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EFFECTS OF DIFFERENT SOIL TILLAGE ON CASTOR BEAN CROP IN SOUTHERN ROMANIA

Cristina MELUCĂ[1], Rodica STURZU[1], Jeni-Mădălina COJOCARU[1], Viorel ION[2]

[1]Agricultural and Development Research Station Teleorman, Drăgănești-Vlașca, Teleorman County, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd., District 1, Bucharest, Romania

Corresponding author email: melucacristina@yahoo.com

Abstract

Castor bean (Ricinus communis L.) is a rustic, drought-resistant plant, with great adaptability to different climatic and soil conditions. Currently, it is known for the versatility of the oil extracted from its seeds, where expectations of rising demand for castor oil in the world market is high. In terms of the crop technology, it has to be considered that there are a number of variables for each growing area, especially when it is desired to adapt the castor bean crop at a certain soil tillage system. In this respect, the objective of the present paper is to put into evidence the effects of different soil tillage on the castor bean crop under the specific growing conditions from South Romania. In this respect, a field experiment was established in the years 2019 and 2020 at the Agricultural and Development Research Station Teleorman (ADRS Teleorman) located in South Romania (Teleorman county). The experimental variants were represented by the soil tillage with the following graduations: 1. Summer plowing performed at 30 cm depth + harrowing performed with a disc harrow in autumn, at 12 cm depth + 2 works of seedbed preparation performed with a seedbed cultivator in spring, before sowing, at 10 cm depth; 2. No tillage; 3. Harrowing performed with a disc harrow in spring, before sowing, at 15 cm depth; 4. Deep tillage performed with a ripper in autumn, at 35 cm depth + harrowing performed with a disc harrow for seedbed preparation in spring, before sowing, at 12 cm depth. The obtained results indicate that the conventional soil tillage is superior to the variants of minimum tillage, which implies giving up to plowing, or direct sowing, which implies no-tillage.

***Key words**: castor bean, conventional tillage, minimum tillage, deep tillage, no-tillage.*

INTRODUCTION

Castor bean (*Ricinus communis* L.) is a rustic, drought-resistant plant, with great adaptability to different climatic and soil conditions. Currently, it is known for the versatility of the oil extracted from its seeds, where expectations of rising demand for castor oil in the world market is high. Despite the great importance of castor oil, it contributes to only 0.15% of the vegetable oil produced in the world (Severino et al., 2012; Patel et al., 2016).

Tillage is one of the important activities in the crop production system that optimizes the conditions of soil bed environment for seed germination, seedling establishment and crop growth (Wlaiwan and Jayasuriya, 2013). The tillage systems have evolved in recent decades, both in Romania and worldwide, and both conceptually and in terms of the extension of conservative tillage methods. The extension, in practice, of soil conservation tillage is different from one country to another depending on the degree of mechanization and it increases with the increase of the tractors power and agricultural machineries capacity, as well as with the diversification of the equipment of loosening, tillage and sowing. Conservative soil tillage (minimum tillage and no-tillage) are considered among the most important components of conservation agriculture (Rusu et al., 2015). But, soil conservation systems in different areas must be differentiated, depending on the ecological characteristics of the area and the technological requirements of cultivated plants (Guş et al., 2004). Practically, choosing the good agricultural practices, especially related to the soil management, is a key factor in granting food, clean water, feed, energy, safe climate, diverse ecosystem services and biodiversity for future generations (Mușat et al., 2021).

The yields obtained, by applying the minimum tillage systems, show that differentiated results can be obtained, the choice of the working variant in relation to the crop plant being decisive (Guș and Rusu, 2011). The results obtained in the countries where conservative agriculture has expanded show that it is of great importance for stopping soil degradation, leads to a good use of water from rainfall and irrigation, reducing climate effects, reducing costs and last but not least, increasing productivity (Sayre and Govaerls, 2010).

Traditional agriculture, based on intensive tillage by plowing with the return of furrow and removal of plant debris followed by numerous secondary works, has the disadvantage of high cost and disproportionate distribution of inputs from crop technology in relation to expected efficiency, low productivity as well as major risks regarding soil degradation and environmental pollution (Cociu, 2011). Actually, soil tillage is one of the greatest energy and labour consumer in a crop technology (Cociu, 2011; Ion et al., 2015). Many farmers are converting to reduce tillage systems to diminish soil erosion and field-work time requirements, and to remain eligible for government programs (Lund et al., 1993).

Regarding the technological level used in castor bean crop, as well as some cultural aspects, such as weed management, it is considered that there are a number of variables for each crop region, especially when it is desired to adapt castor bean crop to a certain system, as it is direct sowing (Maciel, 2006).

The new concepts regarding the way of cultivating the plants aiming at achievement of the yields at the level close to the biological potential of the cultivars, the conservation of the soil and the increase of the economic efficiency, are objectives pursued also in the case of castor bean cultivation.

Soils with loamy-sandy texture and soil acidity close to neutral are the soils on which castor bean plants grow best. Given the slow development of plants in the first part of the growing season and the pivoting root of castor bean, the soil should be well loosened in depth, avoiding soils where minimal work has been applied. After early preceding crops (as straw cereals), immediately after harvest, a work with a disc harrow or cultivator is performed and then a plowing is done at 22-30 cm depth. After maize or other crops harvested in late autumn, plowing is carried out at a depth of 28-30 cm. The germination bed is prepared in spring, a few days before sowing, using a disc harrow or a seedbed cultivator, at the sowing depth (Sărdan, 2003).

Regarding the cultivation of castor bean in the direct sowing system, weed control is directly related to the obtained yield. In the conventional soil tillage systems, weeds are incorporated into the soil, these being destroyed and it being prevented the germination of their seeds or plant emergence from the depths. However, this practice must be performed following the technical criteria, otherwise it can lead to physical, chemical and biological degradation of the soil (Costa et al., 2013)

The adoption of soil and water conservation practices is an essential aspect in the rational exploitation of castor bean crop. This plant has a low leaf area index and is cultivated at greater distances than the main annual crops, leaving the soil between the rows unprotected, prone to erosive agents, which are wind (wind erosion) and rain (water erosion). In addition, castor bean plants export significant amounts from the soil to the detriment of the successive crops. Castor bean can deplete much of the soil nutrients in low-consumption production systems, further exacerbating the risk of erosion (Azevedo et al., 1997).

In terms of the crop technology, it has to be considered that there are a number of variables for each growing area, especially when it is desired to adapt the castor bean crop at a certain soil tillage system. In this respect, the objective of the present paper is to put into evidence the effects of different soil tillage on the castor bean crop under the specific growing conditions from South Romania.

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. The soil has a loam-clay texture on the depth of the ploughed layer (0-

25 cm), this being 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%, mobile phosphorus content of 40-60 ppm, and mobile potassium content 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 experimental variants were represented by the soil tillage with the following graduations:

1. Summer *plowing* performed at 30 cm depth + harrowing performed with a disc harrow in autumn, at 12 cm depth + 2 works of seedbed preparation performed with a seedbed cultivator in spring, before sowing, at 10 cm depth;
2. *No tillage*;
3. *Harrowing* performed with a disc harrow in spring, before sowing, at 15 cm depth;
4. *Deep tillage* performed with a ripper in autumn, at 35 cm depth + harrowing performed with a disc harrow for seedbed preparation in spring, before sowing, at 12 cm depth.

Given the fact that sowing is difficult to be performed manually on different tillage systems, the experiment was performed on large plots, respecting all the rules of rigor applied to small plots.

The surface of the plot was 300 m^2 (L = 50 m, l = 6 m).

Crop management. The preceding crop was common autumn wheat.

In the autumn, 100 kg of nitrocalcar (27% nitrogen) were applied for all the experimental variants (for the experimental variant with plowing the application was made before harrowing performed in autumn and for the variant with deep tillage the application was made before this work). In the spring, before seedbed preparation for the experimental variants with plowing, harrowing and deep tillage, and before sowing for the experimental variant with no tillage, a complex chemical fertilizer of 15:15:15 type was applied, in a dose of 200 kg commercial product on ha.

All studied variants were sown on 26 of April in 2019, respectively on 20 of April in 2020. The sowing was performed mechanized, for direct sowing with the Fabimag FG-01 universal seed drill, and for the other variants with the Romanian seed drill SPC-9. The sowing density was of 60,000 germinating seed on ha, the row spacing was of 70 cm, and the sown variety was Rivlas (mid-late variety created in Romania at ADRS Teleorman).

The control of the weeds was performed by the application immediately after sowing of the herbicide Dual Gold 960 EC (S-metolachlor 960 g/l) at a rate of 1.5 l/ha and Roundup Classic Pro (glyphosate 360 g/l) at a rate of 2.0 l/ha. For controlling of the monocotyledonous weeds in the vegetation period, 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. In our field experiments the control of dicotyledonous weeds in the vegetation period was done by a mechanical hoeing followed by a manual correction hoeing, except for the experimental variant with no tillage for which no mechanical hoeing was performed.

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

Harvesting was done manually. After harvesting, the seeds were peeled by hand on each variant. The seed yield was calculated on hectare and it was reported at 9% moisture content.

The percentage of oil in the seeds was determined based on the magnetic resonance phenomenon performed on the Spinlock device.

The productivity elements were evaluated at 10 plants chosen at random from each experimental variants.

The calculation and interpretation of the results was done based on the analysis of variance (Săulescu and Săulescu, 1967).

Climatic data. In terms of temperature in the experimental years, castor bean plants benefited throughout the vegetation period from temperatures higher than the multiannual average value (Figure 1).

In terms of water, in 2019, castor bean plants benefited from 376.6 mm of rainfall over the entire vegetation period, this being with 76.6 mm more than the crop's requirements for moisture, but their distribution was unfavorable to the castor bean crop. Thus, in the first part of the vegetation period the precipitations were quantitatively higher than the multiannual average value by 27.2 mm in April, by 48.1 mm in May, and by 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), while in April, July and August a cumulative deficit of 92.9 mm was registered, 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. In August, 12.6 mm of rainfall was recorded, of which 12.2 mm in the second decade.

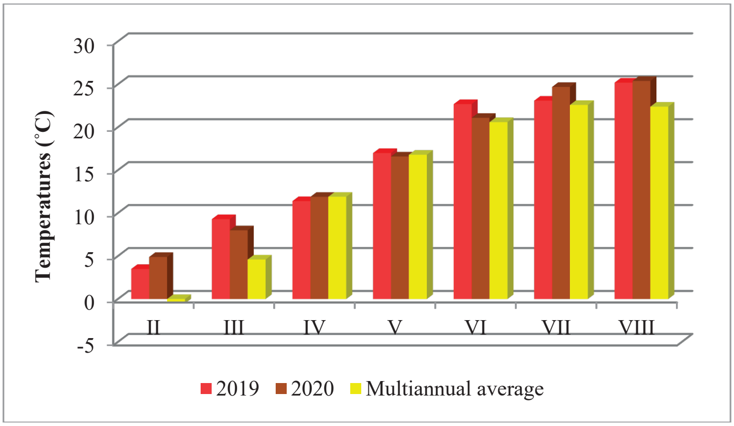

Figure 1. Evolution of the average monthly temperatures at ARDS Teleorman in the years 2019 and 2020

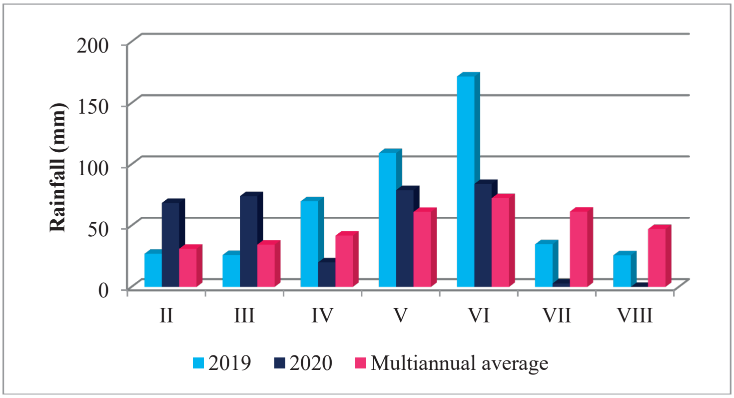

Figure 2. Evolution of the rainfall at ARDS Teleorman in the years 2019 and 2020

RESULTS AND DISCUSSIONS

The castor bean plants emerged in 12 days for the experimental variants with plowing and deep tillage, both in 2019 and 2020 (Table 1). The soil tillage performed only by harrowing delayed the plant emergency by 2 days in 2019 (when the plants emerged in 14 days) and by 4 days in 2020 (when the plants emerged in 16 days). But, in the case of the variant with no-tillage, the emergence period was almost double compared to variants with plowing and deep tillage, the castor bean plants emerging in 22 days in 2019 and in 24 days in 2020.

Following the phenological observations made in 2019, no plants attacked by *Fusarium ricini*, *Botrytis cinerea* and *Macrosporium ricini* were identified (Table 2), but an attack of *Xantomonas ricinicola* was identified in all experimental variants in a percentage of 4-10% of plants attacked per variant. In 2020, due to unfavorable climatic conditions for the development of pathogens, the presence of any of the pathogens mentioned above was not identified.

The percentage of emerged plants by variants had significant differences as follows (Table 3). The variant with plowing registered the highest emergence percentage reported to the sown germinating seeds, respectively 92.7% in 2019 and 90.6% in 2020. The variant with deep tillage was close to the variant with plowing in 2019, registering an emergence percentage of 91.4%, but in 2020 it registered only 76.9%. The variant with no-tillage registered the smallest emergence percentage, respectively 61.1% in 2019 and 71.6% in 2020, while the variant with harrowing was close to the variant with no-tillage, registering an emergence percentage of 71.6% in 2019 and of 75.6% in 2020.

For the control of dicotyledonous weeds there is not yet an herbicide for the castor bean crop, reason for which the weed control was done by a mechanical hoeing followed by a manual correction hoeing for all experimental variants, except for the experimental variant with no tillage for which no mechanical hoeing was performed. In the case of variant with harrowing, after the mechanical plowing, the phenomenon of uprooting the plants was observed. This phenomenon was observed also in the case of the variant with no-tillage, this occurring due to the fact that the root could not grow in the depth of the soil, instead it developed in the surface layer of the soil.

Table 1. Emergence of the castor bean plants at different soil tillage (ARDS Teleorman, 2019 and 2020)

Experimental variant	2019		2020		*Average no of days for emergence*
	Date	No of days for emergence	Date	No of days for emergence	
1. Plowing	8 of May	12	2 of May	12	*12*
2. No tillage	18 of May	22	14 of May	24	*23*
3. Harrowing	10 of May	14	6 of May	16	*15*
4. Deep tillage	8 of May	12	2 of May	12	*12*
Average	-	*15*	-	*16*	*15.5*

Table 2. Disease resistance (notes: 1 - resistant ... 9 - sensible) of the castor bean plants at different soil tillage (ARDS Teleorman, 2019 and 2020)

Experimental variant	*Fusarium ricini*		*Botrytis cinerea*		*Macrosporium ricini*		*Xanthomonas ricinicola*	
	2019	2020	2019	2020	2019	2020	2019	2020
1. Plowing	1	1	1	1	1	1	2	1
2. No tillage	1	1	1	1	1	1	3	1
3. Harrowing	1	1	1	1	1	1	2	1
4. Deep tillage	1	1	1	1	1	1	2	1

Table 3. Plant density and percentage of broken plants at different soil tillage (ARDS Teleorman, 2019 and 2020)

Experimental variant	Sowing (germinating seeds/ha)	Plant density								Broken plants (%)	
		Emergence				Harvesting					
		2019		2020		2019		2020		2019	2020
	2019/2020	plants/ha	%*	plants/ha	%*	plants/ha	%**	plants/ha	%**		
1. Plowing	60,000	55,637	92.7	54,334	90.6	47667	85.7	48667	89.6	13.2	1.7
2. No tillage	60,000	36,667	61.1	42,952	71.6	25000	68.2	25903	60.3	31.8	4.3
3. Harrowing	60,000	42,978	71.6	45,375	75.6	39333	91.5	30750	67.8	19.4	2.3
4. Deep tillage	60,000	54,823	91.4	46,134	76.9	43578	79.5	32267	69.9	16.1	2.0
Average	*60,000*	*47,526*	*79.2*	*47,199*	*78.7*	*38,895*	*81.2*	*34,397*	*71.9*	*20.1*	*2.6*

*Emergence percentage is calculated reported to the germinating seeds.
**The percentage of plants at harvest is calculated reported to the number of plants at emergence.

After the phenological phase of the appearance of the main raceme, it was no longer possible to enter in the crop with agricultural equipment to control weeds, due to the size of the plants.
In the variants with plowing and deep tillage, due to the higher plant density but also due to the castor bean plant vigor, the weeds could no longer develop and they were no longer a problem for castor bean plants. In contrast, in the case of variant with harrowing but especially in the case of variant with no-tillage, weeds were a fierce competitor for nutrition space. Thus, castor bean plants were poorly developed and grown. An impediment in the development of castor bean plants, in 2019, was also represented by the amount of precipitation that fell during the period of vegetative growth, when the weeds grew at the same time as the castor bean plants, even exceeding them.
Regarding the percentage of broken plants, the same tendency can be observed as in the case of plant density (Table 3). Thus, for the variant with plowing the percentage of broken plants was the lowest (13.2% in 2019 and 1.7% in 2020), while in the case of variant with no-tillage the percentage of broken plants was more than double (31.8% in 2019 and 4.3% in 2020). This phenomenon is explained by the fact that castor bean plants have had a deficient development in the variants with minimal soil works.
Biometric determinations of morphological elements show the same differences as in the case of plant density and percentage of broken plants. Thus, it can be observed that all biometric characters (number of nodes/plant, number of branches/plant, plant height, insertion height of the main raceme, and length of the main raceme) have the highest values in the case of variant with plowing and the lowest values in the case of variant with no-tillage (Tables 4 and 5). The variant with deep tillage is close to the variant with plowing, while the variant with harrowing is close to the variant with no-tillage. Following these results, it can be concluded that castor bean plants find the best conditions for growth and development when sown is performed in a soil worked by summer plowing + harrowing with a disc harrow in autumn + seedbed preparation performed with a seedbed cultivator in spring, and a comparable situation can be registered in the case of deep tillage performed with a ripper in autumn + harrowing performed with a disc harrow for seedbed preparation in spring. The direct sown, respectively the conditions of no-tillage assure less favorable growing conditions for castor bean plants, a comparable situation being registered for the case of the soil tillage performed only by harrowing.

Table 4. Number of nodes and branches on castopr bean plant and plant height at different soil tillage (ARDS Teleorman, 2019 and 2020)

Experimental variant	Number of nodes/plant			Number of branches/plant			Plant height (cm)		
	2019	2020	*Average*	2019	2020	*Average*	2019	2020	*Average*
1. Plowing	9	8	*8.5*	2	1	*1.5*	130	117	*123.5*
2. No tillage	7	6	*6.5*	1	1	*1.0*	109	105	*107.0*
3. Harrowing	8	8	*8.0*	1	1	*1.0*	119	108	*113.5*
4. Deep tillage	8	8	*8.0*	2	1	*1.5*	130	117	*123.5*
Average	*8*	*7.5*	*7.75*	*1.5*	*1*	*1.25*	*122*	*111.8*	*116.9*

Table 5. Insertion height of the main raceme and its length at different soil tillage (ARDS Teleorman, 2019 and 2020)

Experimental variant	Insertion height of the main raceme (cm)			Length of the main raceme (cm)		
	2019	2020	*Average*	2019	2020	*Average*
1. Plowing	80	90	*85.0*	50	30	*40.0*
2. No tillage	67	80	*73.5*	38	19	*28.5*
3. Harrowing	75	81	*78.0*	40	27	*35.5*
4. Deep tillage	80	90	*80.5*	48	29	*38.5*
Average	*75.5*	*85.25*	*79.25*	*44*	*26.25*	*35.63*

As in the case of morphological elements of the castor bean plants, the productivity elements of the plants (number of capsules on main raceme, weight of capsules on main raceme, number of seeds on main raceme, weight of seeds on main raceme, and TGW - Thousand Grain weight) varied depending on the soil tillage, the variant with plowing recording the highest values, compared to the other studied soil tillage variants (Tables 6 and 7). Also, the smallest values of the productivity elements were registered in the case of the variant with no-tillage.

The oil content of the seeds varied, on average over the years of experimentation, from 53.5% in the case of variant with plowing to 47.1% in the case of variant with no-tillage (Table 7).

Table 6. Number of capsule, weight of capsules and number of seeds on main raceme at different soil tillage (ARDS Teleorman, 2019 and 2020)

Experimental variant	Number of capsule on main raceme			The weight of capsules on main raceme (g)			Number of seeds on main raceme		
	2019	2020	*Average*	2019	2020	*Average*	2019	2020	*Average*
1. Plowing	72	51	*61.5*	80.5	58.6	*69.6*	165	93	*129.0*
2. No tillage	67	46	*56.5*	53.2	51.4	*53.3*	135	85	*110.0*
3. Harrowing	64	50	*57.0*	60.4	55.6	*58.0*	130	91	*110.5*
4. Deep tillage	62	51	*56.5*	62.8	57.9	*60.4*	135	93	*114.0*
Average	*66.3*	*49.5*	*57.9*	*64.2*	*55.9*	*60.3*	*141.3*	*90.5*	*115.9*

Table 7. The weight of seeds on main raceme, TGW and oil content of the seeds at different soil tillage (ARDS Teleorman, 2019 and 2020)

Experimental variant	The weight of seeds on main raceme (g)			TGW (g)			Oil content of the seeds (%)		
	2019	2020	*Average*	2019	2020	*Average*	2019	2020	*Average*
1. Plowing	53.3	29.3	*41.3*	323	318	*320.5*	53.8	53.2	*53.5*
2. No tillage	39.7	21.8	*30.8*	294	256	*275.0*	46.9	47.2	*47.1*
3. Harrowing	37.9	28.9	*33.4*	292	271	*281.5*	49.6	50.7	*50.2*
4. Deep tillage	39.9	29.3	*36.3*	296	300	*298.0*	50.9	51.3	*51.1*
Average	*42.7*	*27.3*	*35.5*	*301.3*	*286.3*	*293.8*	*50.3*	*50.6*	*50.5*

The seed yields obtained, on average over the years of experimentation, were of 1937 kg/ha for the variant with plowing, 1335 kg/ha for the variant with deep tillage, 921.5 kg/ha for the variant with harrowing, and 750 kg/ha for the variant with no-tillage (Table 8). So, the highest seed yields were registered in the case of variant with plowing, while the smallest seed yields were registered in the case of the variant with no-tillage. The large differences in yields are explained by the differences in plant density at harvest, but also by the way of growth and development of plants throughout the vegetation period according to the soil tillage variant.

The less favorable growing conditions of the year 2020, especially related to the drought registered in this year, affected considerable the yielding capacity of the castor bean plants, the average seed yield of this year being of 888.3 kg/ha, compared to the seed yield registered in the year 2019 of 1583.5 kg/ha.

Table 8. Seed yields obtained at different soil tillage (ARDS Teleorman, 2019 and 2020)

Experimental variant	Seed yields (kg/ha)			Relativ seed yields (%)	Difference (kg/ha)	Significance
	2019	2020	*Average*			
1. Plowing	2454	1420	*1937*	100	Control	-
2. No tillage	980	520	*750*	38.7	-1187.0	000
3. Harrowing	1120	723	*921.5*	47.6	-1015.5	000
4. Deep tillage	1780	890	*1335*	68.9	-602.0	000
Average	*1583.5*	*888.3*	*1235.9*	-	-	-

LSD5% = 150.48 kg/ha; LSD1% = 227.87 kg/ha; LSD0.1% = 366.07 kg/ha

The technological elements can influence the way of capitalization of the water from precipitation.

In order to highlight the role of precipitation in crop formation depending on soil tillage, the precipitation recovery coefficient was calculated (kg of produced seeds/mm precipitation), relating the yields obtained to the amount of precipitation during the growing period of the castor bean plants.

Analyzing the data from the Table 9, we can see that the rainwater is best used when the sowing is performed in a soil worked by summer plowing + harrowing with a disc harrow in autumn + seedbed preparation performed with a seedbed cultivator in spring.

Table 9. Coefficient of recovery of water from precipitation depending on soil tillage (ARDS Teleorman, 2019 and 2020)

Experimental variant	Coefficient of precipitation recovery (kg of produced seeds/mm)		%		Difference .(kg/ha)		Significance	
	2019	2020	2019	2020	2019	2020	2019	2020
1. Plowing	5.97	7.64	Control		100		-	
2. No tillage	2.38	2.80	39.93	36.62	-3.58	-4.84	0	00
3. Harrowing	2.72	3.89	45.64	50.92	-3.24	-3.75	0	0
4. Deep tillage	4.33	4.79	72.53	62.68	-1.64	-2.85		0

For 2019: LSD5% = 2.80 kg/mm; LSD1% = 4.64 kg/mm; LSD0.1% = 8.68 kg/mm
For 2020: LSD5% = 2.60 kg/mm; LSD 1% = 4.30 kg/mm; LSD0.1% = 8.05 kg/mm

CONCLUSIONS

Castor bean is an exigent plant in land preparation. The obtained results indicate that the conventional soil tillage (involving plowing, a harrowing in autumn performed with a disc harrow and the seed bed preparation in spring performed with a seedbed cultivator) is superior to the variants of minimum tillage, which implies giving up to plowing, or direct sowing, which implies no-tillage.

In the case of minimum tillage without deep tillage (based on harrowing performed in spring), but especially in the case of no-tillage, the seed yield of the castor bean crop can be smaller by over 1000 kg/ha compared to the conventional soil tillage.

In the case of giving up at plowing and having a deep tillage in autumn and a harrowing in spring for seedbed preparation, the seed yield at castor bean is between those obtained in the case of conventional soil tillage and those obtained in the case of minimum tillage based on harrowing performed in spring. The variant with a deep tillage in autumn and a harrowing in spring for seedbed preparation could be of interest especially in situations when the plowing cannot be performed in summer or in autumn, as for example in drought conditions.

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