (12.3% on average/year) (Table 1).

Table 1. The influence of the sowing time and the castor bean variety on the percentage of broken plants, at ARDS Teleorman in 2019 and 2020

Sowing time	Variety	% broken plants		
		2019	2020	Average variety
Sowing time I	Teleorman	15.0	1.2	*8.1*
	Cristian	16.0	2.2	*9.1*
	Dragon	15.7	3.7	*9.7*
	Rivlas	14.7	3.2	*9.0*
Average sowing time I		***15.4***	***2.6***	***9.0***
Sowing time II	Teleorman	25.3	3.4	*14.4*
	Cristian	22.7	3.2	*13.0*
	Dragon	24.7	3.6	*14.2*
	Rivlas	23.7	3.4	*13.6*
Average sowing time II		***24.1***	***3.4***	***13.8***
Sowing time III	Teleorman	25.9	3.1	*14.5*
	Cristian	25.7	4.3	*15.0*
	Dragon	26.7	3.0	*14.9*
	Rivlas	27.3	3.3	*15.3*
Average sowing time III		***26.4***	***3.4***	***14.9***
Average years		**22.0**	**3.1**	**12.6**

As the maturity of secondary racemes is uncertain in the specific growing conditions of Romania, due to their later appearance, a safe production of castor bean is achieved only from the main racemes. The percentage of monoracemal plants was not significantly influenced by the sowing time, the differences of the sowing times being 5.2% (Table 2).

In order to highlight the mode of action of sowing times, varieties and years of experiments as well as the existing interactions between factors, the analysis of variance for morpho-productive characters (Table 3) in castor bean was performed (Table 4).

The mass of 1,000 grains, a partially dominant quantitative genetic character, is not influenced by the sowing time. The tested variety has a significant influence, and the year of experimentation (climatic conditions) has a very significant influence as well as the combination of variety x year.

Table 2. The influence of the sowing time and the castor bean variety on the percentage of monoracemal plants, at ARDS Teleorman in 2019 and 2020

Sowing time	Variety	% monoracal plants 2019	2020	Average variety
Sowing time I	Teleorman	65.2	85.1	*75.2*
	Cristian	82.1	89.0	*85.5*
	Dragon	74.0	88.5	*81.2*
	Rivlas	75.3	84.7	*80.0*
Average sowing time I		***74.2***	***86.8***	***80.5***
Sowing time II	Teleorman	84.5	82.1	*83.3*
	Cristian	88.0	88.3	*88.2*
	Dragon	87.6	86.5	*87.0*
	Rivlas	87.0	81.9	*84.5*
Average sowing time II		***86.8***	***84.7***	***85.7***
Sowing time III	Teleorman	85.7	81.5	*83.6*
	Cristian	89.9	87.4	*88.6*
	Dragon	89.3	85.6	*87.5*
	Rivlas	82.3	84.3	*83.3*
Average sowing time III		***86.8***	***84.7***	***85.7***
Average years		**82.6**	**85.4**	**84.0**

The analysis of the variance for the oil content indicates a significant influence of the variety and the year of experimentation. Plant height, main raceme length, number of capsules on the main raceme, number of nodes and height of the first raceme insertion are important agronomic features in the yielding capacity of this species, with the last two directly related to plant precocity, because a main raceme plant with fewer nodes and a shorter vegetation period is harvested earlier and may be more productive in areas with irregular rainfall (Severino et al., 2006.a; Távora, 1982).

On the number of seeds on the main raceme, a very significant influence has the sowing time, the year and the combinations sowing time x year, variety x year, as well as the triple interaction sowing time x variety x year.

Table 3. Morpho-productive characters in the multifactorial experience with castor bean varieties (3 sowing times x 4 varieties x 2 years), at ARDS Teleorman in 2019 and 2020

Sowing time	Variety	Weight of 1000 seed (g)		Oil content (%)		No. seed/MR		Weight seed/MR (g)		No. of capsules / MR		Length of MR (cm)		Plant height (cm)		Insertion height of MR (cm)	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Sowing time I	Teleorman	236	210	47.9	45.9	209	107	49.3	22.4	90	68	46	23	164	104	118	81
	Cristian	286	260	53.8	52.4	243	94	69.4	24.4	94	65	43	21	180	115	137	94
	Dragon	293	315	51.9	50.6	217	95	63.3	29.9	94	68	48	24	188	108	128	84
	Rivlas	322	322	53.4	52.4	188	87	60.3	28.0	86	70	49	21	169	125	120	104
Average sowing I		***284***	***277***	***51.8***	***50.3***	***214***	***96***	***60.6***	***26.2***	***91***	***68***	***47***	***22***	***175***	***113***	***126***	***91***
Sowing time II	Teleorman	230	198	44.9	45.3	212	110	48.9	21.8	88	73	38	23	143	83	105	60
	Cristian	282	240	51.8	52.1	240	97	67.8	23.4	100	65	35	22	162	115	127	89
	Dragon	291	310	50.1	50.1	218	95	63.6	29.5	98	63	44	24	169	110	126	85
	Rivlas	324	318	52.1	52.0	175	91	58.3	28.9	80	64	40	23	171	120	124	96
Average sowing II		***282***	***267***	***49.7***	***49.9***	***211***	***98***	***59.7***	***25.9***	***92***	***66***	***39***	***23***	***161***	***107***	***121***	***83***
Sowing time III	Teleorman	227	200	44.4	46.4	196	106	44.5	21.2	86	71	33	21	139	110	105	60
	Cristian	284	243	51.3	52.8	239	102	68.0	24.8	97	68	44	21	170	117	127	89
	Dragon	295	307	48.3	51.0	211	91	62.4	27.9	97	61	41	21	170	115	126	85
	Rivlas	323	315	50.4	52.8	178	93	57.4	29.3	66	62	40	21	164	120	124	96
Average sowing III		***282***	***266***	***48.6***	***50.8***	***206***	***98***	***58.1***	***25.8***	***87***	***66***	***40***	***21***	***161***	***116***	***121***	***83***
Average years		***283***	***270***	***50.0***	***50.3***	***211***	***97***	***59.4***	***26.0***	***90***	***67***	***42***	***22***	***166***	***112***	***122***	***85***

*MR - main raceme

Table 4. Analysis of variance (ANOVA) for morpho-productive characters in the multifactorial experience with castor bean varieties (3 sowing times x 4 varieties x 2 years), at ARDS Teleorman in 2019 and 2020

Source of variance	Test F: Weight of 1000 seed (g)	Oil content (%)	No. seed/MR	Weight seed/MR (g)	No. of capsules/ MR	Length of MR (cm)	Plant height (cm)	Insertion height of MR (cm)
A (Sowing time)	8.0^{NS}	3.3^{NS}	836.7***	3.2^{NS}	4.0^{NS}	38.9**	5.6^{NS}	7.1^{NS}
B (*variety*)	6.0*	5.9*	7.7*	5.9*	4.6^{NS}	14.1**	6.6*	5.5*
AxB	0.007^{NS}	0.013^{NS}	2.7^{NS}	0.035^{NS}	0.981^{NS}	9.82**	0.415^{NS}	0.3^{NS}
C (*year*)	108.5***	0.5^{NS}	9800.6***	5643.3***	621.9***	541.1***	665.8***	562.3***
A X C	4.9^{NS}	6.5*	91.6***	1.9^{NS}	1.6^{NS}	8.3*	5.61*	0.5^{NS}
B X C	97.3***	0.038^{NS}	240.2***	77.7***	30.0***	1.7^{NS}	3.7^{NS}	7.5*
A X B X C	0.8^{NS}	0.1^{NS}	57.3***	0.9^{NS}	3.0^{NS}	1.2^{NS}	2.0^{NS}	0.7^{NS}

*MR - main raceme

The year of experimentation has a very significant influence on the weight of the seeds. The variety has a significant influence and the combination of variety x years has a very significant influence. A similar influence had the experimental factors on the number of capsules on the main racem.

On the morphological characters (the length of the main raceme, the height of the plant and the insertion height of the main raceme) the factor with very significant influence was the year of experimentation. The variety had a significant influence on the height of the plant and the insertion height of the main raceme, and a disctinct significant influence on the length of the main raceme. The sowing time had a distinctly significant influence only in the case of the length of the main raceme.

În both experimental years (2019 and 2020), the sowing time I determined the highest yields (Table 5). Also the highest yields were obtained in the climatic conditions of the year 2019, and among the castor bean varieties, Teleorman (early variety) realised the smallest yields regardless of sowing time and year, while Rivlas variety (mid-late variety) realised the highest yields in both experimental years at the sowing time I and II and the two mid-early varieties (Cristian and Dragon) realised the highest yeilds at the sowing time III.

Table 5. Seed yield obtained at the multifactorial experiment with castor varieties (3 sowing times × 4 varieties x 2 years), at ARDS Teleorman in 2019 and 2020

Sowing time	Variety	Yield kg/ha 2019	Yield kg/ha 2020	Yield kg/ha Average variety
Sowing time 1	Teleorman	1262	890	***1076***
	Cristian	1915	968	***1442***
	Dragon	1873	1028	***1451***
	Rivlas	2067	1097	***1582***
Average sowing time I		***1779***	***996***	***1388***
Sowing time 2	Teleorman	1000	723	***862***
	Cristian	1661	864	***1263***
	Dragon	1380	1126	***1253***
	Rivlas	1758	1129	***1444***
Average sowing time II		***1450***	***961***	***1205***
Sowing time 3	Teleorman	971	785	***878***
	Cristian	1613	908	***1261***
	Dragon	1377	1055	***1216***
	Rivlas	1450	961	***1206***
Average sowing time III		***1353***	***927***	***1140***
Average years		***1527***	***961***	***1244***

Condensed presentation and interpretation of results is generally difficult due to the large number of comparisons (Săulescu and Săulescu, 1967). However, the analysis of variance indicates which of the comparisons represents a higher statistical interest. If we add to this the criterion of practical or scientific importance of some of the possible comparisons, we will be able to establish on this basis, the most convenient form of data condensation. Thus, analyzing the variance table for the multifactorial experience with castor varieties (3 sowing times × 4 varieties x 2 years), we observe the very significant influence of factor A (sowing time) and factor C (year). Also, the interaction A x C (sowing time x year) and B x C (variety x year) are very significant, and the triple interaction of A x B x C factors is distinctly significant (Table 6).

Table 6. Analysis of variance (ANOVA) for seed yield at the multifactorial experiment with castor bean varieties at ARDS Teleorman in 2019 and 2020

Source of variance	Sum of square (SS)	Degree of freedom (DF)	Mean square (s^2)	Test F
TOTAL	**10833723.37**	**71**		
Large plots	**593256.49**	**8**		
Repetition	15100.47	2		
A (Sowing time)	569941.39	2	284970.69	138.8***
Error (a)	8214.63	4	2053.66	
Medium plots	**2901300.67**	**27**		
B (*Variety*)	2840310.71	3	946770.24	7.4^{NS}
A x B	15211.17	6	2535.19	0.020^{NS}
Error (b)	2316148.12	18	128674.90	
Small plots	**7339166.20**	**36**		
C (*Year*)	5935591.56	1	5935591.56	1847.8***
A x C	399180.90	2	199590.45	62.1***
B x C	809852.41	3	269950.80	84.0***
A x B x C	117447.37	6	19574.56	6.1**
Error (c)	77093.96	24	3212.25	

The seed yield differences obtained from the horizontal comparisons between the sowing times from the two years of experimentation were very significant in 2019 of 783 kg/ha at sowing time I, of 489 kg/ha at sowing time II, and of 426 kg/ha at sowing time III (Tables 7 and 8).

Vertically, the differences obtained between the sowing times in the two years of experiment-tation indicate the fact that only in 2019 seed yield increases were obtained between the 3 sowing times, these being of 329 kg/ha for the sowing time I compared to sowing time II, and of 426 kg/ha for the sowing time I compared to sowing time III.

Table 7. The influence of the interaction of the sowing time and the year on the castor bean yield, at ARDS Teleorman in 2019 and 2020

Sowing time (A)	Yield kg/ha		
	Years (C)		Average sowing time
	2019 (c_1)	2020 (c_2)	
Sowing time I (a_1)	1779	996	1388
Sowing time II (a_2)	1450	961	1205
Sowing time III (a_3)	1353	927	1140
Average years	1527	961	1244

Table 8. Limit differences for the influence of sowing time and year interaction on castor bean yield, at ARDS Teleorman in 2019 and 2020

LSD	Yield kg/ha			
	Between average sowing time	Between average years	Interaction	
			horizontal comparisons (a_1c_1-a_1c_2)	vertical comparisons (a_1b_1-a_2b_1)
5%	36.4	27.5	47.6	44.0
1%	60.2	37.4	64.8	65.8
0.1%	112.6	50.1	86.7	106.1

Another very significant interaction resulting from the analysis of variance (ANOVA) for the seed yield in the multifactorial experiment with castor varieties (3 sowing times × 4 varieties x 2 years) is the interaction between variety and year (B x C). Analyzing the average seed yields, during the two years of experimentation, of the castor bean varieties we can say that the Rivlas variety is the most productive with a seed yield increase of 472 kg/ha compared to the Teleorman variety, very statistically assured (Tables 9 and 10).

On average for the years of experimentation, in 2019 the tested varieties had a very significant increase in seed yield, statistically assured of 566 kg/ha compared to the seed yield obtained in 2020.

Table 9. The influence of variety and year interaction on castor been seed yield, at ARDS Teleorman in 2019 and 2020

Variety (B)	Yield kg/ha		
	Years (C)		Average variety
	2019 (c_1)	2020 (c_2)	
Teleorman (b_1)	1078	799	939
Cristian (b_2)	1730	913	1322
Dragon (b_3)	1543	1070	1307
Rivlas (b_4)	1758	1062	1410
Average years	1527	961	1244

Table 10. Limit differences for the influence of variety and year interaction on castor been seed yield, at ARDS Teleorman in 2019 and 2020

LSD	Yield kg/ha			
	Between average variety	Between average years	Interaction	
			horizontal comparisons (b_1c_1-b_1c_2)	vertical comparisons (b_1c_1-b_2c_1)
5%	251.1	27.5	55.0	181.8
1%	334.8	37.4	74.8	249.3
0.1%	468.7	50.1	100.2	339.2

CONCLUSIONS

In the specific growing conditions of South Romania, castor bean can be sown when in the soil at a depth of 10 cm, temperature reaches 7°C for three days consecutive and the general tendency of the weather is to warm. Sowing in this time gave in the performed experiences the highest seed yields regardless the climatic conditions of the year.

When the castor bean plants reach the sum of the degrees specific to a certain phenophase, they move to the next phenophase regardless of the number of days and the stage of development. Thus, sowing delay reduces the duration of the vegetative phases and the rapid entry of plants into the generative phase, directly influencing the seed yield.

Among the studied varieties, the Rivlas variety which is the latest (mid-late) of them proved to produce the highest seed yields, especially when the sowing is performed early. In the case of sowing delay, comparable seed yields with Rivlas variety gave the mid-early varieties Cristian and Dragon. Teleorman variety, which is an early variety, proved to be less productive, producing the smallest seed yields.

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