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Agronomic performance and profitability of castor bean (*Ricinus communis* L.) and peanut (*Arachis hypogaea* L.) intercropping in the Brazilian semiarid region

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Abstract

Castor bean (*Ricinus communis* L.) is important an important plant due to its easily cultivation, drought tolerance and beneficial adaptation combined to other food crops, like peanuts (*Arachis hypogaea* L.). Castor is an interesting option to increase producer income and improve land use efficiency in intercropping. This research was carried out to evaluate advantages, yield, cost of production and profitability in the intercropping castor/peanut as a function of sowing time. The castor genotype (BRS Energia) and peanut (BR-1) were grown in monocropping and intercropping systems. A randomized block design was used with four replications and eight treatments, being five treatments in intercropping (castor + peanut) varying the interval sowing of peanut regarding to the sowing of castor (0, 10, 15, 20 and 25 days), and three treatments with castor and peanut cultivated in monocropping. The yield of both crops as well the profitability of the cropping systems, cost of production and competitive rates were evaluated. The grain yield of both intercropped crops was affected when the sowing time was expanded. There was better castor yield in longer sowing time compared to peanut. In this case, intercropping was more advantageous to castorbean when peanut was sown between 15 and 20 days late with better competitive ability of castor. The larger total operational cost of US$ 1452.11 ha^{-1} observed in peanut monocropping spaced 1.0 m × 0.2 m mainly due to higher material expenses and inputs, compared to intercropped system. The intercropping castor/peanut in the spaces 2.0 × 0.5 (castor) and 2.0 × 0.2 (peanut) under Brazilian semiarid region can be suitable and profitable when peanut is sown 20 days after castor.

Keywords: cost of production; cropping systems; economic analysis; land use efficient; oil plant.
Abbreviations: AG_Aggressivity; ATER_Area-Time Equivalent Ratio; B/C_Benefic Cost ratio; BRS_Brazil Seeds; CAB_Cost and Administrative Burdens; CP_Cost of Production; CR_Competitivity Ratio; CW_Cost of Irrigation Water; DAS_Days After Sowing; EEC_Electrical Energy Consumption; EOC_Effective Operational Cost; ETo_Evapotranspiration; GI_Gross Income; GM_Gross Margin; NI_Net Income; LEC_Land Equivalent Coefficient; LER_Land Equivalent Ratio; LL_Total Water Level applied; Pe_Electricity Price; PI_Profitability Index; TCW_Total Cost of Water; TOC_Total Operational Cost.

Introduction

Castor is an important non-edible oil seed crop grown throughout the world (Radhamani et al., 2012). It is used primarily in traditional medicine but its main interest is for biofuel production to reduce dependency on fossil fuel (Nahar, 2013). Besides, it has been used for production and manufacturing of cosmetics and candles (Deore and Johnson, 2008). Its greatest production is concentrated in India, China, Brazil and Mozambique, which has around average productivity of 644 kg ha^{-1} and total production around 1.5 million tons (Fao, 2011; Severino and Alud, 2014).

In Brazil, castor production is concentrated in the Northeast, especially in semiarid region, where it is cultivated by small family farmers in intercropping with food crops. In order to increase the productivity of the land, some species are widely suitable for intercropping with castor, such as beans, cassava, peanuts and maize (Alom et al., 2010; Sharath et al., 2010; Obiero et al., 2014). It is emphasized that intercropping is a useful alternative especially at small farms by maximizing the use of the land (Jesen et al., 2010) and improve the food production by providing income and welfare of farmers, intensify the land equivalent ratio and reduce the total risk of loss production. However, the successful intercropping also requires knowledge of production physiology of the mixed crops (Lithourgidis et al., 2011).

In this context, the castor crop is important for agriculture at the semiarid regions by its easy cultivation, drought tolerance and by providing jobs and income in agricultural areas, especially for family farm, besides being promising alternative for biofuel production (Beltrão et al., 2010; Nahar, 2013). Thus, studies have been conducted to evaluate the production of castor in monocropping and intercropping systems, to benefit agriculture in small farms (Beltrão et al., 2010; Kumar et al., 2010; Ferreira et al., 2014; Obiero et al., 2014).

It has been emphasized that the slow growth of castor in the initial phase minimizes competition between species and improve their insertion in productive arrangements. In this case, there are effects in the levels of competition for luminosity, nutrients and space (Beltrão et al., 2010).

In the semiarid region, rainfall distribution is irregular, which may cause inability of agricultural lands. So, the use of irrigation is indispensable to increase agricultural productivity (Frizzone et al., 1994), making necessary economic viability studies of irrigated crops under risk conditions. According to Santos et al. (2009) and Hafle et al. (2010) the economic analysis of the viability for a new technology must consider all factors into production process, allowing and facilitating decision making and control of operations and productive resources. One of the most important indicators is the profitability index, which represents available revenue rate of agricultural activity, after payment of operating costs, enabling the verification of the feasibility of the venture (Garcia et al., 2012).

Although there are publications on intercropped castor, quite few conclusive studies are found regarding the intercropping of castor and peanut (Beltrão et al., 2010; Kumar et al., 2010). So, it is necessary to investigate the effects of interval of peanut sowing on the agronomic and economic yield to manage the tillage sustainability and at lower cost. Peanut has accelerated growth and short cycle and its characteristics are desirable to the intercropping with castor. Therefore, we assessed the advantages, yield, cost of production and profitability in the intercropping castor and peanut as a function of sowing interval between species in the Brazilian semiarid region.

Results and Discussion

Yield of castor and peanut

The grain yield of intercropped castor bean was affected by peanut according to their sowing intervals (Fig 1). The intercropping of castor and peanut reduced the yield potential compared to monocropping. There was greater yield reduction at intercropping of castor/peanuts sown simultaneously (T4). Similar results were also found at castor intercropped with common bean. According to Ferreira et al. (2014) the agronomic traits of common bean were influenced by intercropping with castor. However, Teixeira et al. (2011; 2012) reported non-different yield of castor intercropped with common bean due to the absence of competition by this leguminous.

The yield of castor beans was higher when peanut was sown late (T8). In this treatment, a grain yield of 2843.25 kg ha^{-1} with increase of 42 % was observed, compared to the yield obtained at simultaneous sowing of castor and peanut (T4) (Fig 1). The peanut sown 0 and 15 days after castor did not show significant effect on castor yield. However, a lower value was found when the crops were sown at the same time. This result could be attributed to the faster early growth of peanut, increasing their competition in the intercropping, which affects early development stages of castor bean with a lower rate of emergence and slow initial growth. In species highly competitive such as maize/sorghum/cowpea/peanut, the sowing should be performed at different stages between crops in order to prioritize the consort species of greatest interest (Teixeira et al., 2012). Thus, sowing castor 15 to 20 days before another consort crop is advised (Beltrão et al., 2010).

Between monocropping and intercropping systems of castor, there was difference of 35.5 %, in which a better yield (2724.08 kg ha^{-1}) was observed in monocropping. In intercropping of two crops, the search for environmental resources is more competitive, which reduces the productive potential of the species in the intercropping and provides more aggressive culture. However, intercropping is important for better use of natural resources and reduces risks for family farmers. In both systems, the environment becomes competitive and requires adjustments to avoid aggression from the dominant culture.

The yields obtained in this study were expressive with regard to use of irrigation technique because in rainfed cropping the castor productivity is low, but can be increased under irrigation (Obiero et al., 2014). Another research by Teixeira et al. (2011; 2012) have obtained 1682 and 1763 kg ha^{-1} grain of castor intercropped with common beans and 1500 kg ha^{-1} when intercropping castor and peanut, respectively (Beltrão et al., 2010).

In the intercropping treatments, there was no statistical difference between yield of peanut pods, but the highest yield (980.65 kg ha^{-1}) was obtained at 15 days after sowing of castor bean (T6) and the lowest (753.72 kg ha^{-1}) at 25 days after sowing castor (T8) (Fig 2). The interval of planting peanut enables better utilization of natural resources by castor, reflecting on its dominance in the system. Furthermore, under treatments with late sowing of peanut, castor plants were more aggressive and competitive by the water, nutrient and light, with quick increase of growth (height and leaf area), and provided shading on peanut. Shading reduces solar radiation to the lower crop and its leaf area, which implies the reduction of crop development. The choice of optimal arrangement and sowing of vegetables is essential in the performance of intercropping, by maximizing production. It had 46 % reduction in peanut yield according to increase of time sowing, associated with yield improvement of another crop (Beltrão et al., 2010).

There was decrease of 38.5 % in the yield of peanut intercropping (T4) compared to monocropping with the same spacing (T2) (Fig 2). Beltrão et al. (2010) and Teixeira et al. (2012) have found decrease of yield in peanut and common bean under intercropping system. Similar results were reported by Razzaque et al. (2007) and Alom et al. (2010). It is associated with environmental resources because the higher numbers of plants in an limited area causes reduction in availability of soil and environmental factors for crops.

In the peanut monocropping (T2 and T3), the difference in yield of pods reached 123 %, with maximum yield (2813.21 kg ha^{-1}) in the denser cultivation (T3) and lowest (1261.38 kg ha^{-1}) when was grown with wider spacing (T2) (Fig 2). In the denser peanut, for having twice more plants per area, production was higher than the national average (2674 kg ha^{-1}). In a study of plants density, Rasekh et al. (2010) reported increase of pod yield when increased plant density from 3 to 8.3 plant m^{-2}, but 14.8 plant m^{-2} decreased pod yield of peanut. El Naim et al. (2011) obtained highest peanut yield with spacing of 10 cm between rows and estimated on 40% more yield than that at 40 cm.

Table 1. Effect of intercropping castor and peanut in the indices of land equivalent ratio (LER), land equivalent coefficient (LEC), area-time equivalent ratio (ATER), competitive ratio (CR) and aggressivity (AG).

Treatments	LER Partial		LER	LEC	ATER	CR		AG	
	Castor	Peanut				Castor	Peanut	Castor	Peanut
T4	0.74 b	0.72 a	1.46a	0.53a	2.11 a	6.39 b	0.16 a	1.55 b	-1.55 a
T5	0.88 ab	0.76 a	1.64a	0.67a	2.41 a	7.20 b	0.14 a	1.89ab	-1.89ab
T6	0.94 ab	0.78 a	1.72a	0.73a	2.54 a	7.54 b	0.13 ab	2.03ab	-2.03ab
T7	1.03 a	0.69 a	1.72a	0.71a	2.63 a	9.28ab	0.11 ab	2.30 a	-2.30 b
T8	1.04 a	0.59 a	1.63a	0.62a	2.56 a	10.92a	0.09 b	2.37 a	-2.37 b

T4 (castor + peanut, sown at the same time); T5 (castor + peanut sown 10 days after); T6 (castor + peanut sown 15 days after); T7 – (castor + peanut sown 20 days after); T8 (castor + peanut sown 25 days after). Different letters in the column to significant differences among treatments according to statistical analysis (Tukey's test P≤0.05).

Table 2. Production costs for the cultivation of castor and peanut in monocropping and intercrop system.

Description	Treatments							
	T1	T2	T3	T4	T5	T6	T7	T8
	US$ ha^{-1}							
EOC								
Inputs	380.50	303.40	571.80	494.30	494.30	494.30	494.30	494.30
Soil preparation and planting	190.00	240.00	240.00	215.00	215.00	215.00	215.00	215.00
Crop practices	335.00	285.00	360.00	360.00	360.00	360.00	360.00	360.00
Harvest	250.00	250.00	375.00	375.00	375.00	375.00	375.00	375.00
Subtotal	1155.50	1078.40	1546.80	1444.30	1444.30	1444.30	1444.30	1444.30
CAB								
Burdens financial	841.21	835.42	1045.55	1030.86	1030.86	1030.86	1030.86	1030.86
Depreciation*	202.60	202.60	302.60	302.60	302.60	302.60	302.60	302.60
Subtotal	1043.81	1038.02	1348.15	1333.46	1333.46	1333.46	1333.46	1333.46
TCW	288.80	299.70	299.70	318.10	337.30	353.40	348.00	352.20
CP	2488.11	2416.12	3194.65	3095.86	3115.06	3131.16	3125.76	3129.96

[*] Depreciation of irrigation equipment, being the value of a fixed portion of the total diluted at ten times. Effective operational cost (EOC), costs and administrative burdens (CAB), total cost of water (TCW) and cost of production (CP). T1 (castor in monocropping); T2 (peanut in monocropping); T3 (peanut in monocropping with denser planting); T4 (castor + peanut, sown at the same time); T5 (castor + peanut sown 10 days after); T6 (castor + peanut sown 15 days after); T7 – (castor + peanut sown 20 days after); T8 (castor + peanut sown 25 days after).

Competition indices in the cropping systems with castor and peanut

The value of land equivalent ratio (LER) of castor was increased when a larger time of peanuts sowing was used. However, LER of peanut decreased with sowing 20 days after castor bean (Table 1). Our results highlight the dominance of castor combined with peanut. The decreased LER in peanut may be related to lower availability of light, due to the shading of castor bean, which decreased photosynthetic rate, growth and production. Intercropping performance is largely governed by the availability and the competition for the environmental resources. The competition for growth factors such as light, water or nutrients affects the yield of combined crops (Lithourgidis et al., 2011).

The evaluation of crops systems through the LER revealed advantage for all treatments of intercropping (castor + peanut), compared to the monocropping. There was increasing values as a function of peanut sowing times (Table 1). Maximum LER was obtained in T6 and T7, with productive advantage of 72 %. Pinto et al. (2011) studied the intercropping of castor and sesame. They found gains in production of intercropping systems, with LER from 1.20 to 1.56. Similar to the results of our study, Kumar et al. (2010) reported LER rates from 1.66 to 1.67 in castor intercropped with peanut.

Values of land equivalent coefficient (LEC) in all intercropping treatments were greater than 0.25, which indicate yield advantages in the consortium systems, regardless of sowing date of peanuts. The biggest LEC (0.73) was registered with castor intercropped with 15 days before sowing of peanuts (T6) (Table 1).

Regarding ATER, the values were greater than unity in all cases of intercropping, demonstrating advantage in land use and time in all treatments. ATER values were increased with different sowing times of peanut, though there is greater value in castor and peanut combination sowed 20 days late (T7). These results may be related to the earned income on the combination with temporal difference between species and may have direct association with different sowing dates of peanut.

The competitive ratio (CR) is the degree to which specie competes with another in the intercropping system. Thus, CR for castor bean was always higher than peanut, which evidence their dominance in the system with greater ability to compete for environmental resources (Table 1). This competitive ability of castor was increased with the times of sowing of peanut, which was registered maximum value of 10.92 in most epochs, decreasing 78 % in the competitive ability of peanut. Similarly, the aggressiveness (AG) was positive in castor, indicating be the dominant in the system, exerting greater productive advantage. Moreover, peanut was dominated crop with negative AG characterizing small competitivity in the crop system (Table 1). These results emphasize that the castor has greater competitive ability when associated to peanut. Thus, large intervals of sowing between crops affect the intercropping system. It is necessary to adjust the planting dates of intercropping to avoid large alterations in the competitive relationships between species.

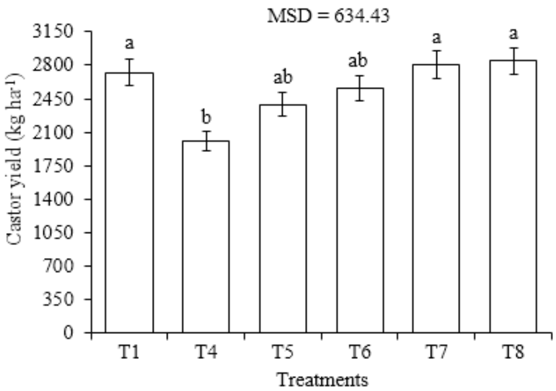

Fig 1. Yield of castor in monocropping and intercropping systems with peanut at different sowing times. T1 (castor in monocropping); T4 (castor + peanut, sown at the same time); T5 (castor + peanut sown 10 days after); T6 (castor + peanut sown 15 days after); T7 (castor + peanut sown 20 days after); T8 (castor + peanut sown 25 days after). Different letters in the column show significant differences among treatments according to statistical analysis (Scott-Knott's test P≤0.05). MSD (minimum significant difference).

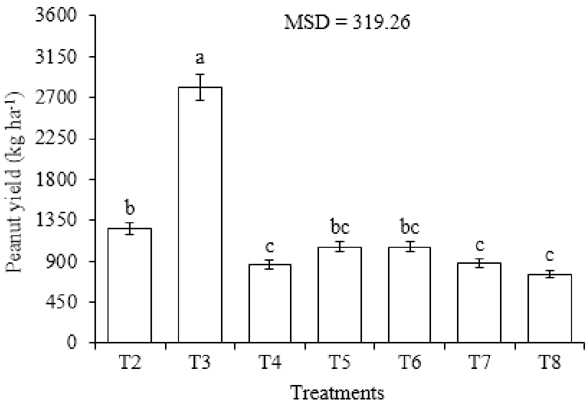

Fig 2. Yield of peanut in monocropping and intercropping systems at different sowing times. T2 (peanut in monocropping); T3 (peanut in monocropping with denser planting); T4 (castor + peanut, sown at the same time); T5 (castor + peanut sown 10 days after); T6 (castor + peanut sown 15 days after); T7 – (castor + peanut sown 20 days after); T8 (castor + peanut sown 25 days after). Different letters in the column show significant differences among treatments according to statistical analysis (Scott-Knott's test P≤0.05). MSD (minimum significant difference).

Cost of production for monocropping and intercropping systems

Greater total cost of production (CP) (US$ 1452.11 ha^{-1}) was observed in monocropping of peanuts (T3), due to the high expense with inputs (US$ 255.91 ha^{-1}), especially with high amount of seeds for planting (Table 2). In the intercropping, there was low variation on CP, but the maximum value (US$ 1423.24.16 ha^{-1}) obtained in T6, when peanuts sowed 15 days after castor. The lowest CP (US$ 1407.21 ha^{-1}) was obtained in cropping system of T4. This small variation in the cost of production in the intercropping treatments is related to the effective operational cost (EOC) and cost and administrative burdens (CAB), which remained constant. Furthermore, small fluctuation in the total cost of water (TCW) varied in the treatments due to rainfall during the experimental period (Table 2). The TCW is directly associated to the volume of water applied and was based on the amount of kilowatt-hours of electrical energy spent in the process of pumping irrigation water. Application of water had direct climatic influence on the different planting seasons, mainly with rainfall, which resulted in variation in the amounts of water applied.

The EOC in the intercropping treatments did not change, but the biggest expense (US$ 224.68 ha^{-1}) was observed with inputs, especially with costs of seeds and chemical fertilizers, which were used in large quantities due to the cultivation of two species associated. In the CAB, there was no variation among the consortium for the financial burdens (US$ 468.57 ha^{-1}) and depreciation of irrigation equipment (US$ 137.55 ha^{-1}), which corresponded to 9.7 % on average CP. We highlight that the acquisition of materials and irrigation equipment had high costs and it became difficult for the small farmer to make the payment at a single time. Therefore, it is necessary to split it in fixed values.

The CP was similar for castor (T1) and peanuts (T2) in monocropping but showed a higher expense (US$ 1130.96 ha^{-1}) in T1 due to the high cost of inputs (US$ 172.95 ha^{-1}), especially with nitrogen fertilization (Table 2).

Petinari et al. (2012) evaluated economic importance of castor bean cultivation and plant population. They identified maximum production costs of US$ 1030.23 and 1062.74 ha^{-1} production in rainfed condition and the cost of fertilizers, pesticides and seeds accounted for 52 % on average the CP. These results were lower than those found in this study because in rainfed crop, there are not necessary expenses with irrigation equipment and water cost, which decreases around 20 % in total cost of production (CP).

Profitability for monocropping and intercropping systems

The gross income (GI) depends directly on yields and price paid for the product. Thus, greatest GI was obtained in T7 and the minimum in T2, due to the lower productivity among monocropping treatments (Table 3). In all intercropping treatments, the net income (NI) was positive, indicating economic return above the monocropping system. The intercropping system with the greatest economic return was T7 with NI of US$ 1862.00 ha^{-1}, gross margin (GM) of US$ 2626.30 ha^{-1} and benefit/cost ratio (B/C) of 2.31. In this system, even US$ 1.00 invested generated US$ 2.31 profit, and profitability index (PI) of 56.72 % (Table 3). The lowest NI (US$ 1202.29 ha^{-1}) was observed in T4, also with low values for GM, B/C and NI. In general, the economic profitability of intercropping treatments is related to the productivity values of castor and the price paid for the product.

Regarding to monocropping with castor (T1), NI was US$ 1283.56 ha^{-1}, GM US$ 1889.34 ha^{-1}, ratio B/C of 2.13 and PI 53.16 % (Table 3). It is emphasized that even with these results, the intercropping system is an interesting alternative because generates better net income and provides family occupation (job) by use in most operations and cultural practices and keeps the farmer on the field, which heats the local economy and increases the land use efficiency.

Regarding to monocropping with peanuts (T2 and T3), economic damage were not perceptive. However, lower NI values were observed in T2, equivalent to US$ 48.47 ha^{-1}, GM of US$ 656.36 ha^{-1}, B/C of 1.04 and PI of 4.23 % (Table 3). A lower economic return for T2 due to the small production (1261.38 kg ha^{-1}) should be noted.

Table 3. Yield, gross income (GI), net income (NI), gross margin (GM), relation benefit/cost (B/C) and profitability index (PI) of castor and peanut in monoculture and intercropping system.

Treatments	Yield (kg ha^{-1})		GI	NI	GM	B/C	PI
	Castor	Peanut	------------- US$ ha^{-1} --------------				%
T1	2724.08	--	5311.95	2823.84	4156.45	2.13	53.16
T2	--	1261.38	2522.76	106.64	1444.36	1.04	4.23
T3	--	2813.21	5626.42	2431.77	4079.62	1.76	43.22
T4	2010.19	910.51	5740.89	2645.04	4296.59	1.85	46.10
T5	2390.28	960.75	6582.54	3467.48	5138.24	2.11	52.68
T6	2556.20	980.61	6945.81	3814.65	5501.51	2.21	54.92
T7	2806.17	875.06	7222.15	4096.40	5777.85	2.31	56.72
T8	2843.25	753.71	7051.75	3921.79	5607.45	2.25	55.61

T1 (castor in monocropping); T2 (peanut in monocropping); T3 (peanut in monocropping with denser planting); T4 (castor + peanut, sown at the same time); T5 (castor + peanut sown 10 days after); T6 (castor + peanut sown 15 days after); T7 – (castor + peanut sown 20 days after); T8 (castor + peanut sown 25 days after).

Table 4. Description of treatments and spacing.

Treatments	Description	Spacings (m)
T1	Castor in monocropping	(2.0 × 0.5)
T2	Peanut in monocropping	(2.0 × 0.2)
T3	Peanut in monocropping with denser planting	(1.0 × 0.2)
T4	Castor + peanut, sown at the same time (C + P)	(2.0 × 0.5) (2.0 × 0.2)
T5	Castor + peanut sown 10 days after (C + P10)	(2.0 × 0.5) (2.0 × 0.2)
T6	Castor + peanut sown 15 days after (C + P15)	(2.0 × 0.5) (2.0 × 0.2)
T7	Castor + peanut sown 20 days after (C + P20)	(2.0 × 0.5) (2.0 × 0.2)
T8	Castor + peanut sown 25 days after (C + P25)	(2.0 × 0.5) (2.0 × 0.2)

The improvement in profitability tends to occur in the next cropping cycles because is not necessary to purchase some equipment and materials, such as irrigation systems and seeds, which is 51.5 % CP, reflecting the decrease in expenditure.

Intercropping and monocropping, based on family crops (beans, maize and vegetables), reduce cost of production after the first cycle, increase the net income, and besides improves the work use, environmental resources and rational use of inputs (Santos et al., 2009). Thus, the intercropping system becomes economically advantageous because it provides high profit. Santos et al. (2009) obtained net income above 56 % in intercropping beans with maize and Kheroar and Patra (2014) in intercropping maize with legumes. According to our results a good economic returns was verified in intercropping, regardless of the cultures used.

Materials and Methods

Plant materials

The castor bean genotype 'BRS Energia' with early cycle (120 to 150 days) and oil content of ~48% and an average yield of 1800 kg ha^{-1} was used. The peanut genotype 'BR1' with the following characteristics was also used cultiavted: average cycle of 89 days, seed yield of 1250 kg ha^{-1} and seed oil content around 45%. According to research conducted at semiarid conditions in Northeast of Brazil, its income can be increased under irrigation. The seeds of the both genotypes were indicated premier by National Center for Research on Cotton, based on the adaptation of genotypes to different environmental conditions, early cycle, high productivity and potential for intercropping systems.

Study site

The study was carried out in one cultivation year under field conditions due to the low variation in seed yield of castor and to their yield ability and yield stability of the cultivars, according to Koutroubas et al. (1999) and Beltrão et al. (2010). They conducted research under similar environmental conditions and reported that cultivars (castor and peanut) intercropped maintained their average yield at one cultivation year. The experiment was performed at the State University of Paraíba, Catolé do Rocha, Paraíba, Brazil (6º21'S e 37º48'W of Greenwich, 250 meters asl). According to Thornthwaite (1948), the climate is the type $Ds_2A'a'$, i.e. semiarid with drought deficiency, showing rainfall of 870 mm $year^{-1}$, air temperature of 27 °C and period rainy season, from February to April 2011. The precipitation of 250 mm, maximum and minimum air temperature of 35.2 °C and 21.8 °C, respectively, during experiment conduction, between June and December 2011 were recorded.

Soil used was a eutrophic Fluvic Entisol of sandy texture and was obtained the following physic and chemical characteristics of soil samples collected at 0.2 m depth: pH, 7.0; organic matter, 13.4 g dm^{-3}; P, 46.8 mg dm^{-3}; K, 0.58 $cmol_c$ dm^{-3}; Ca, 3.37 $cmol_c$ dm^{-3}; Mg, 1.62 $cmol_c$ dm^{-3}; Al, 0.0 $cmol_c$ dm^{-3}; 773.7 g kg^{-1} of sand; 168.3 g kg^{-1} of silt; and 58 g kg^{-1} of clay.

Treatments and experimental set up

Eight treatments were evaluated in a randomized block experimental design with four replications. Five treatments were consisted of cultivation in intercropping (castor + peanut) as a function of sowing interval of peanut regarding to sowing of castor (0, 10, 15, 20 and 25 days), and other three treatments were castor and peanut in monocropping (Table 4).

The experimental area was prepared conventionally with plowing and disking at depths of 0.30 and 0.15 m, respectively. The sowing of castor and peanut in monocropping was performed simultaneously by manual distribution of seeds and the sowing of peanut in intercropping was according to the relative sowing time. The fertilization was performed according to chemical analysis of soil, applying mineral fertilizers NPK, according to Savy Filho (1996).

Weeding was performed to control invasive plants. In cultivated peanut plots ridging and soil adding in base the plants were performed, which protect the base of plant and facilitate the penetration of gynophore in the soil.

Irrigation was performed by drip with emitters spaced of 0.20 m and flow of 2.4 L h^{-1}. The amount of water applied by irrigation corresponded to 100 % of the Reference Evapotranspiration (ETo). Its management was made based on climatic data and ETo calculated by Penman-Monteith model, standardized by Allen et al. (1998). The meteorological data were obtained in the automated weather station next to experimental area.

Yield and economic analysis of cropping systems

The harvest of peanut in monocropping and intercropping systems was performed 93 days after sowing (DAS), following the interval sowing for each treatment. Plots with castor in both cropping systems were harvested at 140 and 165 DAS. The weight of castor grain and pods peanut were determined and the productivity (kg ha^{-1}) was obtained. It were also calculated the indices of land equivalent ratio (LER) (Willey, 1979), land equivalent coefficient (LEC) (Adetiloye et al., 1983), area-time equivalent ratio (ATER) (Hiebsch and McCollum, 1987), competitive ratio (CR) (Willey and Rao, 1980) and aggressivity (AG) (Willey and Rao, 1980).

The cost of production (CP) for 1.0 ha, in the intercropping and monocropping systems of castor and peanuts was according to Matsunaga et al. (1976), which Total Operational Cost (TOC) consisted of expenditures for handing and mechanized operations, equipment and material consumption. The TOC consists of the Effective Operational Cost (EOC) and the Costs and Administrative Burdens (CAB). The EOC corresponded to variable costs or direct costs as financial disbursement for the activities, from soil preparation up to harvest. The values of the items involved in this category were obtained from average prices in the local, along with the various institutions and enterprises from June to December 2011.

The CAB, represents the fixed costs or indirect costs relating to interest rates, social charges, administration fees and depreciation of equipment. It is related to remuneration of the equity capital calculated on the basis 0.5 % per month over the half the value of the EOC, aiming to remunerate the alternative use of the capital producer, choice if it is used in financial savings. The remuneration of the land factor corresponds to the actual rental value of 1.0 ha, depreciation of machine and equipment, or resources needed to cover spare parts, corresponding to 10 % of the value of irrigation equipment and a management fee calculated on the basis of 6 % of the EOC.

The Total Cost of Water (TCW) was obtained using the equation $CW = (EEC / LL) \times Pe$, where CW is the cost of irrigation water (US\$ mm^{-1}), EEC is the electrical energy consumption during the cultivation period (kwh ha^{-1}), LL is the total water level applied (mm) and Pe the price of kilowatt-hours of electricity (US\$ kwh^{-1}) obtained in the Paraíba electrical power company.

The profitability of cropping systems was calculated using the indicators gross income (GI) and net income (NI) and also by gross margin (GM = GI - EOC), benefit/cost ratio (B/C = GI / CP) and profitability index (PI = NI / GI × 100) (Hafle et al., 2010; Garcia et al., 2012). Values used for profitability analysis were based on the market price of the product (castor in grain - US\$ 0.89 kg^{-1} and pods peanut - US\$ 0.91 kg^{-1}) at the harvest period.

Statistical analysis

Data for the variables productivity of castor and peanut were subjected to analysis of variance by F-test ($p \leq 0.05$), and means were compared by Tukey's test ($p \leq 0.05$), using the software SAEG 9.1.

Conclusion

In the present study, we showed that castor grown under intercropping system had highest grain yield in the late sowing epochs of peanut. Regarding to peanut yield, it was higher when sowing was carried out between 10 and 15 days after castor. The biggest total production cost of US\$ 1452.11 ha^{-1} occurred in monocropping peanut spaced of 1.0 m × 0.2 m, due to higher spending on inputs. However, the intercropping castor and peanut was beneficial and profitable with better agronomic and economic feasibility if peanut is sowed 20 days after castor in the spaces 2.0 × 0.5 (castor) and 2.0 × 0.2 (peanut).

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