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Water allocations and mulching in castor bean crops in a semiarid Fluvic Neossol[1]

Dotações hídricas e cobertura morta na cultura da mamona em Neossolo Flúvico no semiárido

Júlio José do Nascimento Silva[2]*, Abelardo Antônio Assunção Montenegro[3], Elvira Maria Régis Pedrosa[3], Napoleão Esberard de Macedo Beltrão[4] e Hugo Manoel Henrique[5]

ABSTRACT - The influence of different irrigation levels, both with and without mulching, was evaluated for the growth variables of productivity, production components and water use efficiency, in a castor bean crop (*Ricinus Comunnis*) cv. BRS Energia, in a Fluvic Neossol of the semiarid in the Brazilian state of Pernambuco. The experimental design used was completely randomised in a factorial of 4 (irrigation levels) × 2 (with and without mulch), with four replications. The irrigation levels were based on the evapotranspiration of the crop (ETc), with L1 = 60% ETc, L2 = 80% ETc, L3 = 100% ETc and L4 = 120% ETc. All growth variables showed significant differences to the mulch at 120 days after germination. The number of racemes per plant, percentage of bark, and water use efficiency responded significantly to the presence of mulch on the ground, while length of racemes, fruit yield and berry yield responded significantly to the isolated effects of the irrigation levels and ground cover. Levels L3 and L4 improved the performance of the crop, with an average productivity of over 2,360 kg berries ha^{-1}.

Key words: Irrigation. Growth. Production components.

RESUMO - Avaliou-se a influência de diferentes lâminas de irrigação na presença e ausência de cobertura morta nas variáveis de crescimento, produtividade, componentes de produção e eficiência do uso da água, da cultura mamoneira (*Ricinus Comunnis*) cultivar BRS Energia em Neossolo Flúvico no semiárido pernambucano. O delineamento experimental utilizado foi o inteiramente casualizado em esquema fatorial 4 (lâminas de irrigação) × 2 (com e sem cobertura morta) com quatro repetições. As lâminas de irrigação basearam-se na evapotranspiração de cultura (ETc), sendo L1 = 60% ETc; L2 = 80% ETc; L3 = 100% ETc e L4 = 120% ETc. Todas as variáveis de crescimento apresentaram diferença significativa à cobertura morta aos 120 dias após a germinação. O número de racemos por planta, o percentual de casca e a eficiência no uso da água responderam significativamente à presença de cobertura morta no solo; enquanto o comprimento de racemos, a produtividade de frutos e produtividade de bagas responderam significativamente aos efeitos isolados das lâminas e da cobertura do solo. As lâminas L3 e L4 foram as que permitiram melhor desempenho da cultura, com produtividade média acima de 2.360 kg ha^{-1} de bagas.

Palavras-chave: Irrigação. Crescimento. Componentes de produção.

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INTRODUCTION

With intensification of the Brazilian National Biodiesel Program it is estimated that more than 50% of Brazil's energy comes from renewable sources (PEREIRA, 2007). Unlike the soybean, sunflower, groundnut and other oilseeds, the castor bean is not intended for human consumption, and consequently does not involve competition with that market (SILVA *et al*., 2009).

Barros Jr. *et al*. (2008) point out that as it is a plant with the capacity for satisfactory production even under conditions of low rainfall, the castor bean is an alternative crop of great importance in the Brazilian semi-arid region. Some authors have confirmed the importance of irrigation in increasing the productivity of the castor bean, with a beneficial effect on the number of racemes per plant and on seed weight (SILVA, 2008). The study of different irrigation levels is essential to determine the water requirements of a species, and the impact on growth and yield (SILVA *et al*., 2011).

Additionally, the use of ground cover on the soil together with irrigation can provide numerous benefits, such as better moisture retention, maintenance of a more stable temperature and conservation of the soil structure (MEDEIROS *et al*., 2007).

Non-destructive growth analysis is an important tool when evaluating the efficiency of an adopted management, and this is why it is widely used by researchers in the agricultural area with a view to studying the performance of crop systems (CARDOSO *et al*., 2006). For the castor bean, it is possible to highlight the studies of Ribeiro *et al*. (2012), who measured stem diameter, plant height and number of leaves; Aires, Silva e Eicholz (2011), who evaluated dry weight, leaf area, relative growth rate, net assimilation rate of the plants, seed to fruit ratio, grain yield per plant and productivity; and Barreto *et al*. (2010), who monitored plant height, stem diameter and number of leaves.

Given the above, the aim of this work was to evaluate the influence of different irrigation levels, both with and without mulching, on growth, productivity, yield components and water use and efficiency in castor-bean crops in a Fluvent Neosol on a family-farming environment in the semi-arid region of the state of Pernambuco, Brazil.

MATERIAL AND METHODS

The study was conducted on an experimental plot on the Nossa Senhora do Rosário Farm, in Pesqueira, located in an alluvial valley in the Agreste region of the state of Pernambuco, 230 km from Recife and 613 m above sea level, at 8°34'17" S and 37°1'20" W (SOUZA; MONTENEGRO; MONTENEGRO, 2008).

Conventional tillage was carried out with disc harrow, followed by digging and fertilising in accordance with the soil analysis (Table 1) performed at the Laboratory of Soil Fertility of the Federal Rural University of Pernambuco (UFRPE). The amounts and fertilizers used were 2 t ha^{-1} of farmyard manure; 15 kg ha^{-1} of nitrogen as foundation and 20 kg ha^{-1} as cover, the source of which was Calcium Nitrate, as recommended by Cavalcanti *et al*. (2008).

Castor beans (*Ricinus communis* L), cv. BRS-Energia were used in the experiment, planted four seeds per hole, in an area of 500 m² and at a spacing of 0.75 m x 1 m, making up a stand of 666 plants.

The physical attributes of the area under study, determined according to Empresa Brasileira de Pesquisa Agropecuária (1997), are described in Table 2, for the layers of 0 to 20, and 20 to 40 cm. The textural class is Sandy loam.

Figure 1 shows soil water-retention curves for the 0 to 20 and 20 to 40 cm layers respectively, in accordance with Empresa Brasileira de Pesquisa Agropecuária (1997).

The experiment lasted 120 days. A localised, self-compensating drip irrigation system was used, with one emitter per plant, following the same spacing as the lines of crops, and having a nominal flow rate of 4 L h^{-1} and a working pressure in the 5 to 40 kPa range, in accordance with the manufacturer.

The experimental design was completely randomised, in a 4 × 2 factorial design (irrigation x with and without mulching) with 4 replications. Irrigation levels were based on crop evapotranspiration (ETc), where L1 = 60% ETc, L2 = 80% ETc, L3 = 100% ETc and L4 = 120% ETc. The mulch used was based on ground up Elephant Grass (*Pennisetum purpureum*) at a density of 12 t ha^{-1}. There were a total of 32 experimental plots with a useable area of 2.25 m² per plot.

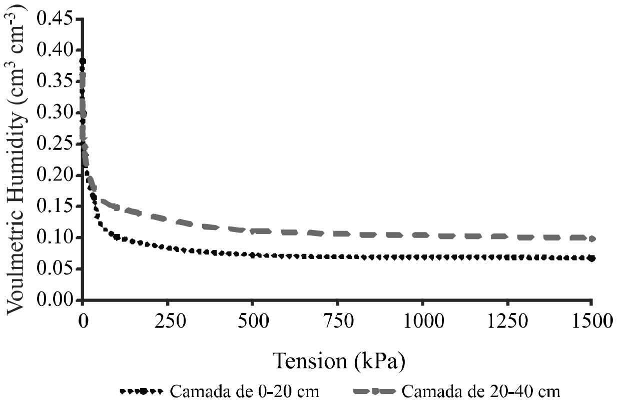
Table 1 - Results of soil fertility analysis in the experimental area. Pesqueira, Pernambuco

Sample	pH	P	Na	K	Ca + Mg	Ca	Al	H + Al	C.O.	M.O.
	(water - 1:2.5)	(mg dm^{-3})	(cmol$_c$ dm^{-3})						(g kg^{-1})	
N.S. Rosário	6.02	100	0.14	0.25	4.5	2.8	0.0	3.31	0.24	0.42

Table 2 - Analysis of texture, density (Ds), particle density (Dp) and total porosity (P) for soil of the experimental area. Pesqueira, Pernambuco

Depth (cm)	Attributes						Textural Class
	Sand	Clay	Silt	Ds	Dp	P	
		g kg^{-1}			g cm^{-3}	(%)	
0-20	647.9	154.4	197.8	1.44	2.61	44.86	Sandy loam
20-40	642.9	173.0	184.1	1.42	2.61	45.44	Sandy loam

Figure 1 - Retention curves for the Fluvent Neosol. Pesqueira, Pernambuco



Evapotranspiration for the crop (ETc) was estimated using meteorological and crop data, as per Equation 1:

$$ETc = \frac{EToxKcxKl}{Ea} \quad (1)$$

where: *ETc* = crop evapotranspiration (mm); *ETo* = Reference evapotranspiration (mm), based on a Class "A" tank; *Kc* Crop coefficient, dimensionless, as a function of the phenological stage of the crop; *Kl* = locational coefficient, dimensionless (KELLER; BLIESNER, 1990); *Ea* = efficiency of the irrigation system.

The values used for the crop coefficients (*Kc*) were adapted from Dias (2009) and are described in Table 3. The tank coefficient, dimensionless, was estimated at 0.75 (ALLEN *et al*., 1998).

At phenological stage 3, there was a gradual increase in the crop coefficients (Kc's) of two-tenths (0.02) over the 18-day duration of this phase.

In order to carry out non-destructive analysis of the growth variables, eight measurements were taken at the following times: 15, 30, 45, 60, 75, 90, 105 and 120 days after germination (DAG), with three plants being evaluated per experimental lot. Non-destructive growth analyses were performed for stem diameter (SD), measured with calipers, plant height (PH), measured with a ruler, and leaf area index (LAI). The determination of LAI was based on the methodology proposed by Severino *et al*. (2004), which is based on the length of the main and lateral inter-vein spaces of each leaf. Adding the results from all the leaves, the total leaf area for the plant is obtained, according to Equation 2.

$$LA = 0{,}2439 \times (P + T)^{2{,}0898} \quad (2)$$

where: *LA*= leaf area (m^2); *P* = length of the main vein; *T* = average of the two lateral veins.

The LAI is then calculated as the ratio of LA to the crop area. For analysis of productivity, yield components and water use efficiency, a single harvest was carried out 120 days after germination (DAG), with three plants per experimental

Table 3 - Crop coefficients (Kc) adopted for the castor bean crop in the experiment Pesqueira, Pernambuco

Phenological stage	Phase characterisation	Duration in days	Kc
F1	From germination to 10% ground cover	14	0.75
F2	F1 - to inflorescence of 1st bunch	34	0.85
F3	F2 - to inflorescence of 2nd bunch	18	0.85-1.15
F4	F3 - to maturation of 1st bunch	36	1.15
F5	F4 - to maturation of 2nd bunch	18	0.85

Source: Adapted from Dias (2009)

plot being sampled. Analyses were made of fruit yield (FP) (kg ha^{-1}), berry yield (BP) (kg ha^{-1}), number of racemes per plant (NRP), length of racemes (LR) (cm); percentage bark (PB) and 100-seed weight (W100) (g). Finally the water use efficiency (WUE) (kg m^{-3}) was analysed.

Variance analysis was used when investigating the variables of growth, productivity, yield components and water use efficiency; this due to the different irrigation levels and the presence and absence of mulching. To analyse the normality of the different factors, the Kolmogorov-Smirnov test was used. In all of these analyses the SAS software (SAS Institute, 1999) was employed.

Where significant, the data were subjected to regression analysis, using linear or quadratic models. Where there was no adjustment to the models, the averages were compared by Tukey test at 5 % probability.

RESULTS AND DISCUSSION

Figure 2 shows the values of ETo, measured in a Class “A” tank, together with the total rainfall for the crop cycle. Three events are seen to have occurred, at 31, 32 and 33 DAG, totalling 154.5 mm.

The results of the Kolmogorov-Smirnov test are shown in Table 4 and demonstrate a normal distribution of the data obtained.

Table 5 shows the effects of the irrigation treatments (L1 = 496.17 mm, L2 = 588.19 mm, L3 = 679.77 mm and L4 = 772.22 mm) and ground cover (WM and NM) at 120 days after germination (DAG), as well as their respective interactions on the studied variables. Plant height (PH), stem diameter (SD) and leaf area index (LAI) were not affected by the irrigation levels, being affected by mulching, at levels of 1.5 and 1% probability respectively. The lack of any significant interaction between factors (level × mulching) indicates that the effect from mulching on plant height is not dependent on the irrigation levels applied. The differences in growth produced by mulching can be seen in Table 6.

Figures 3A and 3B show the behaviour of plant height (PH) as a function of irrigation levels and the presence or absence of mulching respectively, during the crop cycle. For the effect from mulching, the WM treatment was better than

Figure 2 - Distribution of ETo and rainfall during the experiment, Pesqueira, Pernambuco

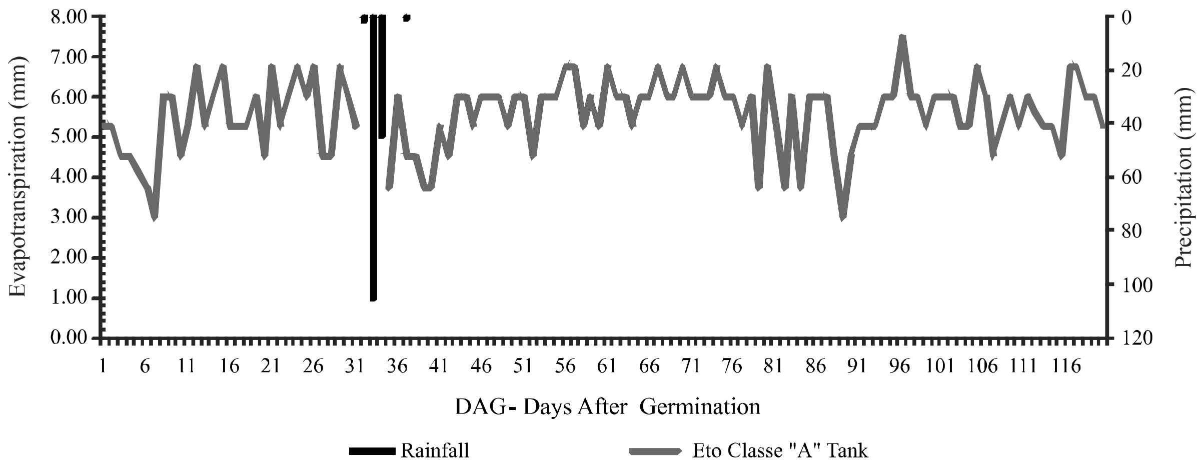


Table 4 - Summary of the Kolmogorov-Smirnov test (KS) for variables obtained 120 days after germination: plant height (PH), stem diameter (SD), leaf area index (LAI), number of racemes per plant (NRP), length of racemes (LR), fruit yield (FP), berry yield (BP), percentage bark (PB), 100-seed weight (W100)

N	PH	SD	LAI	NRP	LR	FP	BP	PB	W100
	32	32	32	32	32	32	32	32	32
K-S (D)	0.09	0.09	0.13	0.13	0.14	0.11	0.07	0.09	0.19
K-S α = 0.05	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23

N - Number of values

NM, with average respective values of 141.78 and 118.66 cm. These values are higher than those found by Silva *et al*. (2009) in Barbalha, in the state of Ceará (maximum of 105.74 cm). Whereas Dias (2009), also working in Barbalha and with the same cultivar, noted that plant height reached about 139.67 cm, while recording an average height of 108.50 cm, still less than that obtained in this study.

For all the growth variables under study, it can be seen that there was no effect from the absence of mulching until approximately 30 DAG; the absence of mulching having excelled from between 30 to 60 DAG. Such behaviour can be attributed to rainfall events during the study period promoting an increase in soil humidity until mid 75 DAG. From that time on, the treatment with mulching begins to surpass that with no mulching by allowing greater retention of soil moisture.

The reduction in crop growth in the absence of mulching can be attributed to a decrease in plant metabolism, and hence in growth, so as to prevent further loss of water to the environment (PEIXOTO *et al*., 2010).

Table 5 - Summary of variance analysis for growth variables at 120 days after germination in the castor bean, BRS Energia. Pesqueira, Pernambuco

SV	DF	SS	MS	F	Pr>F
		Plant height			
Irrigation level	3	1,416.45	472.15	2.50	0.08
Mulch	1	4,666.17	4.666.17	24.72	<0.0001
Irrigation level × Mulch	3	229.52	76.51	0.41	0.75
Residue	24	4,530.47	188.77		
CV=10.44					
		Stem diameter			
Irrigation level	3	24.66	8.22	0.76	0.53
Mulch	1	59.13	59.13	5.47	0.03
Irrigation level × Mulch	3	2.25	0.75	0.07	0.98
Residue	24	259.62	76.50		
CV=13.21					
		Leaf area index			
Irrigation level	3	0.58	0.19	0.75	0.53
Mulch	1	3.15	3.15	12.36	0.002
Irrigation level × Mulch	3	0.24	0.24	0.31	0.82
Residue	24	6.12	0.26		
CV=59.36					

SV - Sources of variation; DF - Degree of freedom; SS - Sum of squares; MS - Mean square; F - F value; Pr>F – Significance; CV - Coefficient of variation

Table 6 - Average growth variables, with mulch (WM) and without mulch (NM), at 120 days after germination of the castor bean, BRS Energia. Pesqueira, Pernambuco

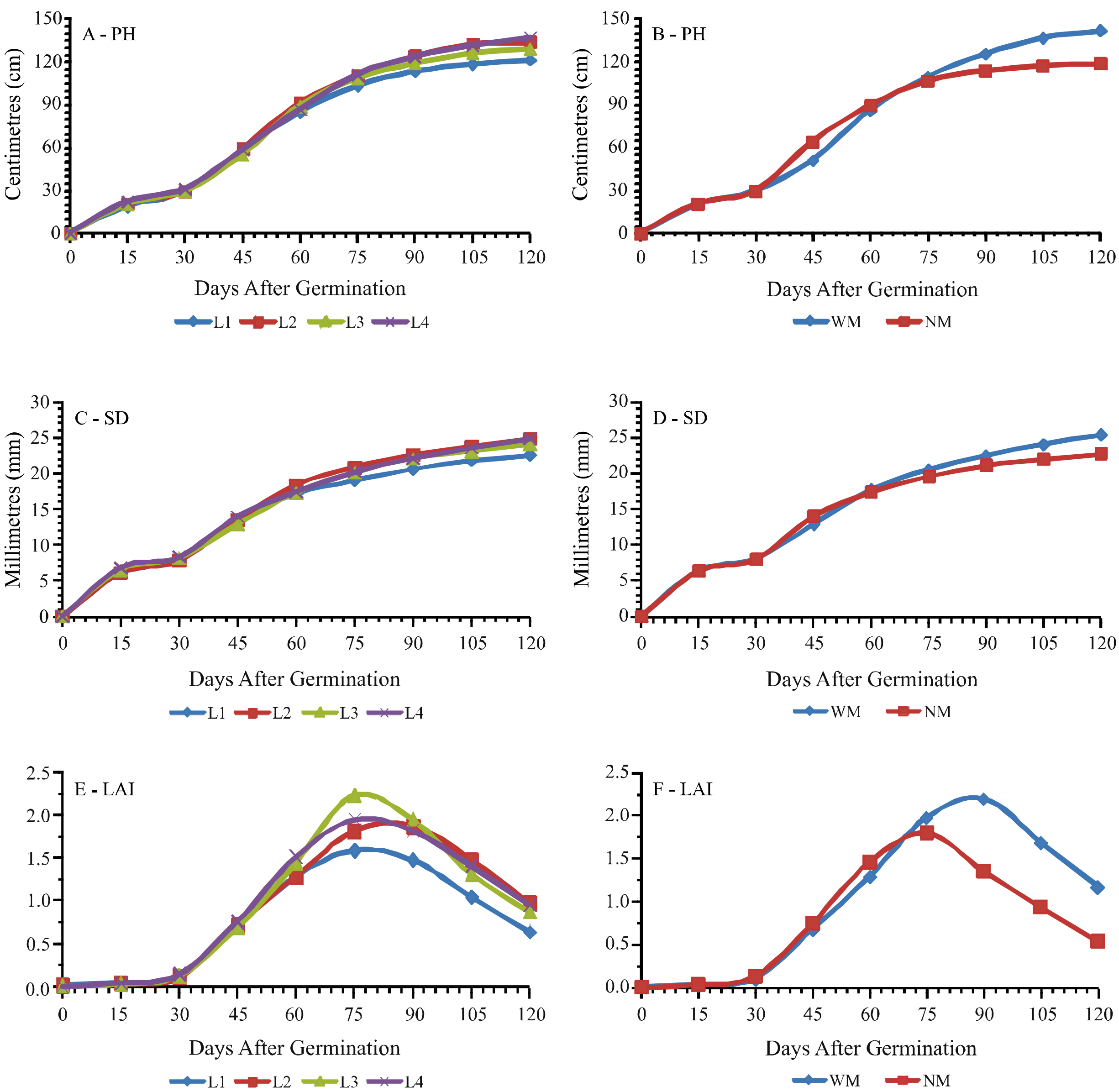
Cover	PH	SD	LAI
	cm	mm	
WM	143.69 a	26.25 a	1.16 a
NM	119.54 b	23.51 b	0.54 b

Different letters in the same column indicate differences between averages at 5% probability by Tukey test. PH - plant height; SD - stem diameter; LAI - leaf área index

Figures 3C and 3D show the behaviour of stem diameter (SD) during the study period. A gradual increase can be seen until the values for SD become stable at 105 DAG. Treatments with mulching are seen to be superior to those treatments with no mulching, with an average maximum value of 25.33 mm for the treatment with mulching and a minimum of 22.72 mm for that with no mulching, at 120 DAG.

It should be mentioned that these can be considered appropriate values. Silva *et al*. (2009) observed for SD, values in the order of 18.0 mm, and Silva (2010) found an average value of 22 mm for SD. For the castor bean cv. Guarani, Bizinoto *et al.* (2010) found maximum and minimum values of SD in the order of 35 and 28 mm respectively, in Bom Jesus in the state of Goiás, higher than those obtained here. On the other hand, Carvalho *et al*. (2010) conducted an experiment in the municipality of Cariri in the state of Tocantins with the cultivars BRS Nordestina and BRS Paraguaçu, and found a maximum and minimum SD of 39.2 and 37.2 mm respectively.

Figure 3 - Evolution of the growth of the castor bean BRS Energia, for treatments of irrigation (L1, L2, L3, L4) and mulching (NM, WM). Pesqueira, Pernambuco



PH - plant height; SD - stem diameter; LAI - leaf área index

Behaviour of the Leaf Area Index (LAI) is shown in Figures 3E and 3F. It can be seen that treatments with mulching were superior in relation to those with no mulching. In all treatments, there is a gradual increase, culminating in the greatest maximum LAI in the period between 75 and 90 DAG, and then decreasing until the end of the crop cycle. The treatment with the best performance was L3, with a maximum value of 2.22 at 75 DAG. The lowest LAI value was 0.63 for treatment L1at 120 DAG. The WM treatment produced a maximum LAI value of 2.18, significantly surpassing the NM treatment with 1.80. This result is associated with the lower availability of water in the soil causing a reduction in leaf area due to the drying out or fall of the leaves.

Peixoto *et al*. (2010), studying the performance of five castor bean cultivars (BRS 149 Nordestina, BRS 188 Paraguaçu, EBDA MPA 17, Mirante 10 and Sipeal 28), in the Reconcavo region of Bahia, obtained values of 2.12, 1.68, 1.36, 1.06 and 1.53 respectively for maximum LAI, all below the maximum obtained here.

Peixoto *et al*. (2010) also point out that high values for LAI are not always positively correlated with the final yield of the cultivated species. However, low values for this growth characteristic can limit the productive potential of the crops. Low LAI values limit yield, since LAI represents the storage system of the plant community and can be considered an important factor in productivity.

As for productivity, yield components and water use efficiency, Table 7 shows the effects of the irrigation and ground cover treatments at the end of the crop cycle (120 DAG), as well as their respective interactions on the variables under study at 1 and 5% levels of probability. It can be seen that all of the variables except W100 presented significant effects from the treatments used. Only W100 did not responded positively to the effect from the ground cover, while LR, FP and BP responded significantly to both the effect from irrigation levels (Table 8) and that from ground cover alone (Table 9), however with no significant difference for the interaction of these treatments on the variables.

Mulching made possible an increase of 22.8% in the number of racemes per plant, resulting in better crop performance. The results for NRP are superior to those obtained by Ferrari Neto *et al*. (2011) when working with the Hybrid Iris, in Botucatu, São Paulo, in different successive sowings intercropped with Pigeon pea (*Cajanus cajan*) and millet (*Pennisetum glaucum*), and obtaining around 2.2 racemes per plant.

There was a significant difference between irrigation levels in relation to the length of racemes (LR). Better performance was noted for L3, illustrated by 100 % ETc, with an average value of 41.43 cm. As for the effect from ground cover, a significant increase, of the order of 9.58%, can be seen with mulch in relation to no mulch.

Bizinoto *et al*. (2010) evaluated LR in the castor bean cv. Guarani, influenced by different plant populations, in Bom Jesus, Goiás, and found no significant difference between treatments, obtaining maximum and minimum values of LR of 58 and 50 cm respectively. Silva *et al*. (2009), when studying the effects of irrigation levels on populations of castor bean plants cv. BRS Energia in Barbalha, Ceará, found maximum values for LR of 41 cm. Dias (2009), also working with irrigation levels on the cultivar BRS Energia, obtained average maximum and minimum LR values of 41 and 33 cm, similar to the results found here.

The variable fruit yield was also seen as statistically significant. It can be seen that the non-deficit irrigation levels produced a greater yield of berries, exceeding 3,300 kg ha^{-1}. Furthermore, there was a significant effect from the mulch on the castor bean crop, since it resulted in an increase of the order of 31.09% in fruit productivity, improving crop performance compared to that seen in bare ground.

Silva *et al*. (2009) observed a fruit yield of 1,937.40 kg ha^{-1} in the castor bean cv. BRS Energia. Additionally, Freitas *et al.* (2010) evaluated the performance of production variables in three castor bean cultivars (IAC Guarani, Mirante 10 and BRS *Paraguaçu*) under five levels of drip irrigation based on the evaporation of a Class “A” tank, at Pentecoste, Ceará, and noted than BRS *Paraguaçu* presented the greatest berry yield, of around 2,872.42 kg ha^{-1}, lower than the values obtained here.

However Moreira *et al*. (2009), in Fortaleza, Ceará, evaluated production factors in the IAC Guarani variety of castor bean under different levels of drip irrigation, also quantified from the evaporation measured in a Class “A” tank, and found that irrigation based on an estimated 100% ECA provided the highest total fruit yield, of approximately 4,100 kg ha^{-1}, higher than the values found in this study.

There was a statistical significance for berry yield, where it was noted that the non-deficit irrigation levels gave the highest yields.

The significant effect from ground cover can also be seen, increasing the berry yield by about 27% compared to no cover, a substantial increase in crop yield. The values for productivity in the castor bean based on PB are much higher than the national average with reference to the 2010 harvest, which was approximately 621 kg ha^{-1}, according to Instituto Brasileiro de Geografia e Estatística (2011).

This result also exceeds that found by Silva (2010) who, when studying the effects of different effluents of treated domestic sewage and irrigation levels (100 and 120 %

Table 7 - Summary of variance analysis for productivity, yield components and water use efficiency in the castor bean, BRS Energy. Pesqueira

SV	DF	SS	MS	F	Pr>F
Number of racemes per plant					
Irrigation level	3	0.27	0.09	0.86	0.48
Mulch	1	0.73	0.73	6.99	0.01
Irrigation level × Mulch	3	0.07	0.34	0.24	0.87
Residue	24	2.50	0.10		
CV		12.79			
Length of racemes					
Irrigation level	3	4.34	1.44	76.96	<0.0001
Mulch	1	0.74	0.74	39.63	<0.0001
Irrigation level × Mulch	3	0.10	0.03	1.70	0.19
Residue	24	0.45	0.02		
CV		2.27			
Fruit yield					
Irrigation level	3	875.97	291.99	5.48	0.0052
Mulch	1	789.77	789.77	14.82	0.0008
Irrigation level × Mulch	3	11.02	3.67	0.07	0.96
Residue	24	1,278.76	53.28		
CV		13.81			
Berry yield					
Irrigation level	3	602.74	200.91	5.37	0.0057
Mulch	1	421.48	421.48	11.26	0.0026
Irrigation level × Mulch	3	6.77	2.26	0.06	0.98
Residue	24	897.99	37.42		
CV		13.51			
Percentage bark					
Irrigation level	3	0.49	0.16	1.87	0.16
Mulch	1	1.07	1.07	12.15	0.002
Irrigation level × Mulch	3	0.03	0.01	0.10	0.96
Residue	24	2.11	0.09		
CV		5.69			
100-seed weight					
Irrigation level	3	0.22	0.07	2.19	0.12
Mulch	1	0.04	0.04	1.13	0.30
Irrigation level × Mulch	3	0.03	0.01	0.29	0.83
Residue	24	0.81	0.03		
CV		3.19			
Water use efficiency					
Irrigation level	3	0.01	0.003	1.25	0.31
Mulch	1	0.02	0.02	11.29	0.003
Irrigation level × Mulch	3	0.0002	0.0001	0.03	0.99
Residue	24	0.053	0.002		
CV		5.15			

CV - Coefficient of variation

Table 8 - Average values for productivity, yield components and water use efficiency for irrigation levels (L1, L2, L3 and L4) in the castor bean, BRS Energia. Pesqueira, Pernambuco

Irrigation Level (mm)	NRP	LR cm	FP kg ha^{-1}	BP kg ha^{-1}	PB %	W100 g	WUE kg m^{-3}
L1 = 496.17	5.17 a	29.96 c	2018.8 b	1494.3 b	26.18 a	31.13 a	0.30 a
L2 = 588.19	6.17 a	33.83 d	2862.4 ab	2118.2 ab	25.82 a	32.52 a	0.36 a
L3 = 679.77	6.38 a	41.41 a	3318.3 a	2461.4 a	25.99 a	33.89 a	0.36 a
L4 = 772.22	6.21 a	38.68 b	3337.2 a	2360.9 a	29.06 a	32.60 a	0.31 a

Different letters in the same column indicate differences between averages at 5% probability by Tukey test

Table 9 - Average values for productivity, yield components and water use efficiency with mulch (WM) and no mulch (NM), in the castor bean, BRS Energy. Pesqueira, Pernambuco

Ground Cover	NRP	LR cm	FP kg ha^{-1}	BP kg ha^{-1}	PB %	W100 g	WUE kg m^{-3}
WM	6.75 a	37.78 a	3415.0 a	2435.0 a	28.66 a	32.94 a	0.38 a
NM	5.21 b	34.16 b	2353.4 b	1782.3 b	24.87 b	32.13 a	0.28 b

Different letters in the same column indicate differences between averages at 5% probability by Tukey test

ETc) on the growth of the castor bean BRS Energia in Ibimirim, Pernambuco, obtained a maximum production of 1,923.28 kg ha^{-1}. However, better results were found by Dias (2009) who, also working with this same cultivar in Barbalha, Ceará, at four irrigation levels, achieved a maximum productivity of the order of 3,361.72 kg ha^{-1}. Devide *et al*. (2010), in Pindamonhangaba, São Paulo, evaluated the performance of the castor bean IAC 80, cultivated under no-tillage in oat straw and intercropped with food crops, and obtained 1,060 kg ha^{-1} of berries.

In this study, the percentage of bark (PB) did not differ for the irrigation levels adopted. For the treatments with and without mulch as ground cover, WM had a higher percentage of bark, of the order of 13.22%, compared to no mulch. These results were better than those found by Zuchi *et al*. (2010), who evaluated the performance of the cultivars Al Guarany 2002, IAC 80, IAC 226 and BRS 188 *Paraguaçu* in Pelotas, Rio Grande do Sul, and obtained maximum values for PB of 39, 44, 34 and 43% respectively.

The 100-seed weight (W100) also showed no difference for irrigation levels. Similar results were obtained by Soratto *et al*. (2011), Ferrari Neto *et al*. (2011), Diniz Neto *et al*. (2009) and Dias (2009), with maximum values for W100 of the order of 38.9, 40.3, 28.6 and 35.4 g respectively.

Dias (2009) points out that the WUE is the ability of the crop to assimilate carbon while limiting water loss through the stomata, and that this depends on the capacity for CO_2 assimilation, photosynthetic efficiency and the type of plant.

In this work, the WUE showed a significant difference only for the presence of mulch, which consequently enabled better water use by the plant. With mulch, an increase of about 26% in WUE was observed when compared to no mulch. These values were improved by Dias (2009), who obtained 0.498 and 0.474 kg m^{-3}, for the 2005 and 2006 crop years respectively.

CONCLUSIONS

1. W100 was the only variable that showed no significant difference between treatments. At 120 days after germination, all the growth variables responded significantly to mulching. NRP, PB and WUE responded significantly to mulch on the ground, while LR, FP and BP to the isolated effects of the irrigation levels and mulching;
2. Mulching resulted in better growth performance in the castor bean, Energy BRS compared to no mulching, and the non-deficit irrigation levels generated berry yields exceeding 2,360 kg ha^{-1}, considered high when compared to the national average.

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