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Cientific Paper

Production and yield components of castor bean BRS energia in function of different levels of irrigation and nitrogen organic fertilization[1]

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Abstract

Aiming to obtain knowledge about the effects of castor bean as a supplier of organic matter of different levels of nitrogen and at different irrigation levels in the crop of early castor bean, cultivar BRS Energia, it was conducted an experiment in randomized blocks with plots subdivided into strips, being the factors: 4 levels of nitrogen via castor bean (TM) (TM_1 = 0, = 90 TM_2, TM_3 and TM_4 = 180 = 270 kg N ha^{-1}) and 4 irrigation levels based on the concept of available soil water (available water - AD) (AD_1 = 20, AD_2 =40, AD_3 = 60 AD_4 = 80%), with four replications. The yield components of castor beans, BRS Energia increased with increasing levels of available soil water and organic fertilizer via castor bean, however, the positive effect of organic fertilization occurred only until the level of fertilization of 180 kg N ha^{-1}, even when associated with the level of soil water availability of 80%. The level of organic fertilization of 180 kg ha^{-1}, associated with 80% of available soil water promoted an increase of 58.84% in the yield of castor bean, compared to treatment with this same level of water availability in the soil, but without fertilization.

Keywords: Fertilization; irrigation management culture; castor bean crop.

Componentes da produção e produtividade de mamoneira BRS energia em função de diferentes níveis de irrigação e adubação nitrogenada orgânica

Resumo

Objetivando obter conhecimento sobre os efeitos da torta de mamona como matéria orgânica fornecedora de diferentes níveis de nitrogênio e de diferentes níveis de irrigação na cultura da mamoneira precoce, cultivar BRS Energia, conduziu-se um experimento em blocos casualizados com parcelas subdividas em faixas, sendo os fatores: 4 níveis de nitrogênio via torta de mamona (TM) (TM_1 = 0, TM_2 = 90, TM_3 = 180 e TM_4 = 270 kg N ha^{-1}) e 4 níveis de irrigação baseados no conceito de água disponível no solo (água disponível - AD) (AD_1 = 20, AD_2 = 40, AD_3 = 60 e AD_4 = 80%), com 4 repetições. Os componentes de produção da mamoneira, cultivar BRS energia aumentaram com o incremento dos níveis de água disponível no solo e de adubação orgânica via torta de mamona; entretanto, o efeito positivo da adubação orgânica ocorreu somente até o nível de adubação de 180 kg N ha^{-1}, inclusive quando associado ao nível de disponibilidade de água no solo de 80%. O nível de adubação orgânica de 180 kg ha^{-1}, associado a 80% de água disponível no solo promoveu um incremento de 58,84 % na produtividade da mamoneira, em relação ao tratamento com este mesmo nível de disponibilidade de água no solo, mas sem adubação orgânica.

Palavras-chave: Adubação; irrigação manejo cultural; Cultura da mamoneira.

Componentes de la producción y productividad del ricino BRS energia en función de distintos niveles de irrigación y fertilización nitrogenada organica

Resumen

Con el objetivo de obtener el conocimiento sobre los efectos de la tarta de ricino como materia orgánica proveedora de diferentes niveles de nitrógeno y de diferentes niveles de riego en el cultivo de ricino temprano BRS Energía, se llevó

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a cabo un experimento en diseño de bloques completos al azar con parcelas divididas en grupos (bandas), siendo los factores: 4 niveles de nitrógeno vía tarta de ricino (TM) (TM_1 = 0, TM_2 = 90, TM_3 = 180 y TM_4 = 270 kg N ha^{-1}) y 4 niveles de riego basados en el concepto de agua disponible en el suelo (agua disponible - AD) (AD_1 = 20, AD_2 = 40, AD_3 = 60 e AD_4 = 80%), con 4 repeticiones. Los componentes del rendimiento del ricino BRS energía aumentaran con el aumento de los niveles de agua disponible en el suelo y con la fertilización orgánica vía tarta de ricino; sin embargo, el efecto positivo de la fertilización orgánica se produjo sólo hasta el nivel de fertilización de 180 kg N ha^{-1}, incluyendo cuando se asocia con el nivel de disponibilidad de agua en el suelo de 80 %. El nivel de la fertilización orgánica de 180 kg ha^{-1}, asociado con 80% de agua disponible en el suelo ocasionó un aumento de 58,84% en el rendimiento del ricino, en comparación con el tratamiento con el mismo nivel de disponibilidad de agua en el suelo, pero sin fertilización orgánica.

Palabras clave: fertilización; riego; manejo de cultivos; ricino.

Introduction

The castor bean (*Ricinus communis L.*), is an oilseed of relevant economic and social importance. From its seeds is extracted an oil of excellent properties, having wide use as industrial input and several applications. It is cultivated since the times of the ancient civilizations, the castor bean is a rustic plant, resistant to drought, belonging to the family of Euphorbiaceae, found in many regions of the world, including in semi arid areas where it is commercially cultivated between the parallels 40°N and 40°S. The expansion of its cultivations was mainly due to the capacity of adaptation to different environmental conditions and the many applications of use of its main product, the oil.

According to BELTRÃO and SILVA (1999), there was in Brazil an annual deficiency in the offer of this product, superior to 80 thousand tons, which made necessary the importation of the crude oil from India and China to meet the needs of the internal market. In its industrialization, it is obtained besides the oil, the pulp, a sub product capable of restoring soils depleted by indiscriminate exploitation.

This crop has gained greater notoriety, with the use of its oil for the production of Biodiesel, which is constituted in a renewable, biodegradable and environmentally correct fuel, being able become, gradually and satisfactorily, a substitute of the mineral diesel oil, which may transform this crop, in short time, in one of the most important agricultural comodits of Brazil, because the country presents the potential of 4.5 millions of hectares only in the Northeast, which may be sowed with castor beans for means of Biodiesel production, taking into consideration that the demand for castor bean will be widely increased (BELTRÃO, 2006).

Its production system can be practiced by small producers, it is intensive in workforce (creates jobs) and can be made in rotation with other crops, besides of using little pesticides and adapting perfectly to the semi arid regions of the Northeast. It is possible to extract from its seeds an oil of unique characteristics among more than 240,000 species of higher plants found in the plant kingdom.

Among the possibilities of use of the castor bean oil, it is found nowadays the biodiesel, the new potential and clean source of Energia; its greater acceptance in the fuel market arises as a form of meeting the consumption need. The reduction of petroleum buying abroad also decreases the deficit of the commercial balance and provides decrease of the emission of harmful gases in the atmosphere, generated by the combustion of fossil fuels.

Therefore, this situation shows the increasingly need of performing studies related to the castor bean production systems, in the several soil and climatic conditions in Brazil, because there is great lack of knowledge about the crop, mostly when it is cultivated early varieties in irrigation conditions, aiming mainly to provide to the small and medium producers information for the improvement of the yield and quality of the seed, that is, the quality of the castor bean oil.

In Brazil the agricultural soils rarely are self-sufficient in the supplying of nitrogen to the cultivated plants, mainly when the high yield is the main objective. According to SANTOS et al. (2006), the consumption of mineral fertilizers in the country was of 22 millions of tons, being the urea and the ammonium sulfate the most used sources, increasing the content of mineral nitrogen in the soil, which favors the emission of nitrous oxide (N_2O), worsening even more the problem of global warming, elevating the planet temperature and causing drastic impacts in the production of food in the next decades. According to SEVERINO et al. (2006), the fertilization is one of the main used technologies to increase the yield and profitability of the agricultural crops, although it has high costs and can increase the agricultural investment risk, existing huge lack of technology for soil fertilization in the castor bean crop in different conditions of irrigation and fertilization, at different levels.

The nitrogen is considered an essential element, due to the structural and functional function that exerts on the life of the plant (amino acids, proteins, nitrogenous bases, nucleic acids, enzymes, coenzymes, etc.), corresponding to the vital processes in its development (MALAVOLTA, 1980), however, the Energia source for the synthesis of the chemical nitrogen depends, directly or indirectly, of the petroleum, which is a finite source of Energia and will fatally lead to an increase of the costs and to other environmental problems.

Being the castor bean a sensible plant to the soil acidity and demanding of fertility, it is possible to increase the yield through the adequate proving of nutrients via fertilization. The nitrogen is the nutrient demanded in greater quantity by the crops, and the castor bean is not different. The interaction between water and nitrogen fertilization is very complex as for the need of comprehending the behavior of the crops in relation to the response of the production. Reason why there is the great interest in studying such relation, in search for a referent and secure knowledge referring to the efficiency of water and fertilizers use by the crops.

The water assumes fundamental importance in the vegetal production, in a way that its lack or excess highly affects the increase and the development of the plant and, therefore, the management is relevant in the maximization of the agricultural production.

Besides of the search for obtaining techniques adapted to the region, capable of providing an economically viable yield, at the level of small and medium producer (family farmer) and the improvement in the product quality, reverting it in profit, it is proposed to obtain in this research, knowledge about the effects of the organic matter (castor beans pulp) as provider of different levels of nitrogen, expecting to verify and quantify it in the crop of irrigated castor bean with different levels of irrigation.

With the exposed, this research aims to investigate the effect of different doses of nitrogen via castor beans (0, 90, 180 and 270kg N ha^{-1}) and different levels of irrigation (20, 40, 60, and 80 %AD), isolated and combined, about the growth and yield of the early castor bean, irrigated in semi arid conditions.

Material and Methods

The experiment was conducted in the Experimental Field of Embrapa Cotton, Experimental Station of Barbalha CE, in 2008, geographically located in the microregion of the Cariri Cearense, presenting coordinates of 7° 19' South, 39° 18' West and 409.03 m of altitude (SUDENE, 1993).

The weather, according to the Köppen classification, is of the type Aw'i (humid tropical weather with dry season from the spring until the early summer), the annual average temperature is 24 °C and the annual average rainfall of 1,200 mm, with rainy period going from December to May, being the most rainy trimester from January to March and the most dry from June to November, with an average relative humidity of 60%. The soil of the area is classified as a NEOSOLO FLÚVICO[1] (alluvial soil) (EMBRAPA, 1999; SUDENE, 1993).

The soil samples of the experimental area were collected through a Dutch auger at depths of 0-20cm, 20-40cm and 40-60cm, and then sent to the Laboratory of Irrigation and Salinity of the Universidade Federal de Campina Grande, for the performing of physical and chemical analysis, both complete. The physical and chemical characterization of the soil where was conducted the experiment is of the type alluvion, and is organized in Table 1, such as the curve of water retention of the soil in Figure 1.

It was used the variety BRS-Energia developed by the Embrapa Cotton, it is of small size and short cycle and belongs to the program of genetic breeding of the Embrapa Cotton, originating from a lineage imported from Costa Rica. The spacing of the planting was in the design of 1.4 x 0.4 x 0.36 m (GONDIM et al., 2004), in continuous double row to obtain a better harnessing of the area in function of the drip irrigation system, the spacing between the double rows was of 1.8 m, that is, each experimental plot consisted of 6 dripping rows, being two extremities of row borders, and the middle row as usable for the experiment, totalizing a width of 6.25 m for each experimental plot, being that the area of the experiment occupied an area of 43.2 m x 50 m, totalizing 2,160 m^2; each subplot had planting density of 3 plants per linear

1 Brazilian soil classification.

Table 1. Physical and chemical characterization of the area soil analyzed in the Experimental Field of the Empraba Cotton.

Physical characteristic of the soil	Depth – cm		
	0 – 20	20 – 40	40 – 60
Sand	48.51	51.58	47.38
Silt	17.53	15.19	11.19
Clay	34.13	33.23	40.99
Texture classification	P. clayey	P.clayey sand	Sandy clay
Apparent density	1.25	1.23	1.32
True density	2.14	2.5	2.55
Sandy clay (cm^3 cm^{-3})	0.22	0.22	0.27
Calcium (meq/100g de solo)	8.76	8.10	8.15
Magnesium (meq/100g de solo)	7.02	6.64	7.55
Sodium (meq/100g de solo)	0.07	0.07	0.07
Potassium (meq/100g de solo)	1.2	0.66	0.33
Aluminum (meq/100g de solo)	0.00	0.00	0.00
Qualitative calcium carbonate	Absent	Absent	Absent
Organic carbon (%)	0.94	0.53	0.50
Available phosphorus (mg/100g)	0.68	0.53	0.53
Soil electrical conductivity (cmmhos/cm, suspension in water)	1.04	1.1	1.38

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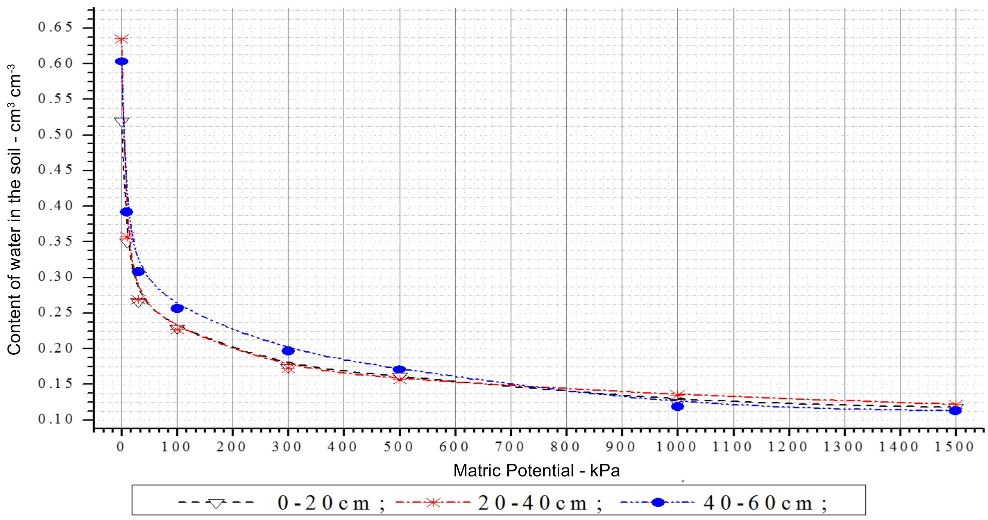

Figure 1. Curve of water retention in the soil, of the Experimental Field of Embrapa Cotton, Barbalha CE, 2008 (Laboratory of Irrigation and Salinity of the Universidade Federal de Campina Grande, PB).

meter, 17 plants per experimental plot, totalizing 6,672 plants in the whole area of the experiment and density of 15,290 plants per hectare.

The marking of the area was done through pickets and ropes and, finally, the plots were identified, by properly identified platelets, with the respective treatment. The plots containing the treatments were obtained randomly by draw; the planting was done manually with the use of four seeds per hole at a depth of approximately 5cm, during the planting was performed chemical fertilization with phosphorus (P) and potassium (K) following the recommendation of fertilization and liming for the Ceará state.

To ensure the uniformity of germination and the initial growth, it was irrigated the whole area uniformly until the 10 days after emergence (DAE), as a form of keeping the level of soil moisture close to the field capacity of the field and thus favor the equality of the stand. The subsequent irrigations were applied and defined for each treatment in the respective rows of irrigation, via drip irrigation system. The weed control was performed through hand weeding with hoe, in intervals of 15 days, with the intention of keeping the crop clean for at least 65 days after the germination, in such form that would not compromise the production. It was not done herbicide, insecticide or fungicide application in any time of the cultivation.

The experiment followed a randomized blocks design distributed in subdivided plots in rows and 4 repetitions, being: 4 levels of nitrogen via castor bean pulp (CBP) (CBP_1 = 0, CBP_2 = 90, CBP_3 = 180, and CBP_4 = 270 kg N ha^{-1}), 4 levels of irrigation having as base the water content in the soil, which was monitored twice a day with the use of the TDR, (available water – AW) (AW_1 = 20%, AW_2 = 40%, AW_3 = 60% and AD_4 = 80%), totalizing 16 treatments. In Table 2 are described with more details the levels of each treatment, with the amount of castor bean pulp applied per hectare, respectively.

Aiming the estimative of water demand of the castor bean crop, it was adopted the monitoring of water content of the soil through a TDR probe, Delta T type, segmented, model PR2. The same equipment was assessed in field for a period of 12 days, being that its readings were compared with the determination of the water content in the soil of the gravimetric method and with the use of a battery of 3 tensiometers, before definitively using it in the experiment. The readings were performed twice a day, always between 7:00 and 7:30 am, and during 16:00 and 16:30 pm, in a way that the content of water of the soil was always monitored before and after each irrigation, such as the determination of the necessity of performing other water reposition via irrigation.

The frequency and the required irrigation were determined via water content of the soil, determined by the Time Domain Reflectometry technique; the water reposition in the soil followed the criteria of percentage of available water for the plants (AW); in its respective treatments, it is determined the level of irrigation through the equation 8 (BERNARDO et al., 2006).

$$\mathrm{Lb} = \frac{\left[\left(\frac{\mathrm{Cc} - \mathrm{CAA}}{100}\right) * \mathrm{Ds} * \mathrm{Z} * f\right]}{\mathrm{Ea}} \qquad (1)$$

Where: Lb - Gross irrigation depth (mm); Cc – Field capacity (%); CAA – Content of actual water of the soil, determined with the TDR (%); Ds – Soil density (g cm^{-3}); Z – Effective depth of the crop root system (mm); *f* – Factor of water reposition of the soil, 20, 40, 60 and 80% AW (decimal <1); Ea – Efficiency of the irrigation system (decimal <1), (93%);

The variables of production were made during the conduction of the experiment, where were performed in three steps, at the 65 DAE, 80 DAE, 95 DAE, bunch length and number of fruit per bunch.

The harvest was manually performed cutting the bunch base, then the berries were separated and these were placed inside fabric bags, individually for each plot, where was obtained the value of production of the same, which after being properly identified were weighed, counted and peeled at one time, when all bunches were completely dry, thus occurring an increase in the crop cycle, this fact was given to the indehiscence of the cultivar.

From the seed oil content obtained through chemical extraction, samples of each treatment were taken to the laboratory of bromatology of the Center of Technological Education Institute of Ceara, Fatec

Table 2. Levels of organic matter applied in the soil, in function of the nitrogen doses per hectare, for the studied source of organic matter (castor bean pulp).

Nitrogen (kg ha^{-1})	Castor bean pulp (t ha^{-1})*	Levels of irrigation (NI)**	Applied irrigation
0	0	20	Available water (AW)
90	1.67	40	Available water (AW)
180	3.33	60	Available water (AW)
270	5.00	80	Available water (AW)

Cariri in Juazeiro do Norte-CE, for performing the oil extraction and determination of the content of oil in the seeds.

The data were submitted to variance analysis at level of 5% and 1% ($p<0.05$ and $p<0.01$) of probability, by the F test in accordance with FERREIRA (2003), using the SISVAR program v. 4.2. when verifying the significant effect in the variance analysis, the quantitative treatments were submitted to analysis of polynomial regression (ZIMMERMANN, 2004 and SANTOS et al., 2008).

Results and Discussion

The results of the summaries of the variance analysis for the variables bunch length (BL) and number of fruit per bunch (NFB) are shown in Table 3. According to these results, it is verified existence of significant effect both for the factor irrigation as for fertilization at the level of 1% of probability ($p<0.01$), in all times of the assessment. Both for the isolated effect of the factors as for the interaction, indicating that there is dependence between the studied variables, being influenced following the same tendency of the BL and NFB, which was significant for all the times of assessment.

Observing the Figure 2 and Tables 3, 4, it is verified that when the early castor bean plants were submitted to different levels of irrigation, it was obtained better values of number of fruit (NFB) per bunch and bunch length (BL) for the irrigation levels of 80% of available water (AW), with 270kg N ha^{-1}, via castor bean pulp (CBP), this when it was evaluated at the 65 DAE, in the subsequent evaluations was observed that in all times of assessment these values tend to reduce when the fertilization value is elevated to 270kg N ha^{-1}.

The smallest values were observed when the early castor bean plants were submitted to levels of 20 of available water (AW), without nitrogen fertilization (via castor bean pulp – CBP), having bunches with lengths of 30 cm in average (20%AD/0

Table 3. Summaries of the variance analysis of the bunch length (BL) and number of fruit per bunch (NFB) of the early castor bean (BRS Energia) irrigated with different levels of irrigation and doses of nitrogen fertilization at the 65, 80 and 95, days after emergence (DAE).

FV	GL	Average Square 65 DAE	Average Square 80 DAE	Average Square 95 DAE
Bunch Length (BL)				
Block	3	1.9 ns	356.77 ns	4.42 ns
Irrigation (I)	3	1142.77**	1033.53 ns	2314.89**
Residues (1)	9	2.44	397.8	5.56
Fertilization (F)	3	310.51**	873.93 ns	458.53**
Residues (2)	9	0.93	417.72	3.38
I*F	9	20.05**	325.25 ns	97.62**
Residues (3)	27	2.51	391.31	2.99
Total	63			
CV 1 (%)		7.44	64.31	7.1
CV 2 (%)		4.6	65.9	5.54
CV 3 (%)		7.54	63.78	5.21
Number of fruit per bunch (NFB)				
Block	3	0.27 ns	7.39 ns	4.42 ns
Irrigation (I)	3	1142.77**	1033.53 ns	2314.89**
Residues (1)	9	2.44	397.8	5.56
Fertilization (F)	3	310.51**	873.93 ns	458.53**
Residues (2)	9	0.93	417.72	3.38
I*F	9	20.05**	325.25 ns	97.62**
Residues (3)	27	2.51	391.31	2.99
Total	**63**			
CV 1 (%)		7.44	64.31	7.10
CV 2 (%)		4.60	65.90	5.54
CV 3 (%)		7.54	63.78	5.21

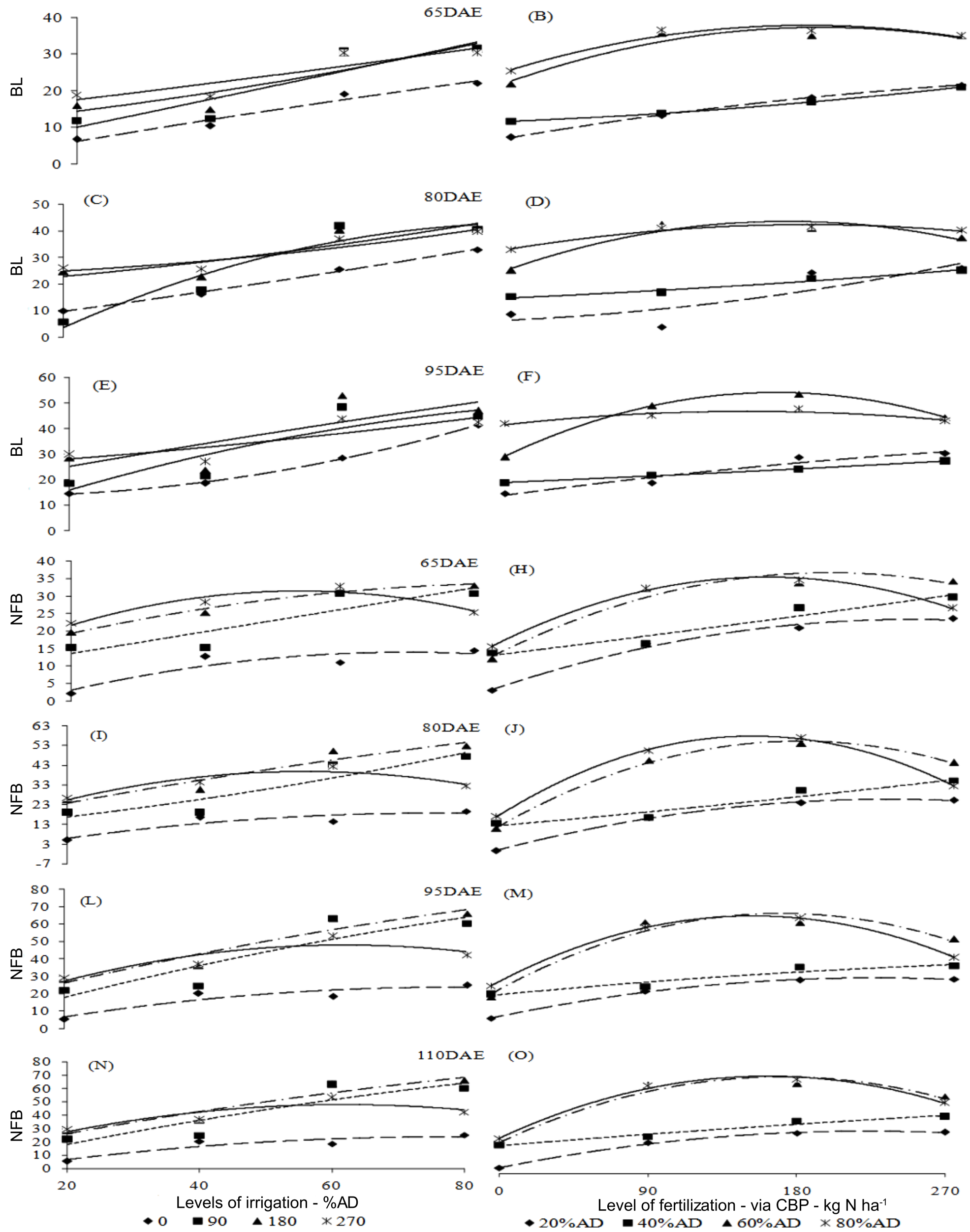

Figure 2. Analysis of regression for interaction between the different levels of irrigation and nitrogen fertilization via castor bean pulp (CBP) for the variable bunch length (BL) and number of fruit per bunch (NFB).

kg N ha^{-1}). However, when the plants were submitted to 60% of AW, this variable positively increased with the increment of the level of nitrogen fertilization via castor bean pulp of 185kg N ha^{-1}, this response of the crop in the conditions which the research was conducted, proves the thesis that the application of nitrogen fertilization on the soil through organic matter improves the soil physical characteristics, thus making possible that the crop grow in an environment with less water.

According to BELTRÃO et al. (2006), and BABITA et al. (2010) the castor bean is a crop which demands fertile soils and good availability of water in the soil, this that can be improved by the increase of the water retention capacity of the soil with organic fertilizer (Castor bean pulp - CBP). REDDY and MATCHA (2009), when researching different levels in the castor bean crop found low productivities when the plant was cultivated in soils of low fertility, and when the crop had received 100% of the recommendation of fertilization, this when fertilized with only 20% of the total fertilization obtained low productivities and restriction on the leaf area.

In the Figure 2 A and Table 4, it is verified that the irrigation levels of 60 and 80% of AW provided the best yields for bunch length and number of fruit per bunch, and following the same tendency, the irrigation level which had the worst results was the 20% of AW. To the different levels of nitrogen fertilization via castor bean pulp, the best result was after the 65 DAE was of 180 kg N ha^{-1}, being that in the previous days the worst result was when the plants were cultivated with 0 kg N ha^{-1}, respectively.

According to the variance analysis in Table

Table 4. Values of the parameters (A, B and C) and coefficients of determination (R^2) of the regressions, for the variables bunch length and number of fruit per bunch (NFB).

Terms	Irrigation				Fertilization			
	0	90	180	270	20	40	60	80
Bunch length								
65 – DAE								
A	0.012 ns	2.593 ns	10.600**	13.381**	6.776 **	10.095**	19.863**	22.56**
B	0.323**	0.371**	0.168 ns	0.207*	0.064**	0.029**	0.134**	0.115**
C	0.000 ns	0.000 ns	0.001ns	0.000 ns	-0.000 ns	---	-0.000**	-0.000**
R^2	0.96	0.82	0.8	0.78	0.99	0.98	0.91	0.93
80 - DAE								
A	2.975 ns	91.018**	18.687ns	22.8 ns	15.447ns	15.853 ns	26.267*	33.045**
B	0.320 ns	-2427 ns	0.173 ns	0.067 ns	0.392*	0.026 ns	0.199 ns	0.095 ns
C	0.000 ns	0.023 ns	0.001 ns	0.001 ns	-0.001*	0.000 ns	-0.000 ns	-0.000 ns
R^2	0.99	0.48	0.76	0.86	0.45	0.97	0.92	0.96
95 – DAE								
A	13.912**	-1.381 ns	15.418**	24.262**	13.761**	18.662**	28.661**	41.027**
B	-0.087 ns	0.944**	0.496**	0.171 ns	0.084**	0.027 ns	0.296**	0.070**
C	0.005**	-0.004**	-0.000 ns	0.001 ns	-0.000 ns	0.000 ns	-0.000**	-0.000**
R^2	0.99	0.78	0.6	0.67	0.94	0.99	0.99	0.88
Number of fruit per bunch (NFB)								
65 – DAE								
A	0.012 ns	2.593 ns	10.600**	13.381**	6.776 **	10.095**	19.863**	22.56**
B	0.323**	0.371**	0.168 ns	0.207*	0.064**	0.029**	0.134**	0.115**
C	0.000 ns	0.000 ns	0.001 ns	0.000 ns	-0.000 ns		-0.000**	-0.000**
R^2	0.96	0.82	0.8	0.78	0.99	0.98	0.91	0.93
80 – DAE								
A	2.975 ns	91.018**	18.687 ns	22.8 ns	15.447 ns	15.853 ns	26.267*	33.045**
B	0.320 ns	-2.427 ns	0.173 ns	0.067 ns	0.392*	0.026 ns	0.199 ns	0.095 ns
C	0.000 ns	0.023 ns	0.001 ns	0.001 ns	-0.001*	0.000 ns	-0.000 ns	-0.000 ns
R^2	0.99	0.48	0.76	0.86	0.45	0.97	0.92	0.96
95 – DAE								
A	13.912**	-1.381 ns	15.418**	24.262**	13.761**	18.662**	28.661**	41.027**
B	-0.087 ns	0.944**	0.496**	0.171 ns	0.084**	0.027 ns	0.296**	0.070**
C	0.005**	-0.004**	-0.000 ns	0.001 ns	-0.000 ns	0.000 ns	-0.000**	-0.000**
R^2	0.99	0.78	0.6	0.67	0.94	0.99	0.99	0.88

For the polynomial equation of 2^0.degree: $Y = A + BX + CX^2$ and linear: $Y = A + BX^2$

3, the variables seeds depth and seed oil content, the main castor bean product, were influenced by the interaction of the factors: irrigation levels and nitrogen fertilization (via CBP), at the level of 1% of probability ($p<0.01$), also occurred isolated effects of the treatments irrigation and nitrogen fertilization via castor bean pulp.

Analyzing the Figure 3 A, 3 B and Table 5, which is referred to the oil content of the first bunch, it is observed that the best response was when the castor bean plants were submitted to the treatments 80% AW with 180 kg N ha^{-1} (via CBP). Working on the derivative of the equation it is verified that (Figure 3) the castor bean oil content decreases with nitrogen fertilization superior to 175 kg N ha^{-1}, this value is very close to the tested treatment (180 kg N ha^{-1}) for the irrigation level, the oil content of the seeds begins to decreases at 20% AW. These responses were similar for the first and second bunch.

The castor bean cultivar, early BRS energia (100 – 120 days of cycle), in the average height and indehiscent fruits had seeds productivity and oil yield compromised by the water deficiency and by the soil without fertilization via castor bean pulp, besides of having a significant reduction in productivity, bunches number per plant and bunches length, considering the water at 20% of availability on the soil.

The castor bean cultivar yield, early BRS energia, planted in double spacing (1.4 x 0.4 x 0.36m), in soil without organic fertilizer (CBP), with phosphorus contents below 10 ppm, even when performing application of P_2O_5 40 kg ha^{-1} was low, less than 400 kg of berries per hectare, however was inferior to 3838.31 kg ha^{-1} of berries, with the dose of 180 kg ha^{-1} of nitrogen in the form of castor bean pulp, with 80% AW, considering the productivities of the first and second bunches. Thus not achieving its whole productive potential, being inferior to 6 t ha^{-1} even with 80% AW and 270 kg ha^{-1}, in the form of castor bean pulp, possibly due to limitation of other factors, such as low nutrition of phosphorus and the unbalance between calcium and magnesium. However, it still was of 3,838.31 kg ha^{-1} of berries with the treatments 80% AW and 180 kg ha^{-1}, superior to the treatment of 20% AW and 0 kg ha^{-1} in 3457,014 kg ha^{-1} of berries, being yield was superior in 88.97%.

RODRIGUES et al. (2006) and SILVA (2008), studying levels of evapotranspiration, found similar results for the levels of low water availability. BABITA et al. (2010), studying hybrids of castor bean with elevated matric potentials obtained significant reduction in the seeds productivity and oil content of the same.

The oil percentage of the seeds with 80% AW and 180 kg ha^{-1} nitrogen in the form of castor bean pulp was the treatment which resulted in the best seed oil contents (52.5%), and the water deficiency

Table 5. Summaries of the variance analysis of the seeds productivity and oil yield (%) of the early castor bean seeds (BRS Energia) irrigated with different levels of irrigation and doses of nitrogen fertilization.

FV	GL	Average Square (1° Bunch)		Average Square (2° Bunch)	
		Production	% of Oil	Production	% of Oil
BLOCK	3	10320.062	10.68*	27085.63ns	7.68ns
IRRIGATION (I)	3	6260764.687**	2483.39**	5589565.14**	3119.47**
Error 1	9	7524.298	2.07	16415.71	9
FERTIL. (F)	3	1811130.895**	633.68**	1565540.68**	406.47**
Error 2	9	5363.506	5.59	16252.34	6.66
I*A	9	486931.298**	106.52**	377652.09**	22.46**
Error 3	27	6344.576	3.84	10398.23	4.78
Total	**63**				
CV 1 (%)		9.03	4.03	15.08	8.93
CV 2 (%)		7.63	6.62	15.00	7.68
CV 3 (%)		8.3	5.49	12.00	6.51

(*) Significant at the level of 5% of probability, (**) Significant at the level 1% de probability and ns, non significant.

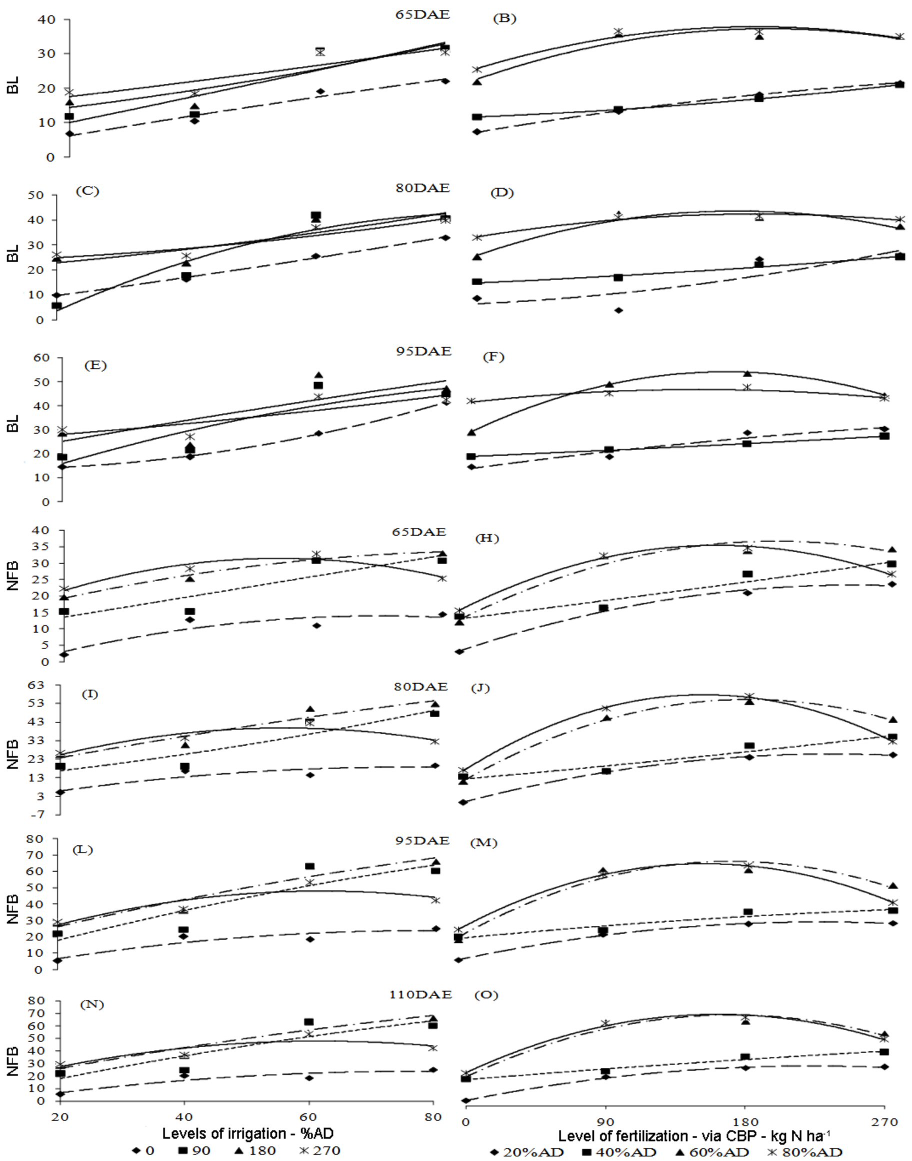

Figure 3. Analysis of the regression for interaction between different levels of irrigation and nitrogen fertilization via castor bean pulp (CBP) for the seeds productivity and oil yield (%), Barbalha CE, 2008.

(20% AW) drastically reduced the oil content (16.4%) in the lowest levels of water availability and nitrogen fertilization in the form of castor bean pulp.

Conclusions

The positive effect of the organic fertilization occurred only until the fertilization level of 180 kg N ha^{-1}, even when associated to the level of water availability in the soil of 80%.

The level of organic fertilization of 180 kg ha^{-1} associated to 80% of AW in the soil promoted an increment of 58.84% in the castor bean yield, in relation to the treatment with the same level of AW in the soil but without organic fertilization.

The level of 80% AW in the soil associated to an organic fertilization of 180 kg ha^{-1}, promoted an increment of 22.11 % in the castor bean yield, in relation to the treatment with this same level of organic fertilization and with the level of 20% of AW.

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