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ECONOMIC VIABILITY OF BEET CROPS USING *Calotropis procera* BIOMASS AS SOIL FERTILIZER IN TWO GROWING SEASONS[1]

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ABSTRACT – The use of green manure from spontaneous species has gained prominence for vegetable crops focused on environmental sustainability and is an alternative method for the Semiarid region in the Northeast of Brazil. Two experiments were conducted in two growing seasons (autumn and spring-summer), in Serra Talhada, PE, Brazil, to evaluate the effects of different amounts of biomass of *Calotropis procera* (roostertree) and incorporation times on the agro-economic performance of beet crops. A randomized block experimental design was used, with three replications, in a 4×4 factorial arrangement; the first factor consisted of amounts of *C. procera* biomass (5.4, 8.8, 12.2, and 15.6 Mg ha^{-1} on a dry basis) and the second factor consisted of times of incorporation into the soil (0, 10, 20, and 30 days before planting beet). Commercial root yield, production costs, and the following economic indicators were determined: gross income, net income, return rate, and profitability index. The use of 15.6 Mg ha^{-1} of *C. procera* biomass resulted in the highest gross and net incomes and the use of 5.4 and 12.2 Mg ha^{-1} resulted in the best return rates and profitability indexes in autumn and spring-summer seasons, respectively; the planting time was considered as ideal for the biomass incorporation. The spring-summer growing season resulted in a higher economic return than the autumn growing season. The use of *C. procera* as a green manure for beet production is economically viable, regardless of the factors evaluated.

Keywords: *Beta vulgaris* L. Cost. Profitability. Roostertree. Sustainable agriculture.

VIABILIDADE ECONÔMICA DA BETERRABA ADUBADA COM *Calotropis procera* EM DUAS ÉPOCAS DE CULTIVO

RESUMO – A utilização da adubação verde com o uso de espécies espontâneas tem ganhando destaque no cultivo de hortaliças, visando a sustentabilidade do ambiente e sendo um método alternativo para o Semiárido nordestino. Dois experimentos foram conduzidos em duas épocas de cultivo (outono e primavera-verão), em Serra Talhada, PE, Brasil, a fim de se avaliar os efeitos de quantidades de biomassa e tempos de incorporação de *Calotropis procera* (Flor-de-seda) no desempenho agroeconômico da beterraba. O delineamento experimental utilizado foi em blocos casualizados, com três repetições. Os tratamentos foram arranjados em esquema fatorial 4 x 4, sendo o primeiro fator correspondente às quantidades de *C. procera* (5,4; 8,8; 12,2 e 15,6 Mg ha^{-1} em base seca) e o segundo, aos tempos de incorporação ao solo (0, 10, 20 e 30 dias antes da semeadura da beterraba). Além da produtividade comercial de raízes e dos custos de produção, foram determinados: renda bruta, renda líquida, taxa de retorno e índice de lucratividade. A quantidade de 15,6 Mg ha^{-1} de *C. procera* promoveu as maiores rendas bruta e líquida, enquanto que as quantidades de 5,4 e 12,2 Mg ha^{-1} obtiveram as melhores taxas de retorno e índices de lucratividade no outono e primavera-verão, respectivamente, sendo considerada ideal a adubação realizada no momento do plantio. O cultivo de primavera-verão possibilitou retorno econômico superior à semeadura de outono. Independente dos fatores, o uso da *C. procera* como adubo verde na produção de beterraba foi viável agroeconomicamente.

Palavras-chave: *Beta vulgaris* L. Custo. Rentabilidade. Flor-de-seda. Agricultura sustentável.

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INTRODUCTION

Beet (*Beta vulgaris* L.; Quenopodiaceae) is one of the most important vegetables in Brazil. According to the Companhia Nacional de Abastecimento (CONAB, 2020), 112,993,960 kg of beet were traded in 2019 in food supply centers in the country, generating a revenue of US$ 99,215,624.37, with an average price of US$ 0.87 kg^{-1}. Beet is widely grown throughout the country, presenting a better crop development in regions with mild or low temperatures, close to 20 °C.

However, high crop yield and quality requires correct monitoring and management of all production stages; thus, a proper management of soil organic and mineral fertilizers is essential. Beet is a crop that demands balanced fertilization. According to Grangeiro et al. (2007), the decreasing order of nutrients accumulated by beet plants is nitrogen (N), potassium (K), magnesium (Mg), calcium (Ca), and phosphorus (P).

In recent years, the use of green manure has gained prominence. This practice consists of incorporating plant biomasses rich in nutrients into the soil, which improves the soil physical, chemical, and biological characteristics, and consequently, soil fertility and conservation. In addition, green manure adds organic matter, which favors soil aggregation and water retention capacity, reduces erosion rates, increases soil microbiota activity, and promotes nutrient availability (NASCIMENTO; MATTOS, 2007; MORAES et al., 2019).

Spontaneous plants from the Caatinga biome in the semiarid region of the Northeast of Brazil present several desirable characteristics for use as green manure. Among these plants, Jitirana (*Merremia aegyptia* L.), Mata-pasto (*Senna uniflora* L.), and Roostertree [*Calotropis procera* (Ait.) R. Br.] stand out due to their availability, ease of obtaining, high fresh mass production, and high N contents (BATISTA et al., 2016). Some studies have been conducted using these species, which have shown good results as soil fertilizers for leafy and root vegetables and increased commercial yields for single crops (GÓES et al., 2011; SILVA et al., 2011; BEZERRA NETO et al., 2014; OLIVEIRA et al., 2015a; SOUZA et al., 2016; SOUZA et al., 2017; SILVA et al., 2017; SOUZA et al., 2019; NUNES et al., 2020) and intercrops (ALMEIDA et al., 2015; OLIVEIRA et al., 2015b; BEZERRA NETO et al., 2019).

C. procera plants have stood out among other plants studied as green manure due to their high resistance to drought and development throughout the year. This species also has high regrowth capacity after cut, emitting large number of vigorous leaves and presenting high accumulation of biomass, which is rich in N (ANDRADE et al., 2008). Studies have reported economic viability of the use of *C. procera* plants as green manure for radish (SILVA et al., 2015) and rocket (SOUZA et al., 2015) crops.

In this context, the objective of this work was to evaluate the effects of different amounts of biomass of *Calotropis procera* plants (roostertree) and incorporation times on the agro-economic performance of beet crops grown in Serra Talhada, state of Pernambuco, Brazil.

MATERIAL AND METHODS

The experiments were carried out at the Universidade Federal Rural de Pernambuco (UFRPE), in Serra Talhada, Pernambuco, Brazil (7º57'15"S, 38º17'41"W, and 461 m altitude), in two growing seasons: autumn (March 27 to June 20, 2012) and spring-summer (October 31 to January 19, 2013). The region presents a Bwh, semiarid, hot and dry climate, according to the Köppen classification, with a rainy summer, mean annual temperature of 24.7 ºC, and mean annual rainfall depth of 642.10 mm.

The soil of the experimental area had a sandy loam texture, with total porosity of 47.58%. The soil chemical characteristics (0-0.20 m layer) before the experiments were: pH = 7.2; P = 14.0 mg dm^{-3}; K^+ = 0.55 cmol$_c$ dm^{-3}; Al^{3+} = 0.0 cmol$_c$ dm^{-3}; Ca^{2+} = 3.90 cmol$_c$ dm^{-3}; Mg^{2+} = 1.20 cmol$_c$ dm^{-3} in the autumn season; and pH = 6.6; P = 150 mg dm^{-3}; K^+ = 0.69 cmol$_c$ dm^{-3}; Al^{3+} = 0.0; Ca^{2+} = 3.40 cmol$_c$ dm^{-3}; Mg^{2+} = 2.0 cmol$_c$ dm^{-3}; in the spring-summer season.

A randomized block experimental design was used, with three replications, in a 4×4 factorial arrangement; the first factor consisted of four amounts of *C. procera* biomass (5.4, 8.8, 12.2, and 15.6 Mg ha^{-1} on a dry basis) and the second factor consisted of four times of incorporation into the soil (0, 10, 20, and 30 days before planting beet).

The experimental plots had an area of 1.44 m^2, with an evaluation area of 0.80 m^2. Six plant rows were arranged transversely in each plot, with spacing of 0.20 m × 0.10 m. The beet cultivar used was the Early Wonder (AGRISTAR, 2021), which is recommended for the semiarid conditions of the Northeast of Brazil. The soil preparation for both experiments consisted of raising the beds using hoes.

C. procera plants were collected from a native vegetation area close to the Unidade Acadêmica de Serra Talhada (UAST). The plants were crushed in a conventional forage cutter, obtaining fragments between 2.0 to 3.0 cm, which were dried until reaching 10% moisture, stored as hay, and used for both experiments. The hay obtained from *C. procera* plants presented the following nutrient contents: N = 17.4 g kg^{-1}; P = 4.4 g kg^{-1}; K = 23.5 g kg^{-1}; Ca = 14.3 g kg^{-1}; Mg = 23.0 g kg^{-1}; Fe = 463.0 mg kg^{-1}, Zn = 40.0 mg kg^{-1}; Cu = 29 mg kg^{-1}; Mn = 90 mg kg^{-1}; B = 71 mg kg^{-1}; Na = 1,640.00 mg kg^{-1}, organic matter = 764.0 mg kg^{-1}; C/N = 25/1.

The plant biomass was manually incorporated into the 0-0.20 m soil layer of the experimental plots with the aid of a hoe, according to the treatments. Mineral fertilizers were not applied. The soil was irrigated in two daily shifts to favor the soil microbial activity for organic matter mineralization.

Beet propagules were planted on March 27, 2012 for the first growing season (autumn), and on October 31, 2012 for the second growing season (spring-summer), directly to the soil, at two centimeters depth, using three propagules per pit. A thinning was carried out at ten days after emergence, leaving one plant per hole. Manual weeding was carried out as needed.

The autumn beet harvest was carried out at 85 days after planting, and the spring-summer harvest was carried out at 80 days after planting. The commercial root yield of plants in the evaluation area were estimated (Mg ha^{-1}) considering a correction for 70% of the area actually planted. Economic indicators were used to assess the efficiency of the treatments. The production costs for the municipality of Serra Talhada in 2012 were estimated and analyzed at the end of the production process, according to the methodology described by Souza et al. (2015).

Gross income (GI) was measured using the values of the production per hectare in June 2012 (US\$ 0.76 kg^{-1}) and January 2013 (US\$ 1.01 kg^{-1}). Net income (NI) was calculated through the difference between the gross income (GI) per hectare and the total production costs (TC). The TC were calculated for each treatment, considering the cost coefficients of inputs and services used in one hectare of beet at experimental level. The rate of return was obtained by the ratio between GI and TC, representing how many dollars are obtained per dollar invested in the beet crop, according to the treatment applied. The profitability index (PI) consisted of the ratio between NI and GI, which were expressed as a percentage (BEZERRA NETO et al., 2010).

The results of the evaluated characteristics were subjected to analysis of variance (ANOVA) for each growing season, using the SISVAR program (FERREIRA, 2011). A joint analysis was carried out for the characteristics that presented homogeneity of variance between growing seasons. Response curves were determined for the evaluated characteristics in each treatment.

RESULTS AND DISCUSSION

The results of the joint analysis of the variables evaluated, according to growing season, amount of biomass of *C. procera* plants, and time of incorporation of biomass into the soil, showed that the interaction between the three factors was significant for all characteristics evaluated.

The commercial production of beet roots showed increases in yield as the amount of *C. procera* biomass incorporated into the soil was increased, regardless of the other factors evaluated (Figures 1A and 1B). In the autumn season (Figure 1A), the treatment with addition of 14.23 Mg ha^{-1} of biomass to the soil at 10 days before planting (DBP) the beet crop resulted in the highest commercial beet root yield (35.53 Mg ha^{-1}). In the spring-summer season, the highest estimated commercial beet root yield was 33.78 Mg ha^{-1} for the highest rate of *C. procera* biomass (15.6 Mg ha^{-1}) applied on the day of planting (Figure 1B), followed by the treatments with biomass incorporation into the soil at 10 DBP (29.52 Mg ha^{-1}), 20 DBP (28.54 Mg ha^{-1}), and 30 DBP (26.96 Mg ha^{-1}) using the highest biomass rate.

These results are related to a great availability of nutrients released by *C. procera* biomass and the simultaneity in which the elements are released and absorbed by the plants with no losses by leaching. However, they may also be due to increases in organic matter and phosphorus contents as the rate of incorporated biomass was increased (BATISTA et al., 2016).

In general, when the green manure stayed longer in the soil, before planting the beet crop, the commercial beet root yield was lower (Figures 1C and 1D). The incorporation of 15.6 Mg ha^{-1} of biomass into the soil on the day of planting the crop resulted in higher commercial root yields, with statistically equal yields for the autumn (34.43 Mg ha^{-1}) and spring-summer (32.80 Mg ha^{-1}) growing seasons.

These results can be explained by the fact that beet has a higher nutrient requirement from 30 to 60 days after planting (GRANGEIRO et al., 2007), and that the *C. procera* has a low C to N ratio (25/1) and most of its nutrients, mainly N, is mineralized within 40 to 45 days after the incorporation of *C. procera* biomass into the soil (TORRES et al., 2005).

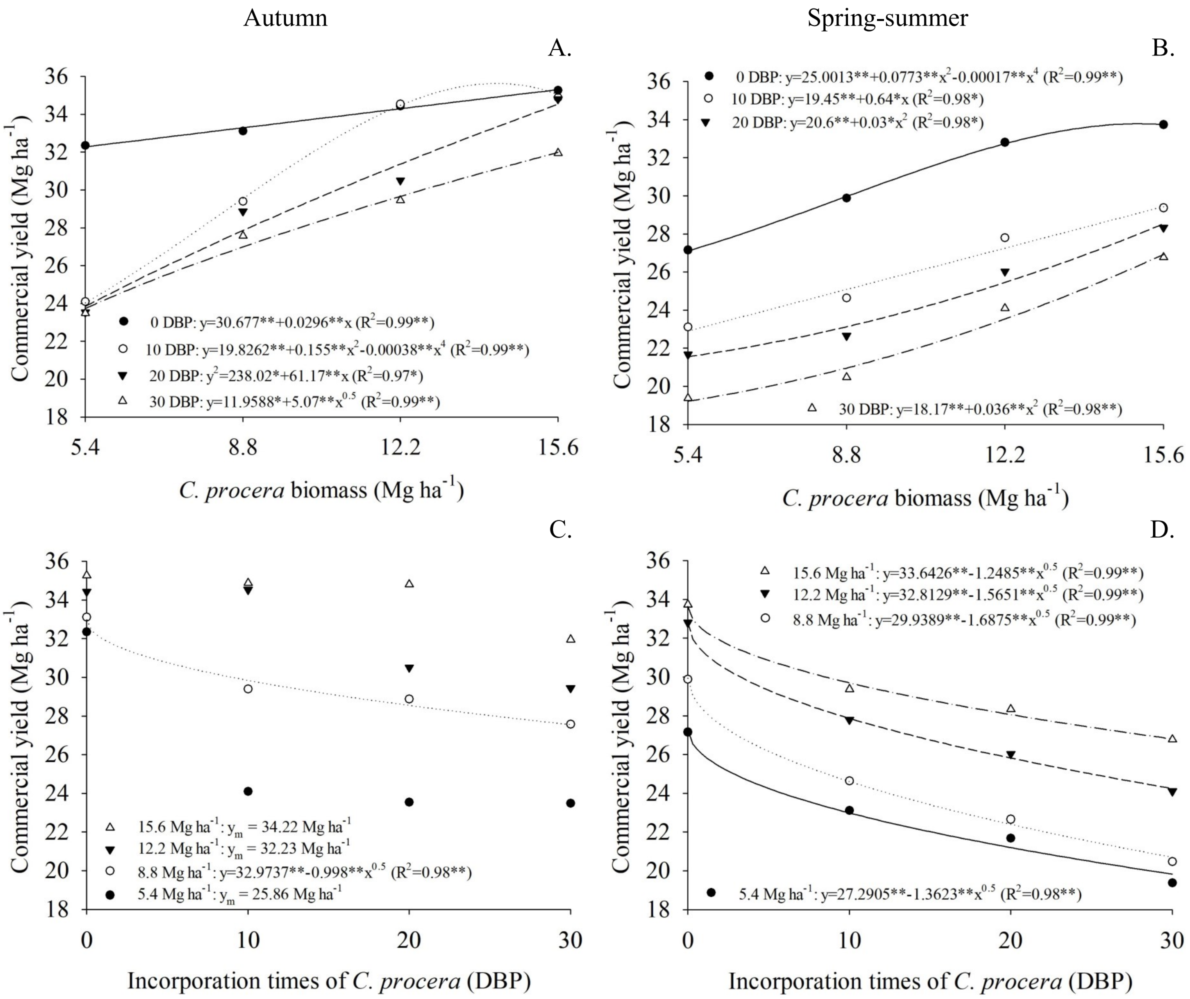

Figure 1. Commercial yield of beet roots as a function of application of different amounts of biomass of *Calotropis procera* in the Autumn (A) and Spring-summer (B) growing seasons, and different times of biomass incorporation (days before planting - DBP) in the Autumn (C) and Spring-summer (D) growing seasons.

The gross income showed similar results to those found for commercial beet productions, i.e., increasing the amounts of green manure (*C. procera*) applied to the soil increased the gross income, and the highest values were found with biomass incorporation on the day of planting the beet, in both growing seasons (Figure 2). The biomass rate of 15.6 Mg ha^{-1} incorporated on the day of planting provided an average gross income of US$ 26,877.43 ha^{-1} in the autumn and US$ 34,304.90 ha^{-1} in spring-summer season, which differed statistically, mainly, due to the price paid for the product in each season: US$ 0.76 and US$ 1.01 kg^{-1}, respectively.

Oliveira et al. (2012) found positive effects of green manure from spontaneous species of the Caatinga biome on radish crops, with the highest gross income found when using the greatest amount (15.6 Mg ha^{-1}) of *Merremia aegyptia* incorporated into the soil. In addition, Oliveira et al. (2015a) found increases in gross income for arugula crops as the rates of *C. procera* was increased.

The sum of variable, fixed, and opportunity costs was US$ 5,965.68 ha^{-1} (autumn) and US$ 5,994.11 ha^{-1} (spring-summer) (Table 1). The total production cost per hectare of beet using *C. procera* plants as green manure was estimated for each amount of biomass incorporated into the soil. The results found for the biomass rates of 5.4, 8.8, 12.2, and 15.6 Mg ha^{-1} were US$ 6,615.93 ha^{-1}, US$ 7,039.71 ha^{-1}, US$ 7,465.02 ha^{-1}, and US$ 7,888.81 ha^{-1} for the autumn, and US$ 6,644.36 ha^{-1}, US$ 7,064.14 ha^{-1}, US$ 7,493.45 ha^{-1}, and US$ 7,917.23 ha^{-1} for the spring-summer growing season, respectively (Table 2). The difference between production costs was due to differences in the costs of cutting, transport, crushing, drying, bagging, distribution, and incorporation of *C. procera* plants and electrical energy (forage cutter), which increased as the amount of incorporated biomass was increased.

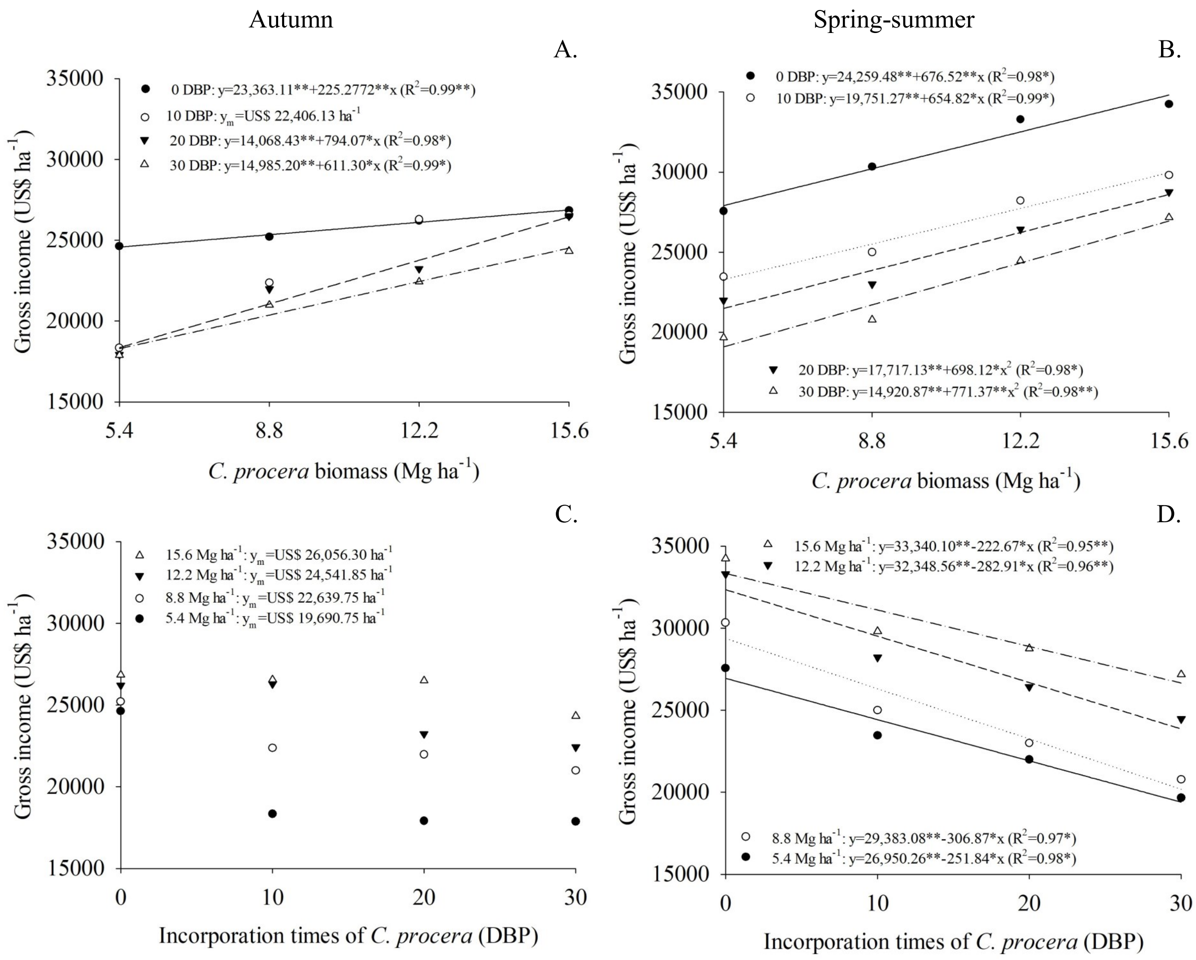

Figure 2. Gross income (US\$ ha^{-1}) from beet production as a function of application of different amounts of biomass of *Calotropis procera* in the Autumn (A) and Spring-summer (B) growing seasons, and different times of biomass incorporation (days before planting - DBP) in the Autumn (C) and Spring-summer (D) growing seasons.

Table 1. Coefficients of variable, fixed, and opportunity costs to produce one hectare of beet, in two growing seasons.

Components of Production Costs	Unity	Amount	Total (US$)	
			Autumn	Spring/ summer
Variable costs			4,085.48	4,085.48
1 – Inputs			571.07	571.07
Seeds: Beet cv. Early Wonder	kg	15.0	571.07	571.07
2 – Labor			3,350.25	3,350.25
Raising of beds	daily	40	609.14	609.14
Beet planting	daily	30	456.85	456.85
Beet thinning	daily	15	228.43	228.43
Manual weeding	daily	15	228.43	228.43
Heap	daily	20	304.57	304.57
Irrigation	daily	45	685.28	685.28
Beet harvest	daily	50	761.42	761.42
Beet transport	daily	5	76.14	76.14
3 – Energy			164.16	164.16
Energy used for irrigation	kW	1470.0	164.16	164.16
Fixed Costs			1,575.63	1,604.06

*Ratio between market value and useful life of the equipment multiplied by the use time; ** Value of fixed capital (US\$ 10,152.28 ha^{-1}) multiplied by its possible remuneration throughout the crop period.

Table 1. Continuation.

Components of Production Costs	Unity	Amount	Total (US$)	
			Autumn	Spring/ summer
4 – Depreciation			307.61	307.61
Irrigation pump	month*	4	116.75	116.75
Irrigation pipes	month	4	7.11	7.11
Connections	month	4	26.40	26.40
Micro sprinklers	month	4	81.22	81.22
Forage cutter	month	1	76.14	76.14
5 – Taxes and fees			5.08	5.08
Rural land tax	ha	1	5.08	5.08
6 – Fixed labor			1,262.94	1,291.37
Administrative Assistant	salary	4	1,262.94	1,291.37
Opportunity Costs			304.57	304.57
7 – Land remuneration			101.52	101.52
Rent	ha	1	101.52	101.52
8 – Remuneration of fixed capital (0.5% per month)			203.05	203.05
Infrastructure and equipment	US$ 50.76 $month^{-1}$**	4	203.05	203.05
Total (Variable costs + Fixed costs + Opportunity costs)			5,965.68	5,994.11

*Ratio between market value and useful life of the equipment multiplied by the use time; ** Value of fixed capital (US$ 10,152.28 ha^{-1}) multiplied by its possible remuneration throughout the crop period.

Table 2. Total costs to produce one hectare of beet grown using different amounts of *Calotropis procera* plants as green manure, in two growing seasons.

Components of Production Costs	Unit	Amount	Total (US$)	
			Autumn	Spring/ summer
1 – 5.4 Mg ha^{-1} in *C. procera*			6,615.94	6,644.37
Cut	daily	20.0	304.57	304.57
Transport	freight	1.0	40.61	40.61
Crushing	daily	2.5	38.07	38.07
Electrical energy (forage cutter)	kW	100	11.17	11.17
Drying	daily	5.0	76.14	76.14
Bagging	daily	1.0	15.23	15.23
Distribution and incorporation	daily	10.8	164.47	164.47
Variable, fixed, and opportunity costs			5,965.69	5,994.11
2 – 8.8 Mg ha^{-1} in *C. procera*			7,039.72	7,068.14
Cut	daily	32.6	496.45	496.45
Transport	freight	2.0	81.22	81.22
Crushing	daily	4.1	62.44	62.44
Electrical energy (forage cutter)	kW	162.9	18.19	18.19
Drying	daily	8.1	123.35	123.35
Bagging	daily	1.6	24.37	24.37
Distribution and incorporation	daily	17.6	268.02	268.02
Variable, fixed, and opportunity costs			5,965.69	5,994.11
3 – 12.2 Mg ha^{-1} in *C. procera*			7,465.03	7,493.45
Cut	daily	45.2	688.32	688.32
Transport	freight	3.0	121.83	121.83
Crushing	daily	5.6	85.28	85.28
Electrical energy (forage cutter)	kW	225.9	25.23	25.23
Drying	daily	11.3	172.08	172.08
Bagging	daily	2.3	35.03	35.03
Distribution and incorporation	daily	24.4	371.57	371.57
Variable, fixed, and opportunity costs			5,965.69	5,994.11
4 – 15.6 Mg ha^{-1} in *C. procera*			7,888.81	7,917.24
Cut	daily	57.8	880.20	880.20
Transport	freight	4.0	162.44	162.44
Crushing	daily	7.2	109.64	109.64
Electrical energy (forage cutter)	kW	288.9	32.26	32.26
Drying	daily	14.4	219.29	219.29
Bagging	daily	2.9	44.16	44.16
Distribution and incorporation	daily	31.2	475.13	475.13
Variable, fixed, and opportunity costs			5,965.69	5,994.11

The green manure cutting and preparation represented 9.8, 15.2, 20.0, and 24.3% of the total costs for the *C. procera* biomass rates of 5.4, 8.8, 12.2, and 15.6 Mg ha^{-1}, respectively. The production costs in the spring were higher due to a raise in the wage to the administrative assistant in January 2013 (from US$ 622.00 to US$ 678.00). Daily expenses (labor) ranged from 66 to 85% of the total costs between the lowest and greatest amounts of *C. procera* biomass (Tables 1 and 2). Some studies using this green manure have shown similar results, in which labor was the most expensive operating cost, representing, on average, 68% of the total costs in radish crops (SILVA et al., 2015) and 69% in rocket crops (SOUZA et al., 2015).

Production costs include the labor cost, which is the key for a sustainable production for small growers. Thus, costs can be reduced by using family labor for growth and preparation of green manure in the property, reducing transport costs.

The estimated highest net income was US$ 19,316.28 ha^{-1} in the autumn growing season, with 14.16 Mg ha^{-1} of *C. procera* biomass incorporated at 10 days DBP (Figures 3A and 3C). In the spring-summer growing season, the biomass rate of 15.6 Mg ha^{-1}, incorporated on the day of planting resulted in a net income of US$ 26,329.80 ha^{-1} (Figures 3B and 3D).

Despite these similar high results in gross income (commercial yield) between growing seasons, different remunerations for the product were found. In addition, the growing seasons had little impact on the total production costs (Tables 1 and 2). Thus, a relative increase of 36.3% in net income was found for the spring-summer over the autumn growing season.

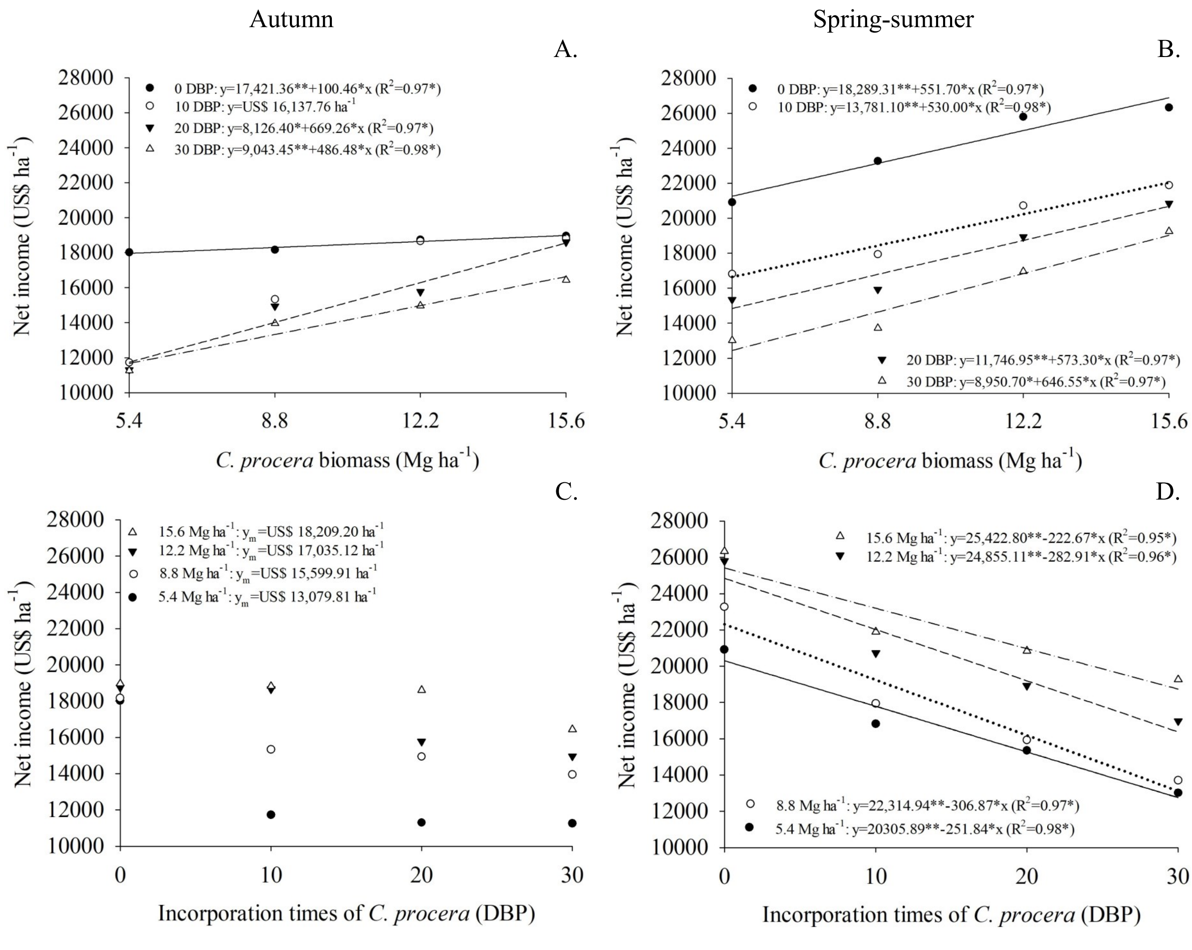

Figure 3. Net income (US$ ha^{-1}) from beet crops as a function of application of different amounts of biomass of *Calotropis procera* in the Autumn (A) and Spring-summer (B) growing seasons, and different times of biomass incorporation (days before planting - DBP) in the Autumn (C) and Spring-summer (D) growing seasons.

In the autumn, the incorporation of 5.4 Mg ha^{-1} of biomass on the day of planting resulted in the highest rate of return (3.71) (Figures 4A and 4C). This better result when using the lower green manure rate is explained by the high commercial root yield (32.05 Mg ha^{-1}) and the reduced cost to obtain and incorporate the *C. procera* biomass (US$ 650.25 ha^{-1}). This yield was only 9%

lower than that found when using 15.6 Mg ha^{-1}.

In the spring-summer, the highest estimated rate of return was US$ 2.25 per dollar invested when incorporating 12.7 Mg ha^{-1} of biomass into the soil on the day of planting the beet crops (Figures 4B and 4D). These results denote the high commercial root yield achieved when incorporating 12.7 Mg ha^{-1} of biomass into the soil on the day of planting, resulting in an increase in gross income, which is connected to a labor cost lower than that found using the greatest amount of *C. procera* biomass. The spring-summer showed a higher rate of return than the autumn growing season due to a higher crop yield (33.33%); however, the commercial root yield and production costs varied little between growing seasons.

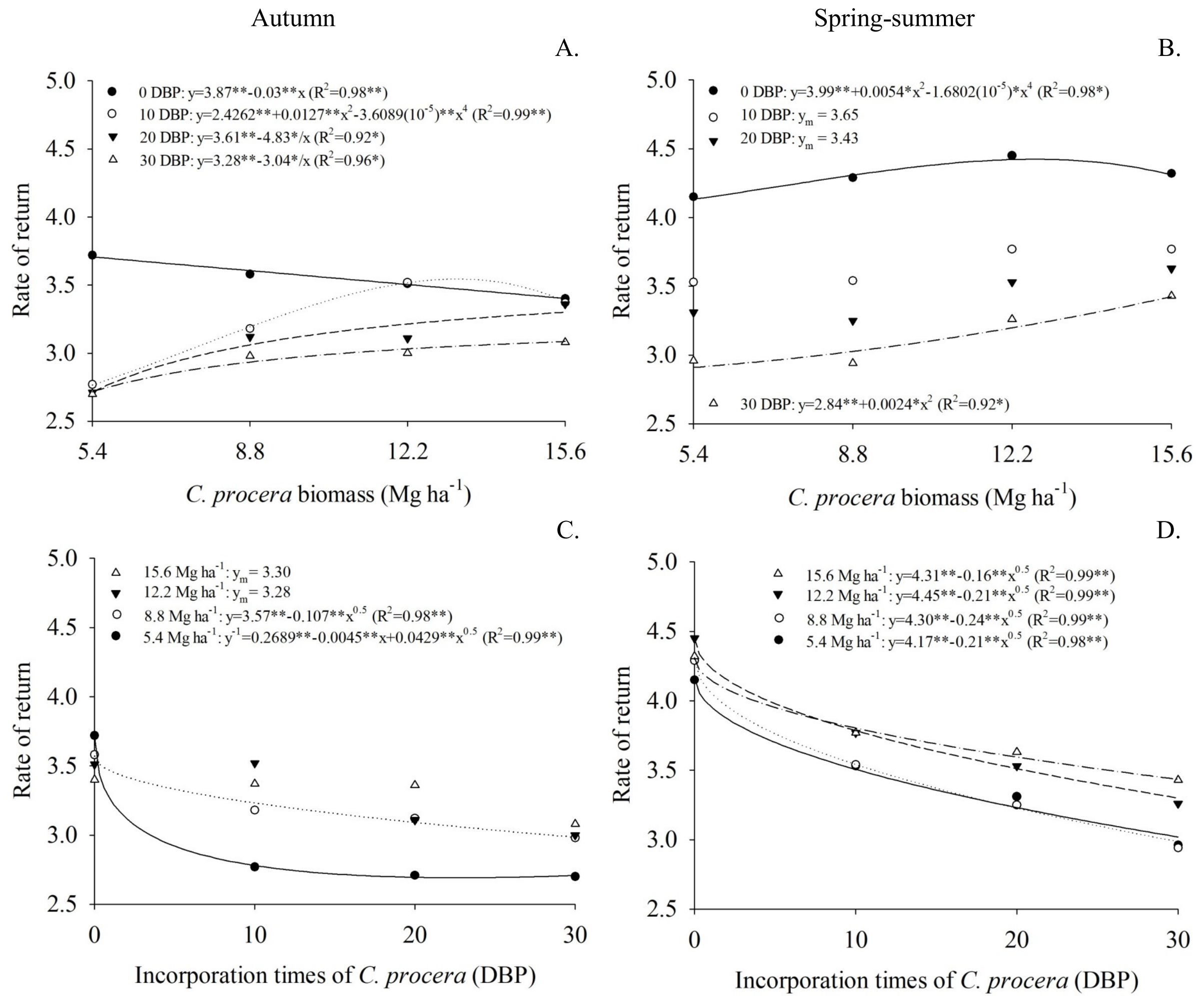

Figure 4. Rate of return to produce one hectare of beet as a function of application of different amounts biomass of *Calotropis procera* in the Autumn (A) and Spring-summer (B) growing seasons, and different times of biomass incorporation (days before planting - DBP) in the Autumn (C) and Spring-summer (D) growing seasons.

Silva et al. (2015) evaluated the economic viability of radish crops for Serra Talhada using *C. procera* biomass as green manure and found a higher rate of return in the spring-summer when compared to that found in the autumn growing season. The Semiarid region of Pernambuco usually presents rainfall events in late summer, which fills reservoirs and enables the planting of vegetables in the autumn-winter seasons, consequently, increasing the supply and decreasing prices of these products. In the second half of the year, occurrences of high temperatures and droughts restrict vegetable production to a few rural areas, which have greater water security. This situation usually increases the price of vegetables in the spring.

Oliveira et al. (2015a) evaluated increasing rates of *C. procera* for arugula crops in the spring-summer growing season and found a rate of return of 1.83 per dollar invested when incorporating the greatest amount (70 Mg ha^{-1}) of the green manure.

Bezerra Neto et al. (2014) evaluated carrot crops using 13 Mg ha^{-1} of *M. aegyptia* biomass incorporated into the soil (50% at 20, and 50% at 55 days after planting) and the highest rate of return found was US$ 1.00 per dollar invested. This low value compared to that found in the present study may be related to the price paid for the product (US$ 0.41 kg^{-1}), which results in a lower gross income, which is directly related to the rate of return.

The profitability index had similar results to those found for the rate of return, i.e., the values decreased in the autumn growing season as the amount of *C. procera* biomass and incorporation time were increased. The amount of 5.4 Mg ha^{-1} of *C. procera* incorporated on the day of planting resulted in the highest profitability index, 73.1% (Figures 5A and 5C). In the spring-summer growing season, the profitability index also decreased as the time of biomass incorporation was increased, but reached the highest value (77.4%) with 12.8 Mg ha^{-1} of *C. procera* incorporated into the soil on the day of planting the crop (Figures 5B and 5D). The profitability index found in the spring-summer growing season was higher than that found in the autumn, presenting similarity to the other economic indicators.

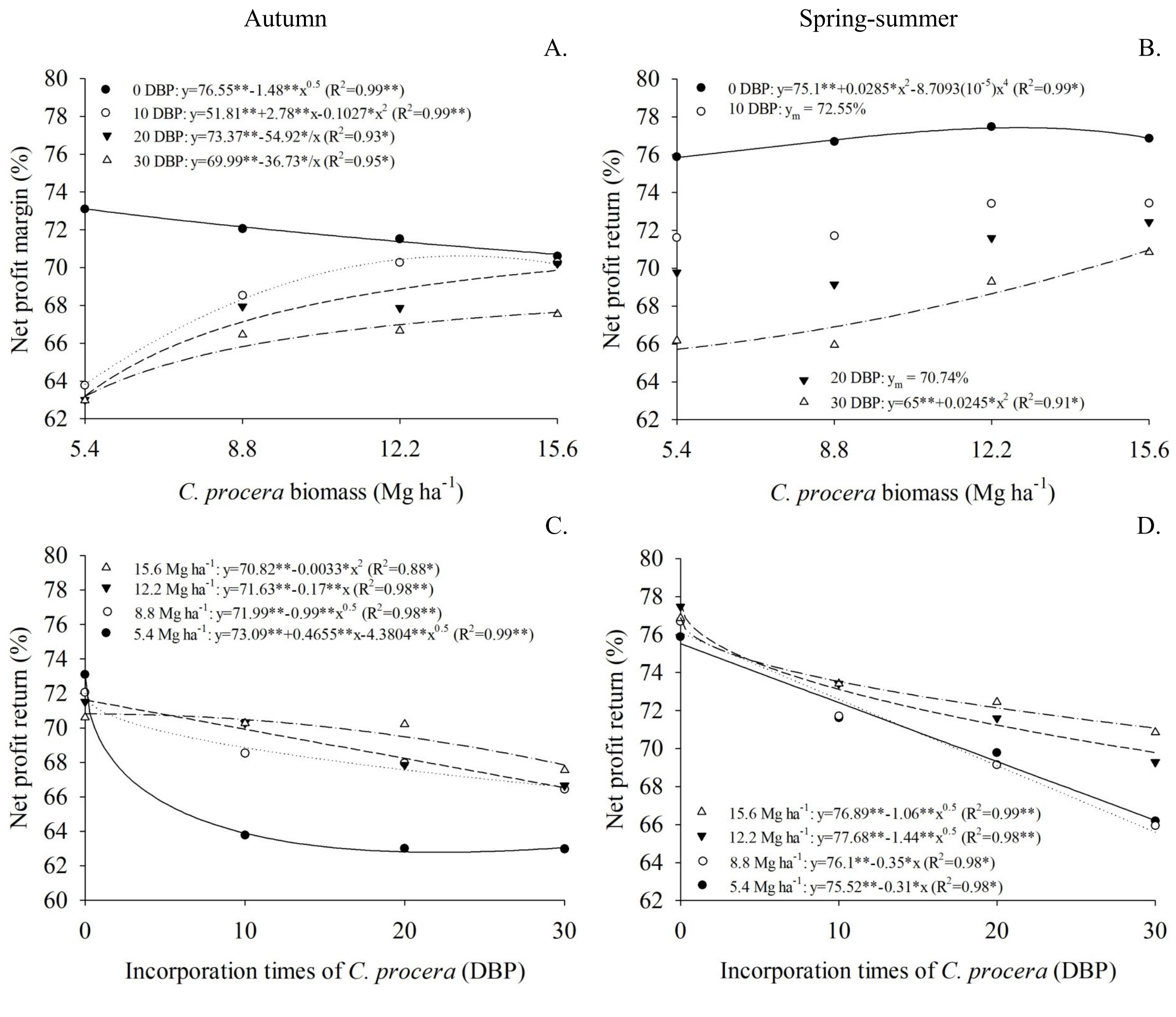

Figure 5. Profitability index (%) to produce one hectare of beet as a function of application of different amounts of *Calotropis procera* biomass in the Autumn (A) and Spring-summer (B) growing seasons, and different times of biomass incorporation (days before planting - DBP) in the Autumn (C) and Spring-summer (D) growing seasons.

The results of the present study showed similar profitability indexes to those found in studies using *C. procera* as green manure for radish (SILVA et al., 2015) and rocket (OLIVEIRA et al., 2015a; SOUZA et al., 2015) crops. These results denote that beet crops respond well to this green manure, improving the commercial root yield and the profitability of the investment due to reductions in production costs. In addition, organic inputs allow for a better use of local environmental resources, reducing the dependence on external inputs.

In general, the beet crops were agronomically and economically viable in both growing seasons evaluated, presenting satisfactory results even for the lowest amounts of *C. procera* biomass used. Thus, this green manure proved to be a good option as soil organic fertilizer for family farmers in the Semiarid region of Brazil because of its high rusticity and high biomass production throughout the year.

CONCLUSIONS

Beet crops grown in soils fertilized with biomass of *Calotropis procera* are economically viable, regardless of the amount of green manure, time of incorporation of biomass into the soil, and growing season. The highest profitability of the beet crop was found when added to the soil biomass rates of 5.4 Mg ha^{-1} (autumn growing season) and 12.2 Mg ha^{-1} (spring-summer growing season) on the day of planting the crop. The rate of return and profitability index of beet crops fertilized with *C. procera* biomass were higher in the spring-summer when compared to the autumn growing season.

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