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Production costs and profitability in coriander fertilised with *Calotropis procera* under organic cultivation[1]

Custos de produção e rentabilidade de coentro adubado com *Calotropis procera* em cultivo orgânico

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ABSTRACT - The present study was carried out to determine the amount of biomass of *Calotropis procera* and itsincorporation time into the soil that provide maximum productivity and profitability in the organic cultivation of coriander during the spring and autumn-winter, under the conditions of Serra Talhada, in the state of Pernambuco, Brazil. The experiment was conducted in a randomised complete block design, in a 4 x 4 factorial scheme with three replications. The first factor corresponded to the amount of biomass (5.4, 8.8, 12.2 and 15.6 t ha^{-1} on a dry basis), and the second to the incorporation time (0, 10, 20 and 30 days prior toplanting the coriander). In addition to the green-matter yield and production costs, the following economic indicators were determined: gross and net incomes, rate of return and profitability index. An amount of 12.2 t ha^{-1} *C. procera* in the spring and 8.8 t ha^{-1} in the autumn-winter resulted in greater productivity and profitability in coriander production. The incorporation of green manure 13 days (spring) and 23 days (autumn-winter) prior to sowing the crop was considered ideal for the economic viability of the activity. For the autumn-winter crop, the net income (BRL 19,607.10 ha^{-1}) and rate of return (3.31) were respectively 58.6% and 28.8% higher than those obtained in the spring.

Key words: *Coriandrum sativum* L. Green manure. Period of cultivation. *Calotropis procera*. Net income.

RESUMO - O presente estudo foi realizado com o objetivo de determinar a quantidade de biomassa de Flor-de-seda (*Calotropis procera*) e o seu tempo de incorporação ao solo que proporcionem máximas produtividade e rentabilidade ao cultivo orgânico do coentro na primavera e no outono-inverno, nas condições de Serra Talhada, Pernambuco. O delineamento experimental utilizado foi em blocos casualizados, em esquema fatorial 4 x 4, com três repetições. O primeiro fator correspondeu às quantidades de biomassa de Flor-de-seda (5,4; 8,8; 12,2 e 15,6 t ha^{-1} em base seca), e o segundo aos tempos de incorporação ao solo (0, 10, 20 e 30 dias antes da semeadura do coentro). Além do rendimento de massa verde e dos custos de produção, foram determinados os seguintes indicadores econômicos: rendas bruta e líquida, taxa de retorno e índice de lucratividade. As quantidades de 12,2 t ha^{-1} de Flor-de-seda (primavera) e de 8,8 t ha^{-1} (outono-inverno) apresentaram maiores produtividade e rentabilidade à produção do coentro. As incorporações do adubo verde 13 (primavera) e 23 (outono-inverno) dias antes da semeadura da cultura foram consideradas ideais à viabilidade econômica da atividade. No cultivo de outono-inverno, a renda líquida (R$ 19.607,10 ha^{-1}) e a taxa de retorno (3,31) foram, respectivamente, 58,6% e 28,8% superiores as obtidas na primavera.

Palavras-chave: *Coriandrum sativum* L. Adubação verde. Épocas de cultivo. Flor-de-seda. Renda líquida.

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INTRODUCTION

Coriander (*Coriandrum sativum* L.) is a leafy vegetable widely used in Brazilian cuisine in the composition and decoration of various dishes, especially in the Northeast of Brazil. It is a crop with high commercial turnover, due to its short cycle (on average 30 to 40 days) and good emergence, generating a fast economic return for producers, which is one of the main reasons for its presence in vegetable farming (PEREIRA *et al*., 2011).

It is traditionally cultivated by small producers, in home, school and community gardens, as a single crop or intercropped with other vegetables, especially chives and lettuce, using manure (cattle and goat) as a source of organic fertiliser. As this resource is not always available on their own property, a dependence on these inputs leaves the producer vulnerable to any scarcity, and consequently increases the cost of production (GRANGEIRO *et al*., 2011; LINHARES *et al*., 2012).

Organic fertilisers are frequently used in cultivating vegetables, especially as a substitute for mineral fertilisers, making it possible to increase the nutritional value of vegetables, and improve the chemical, physical and biological properties of the soil. Among the organic fertilisers used, those of vegetable origin deserve attention: a technique that has recently been studied in the production of leafy and tuberous vegetables in the Northeast of Brazil (SILVA, M. *et al*., 2013).

Legumes are the most widely used species for green manure, promoting greater benefit to the soil due to the biological fixation of nitrogen through symbiosis of the bacteria present in their root systems. Several spontaneous species of the Caatinga biome can be used for green manure, such as *Merremia aegyptia* L., *Senna uniflora* L. and *Calotropis procera* (Ait.) R. Br., and are an important option in agricultural production for achieving a balance between increased crop productivity and exploitation of the environment (FERNANDES *et al*., 2014; LINHARES *et al*., 2012).

Among these species, *C. procera*, belonging to family *Apocinaceae*, is characterised by being fairly widespread due to its adaptation to degraded environments, high biomass production, vigorous regrowth, low susceptibility to pests and diseases, and having leaves which contain 94.62% dry matter and 19.46% crude protein (ALMEIDA *et al*., 2015; SILVA, M. *et al*., 2013).

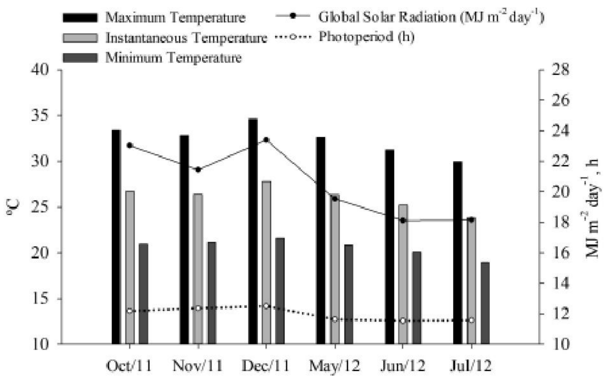
In recent years, studies have described the agronomic and economic viability of using *C. procera* as green manure, as it has promoted an increase in green-matter yield in lettuce, rocket and coriander (ALMEIDA *et al*., 2015; LINHARES *et al*., 2014; SOUZA *et al*., 2015), as well as in commercial-root productivity in the carrot (SILVA, M. *et al*., 2013), beetroot (BATISTA *et al*., 2016) and radish (BATISTA *et al*., 2013; SILVA, A. *et al*., 2015). However, most results are obtained during just one growing season, and there is little research on the productive potential and financial return of the coriander crop under green manure as a function of local weather factors.

As such, the aim of this study was to determine the amount of biomass of *C. procera* and the time for it to incorporate into the soil that provide maximum productivity and profitability in the organic cultivation of coriander at different periods (spring and autumn-winter), under the conditions of Serra Talhada, Pernambuco, Brazil.

MATERIAL AND METHODS

Two field experiments were conducted during spring (October to December 2011) and autumn-winter (May to July 2012) at the Academic Unit Serra Talhada (UAST) of the Federal Rural University of Pernambuco (UFRPE), in Serra Talhada, Pernambuco, located at 7°57'15" S and 38°17'41" W, at an altitude of 461 m, in the Sertão do Pajeú microregion in the north of Pernambuco. Mean meteorological data for the period of the experiments are shown in Figure 1.

Figure 1 - Mean monthly values for instantaneous, maximum and minimum temperatures (ºC), global solar radiation (MJ m^{-2} day^{-1}) and photoperiod (h) during each season of the coriander crop fertilised with *Calotropis procera*



The soil of the experimental area has a sandy loam texture, whose chemical characteristics at a depth of 0-0.20 m in the spring, before the experiments were setup,were pH in H_2O (1:2.5) = 6.6, OM = 8.4 g kg^{-1}, P = 15.0 mg dm^{-3}, K^+ = 0.7 cmol$_c$ dm^{-3}, Ca^{2+} = 3.4 cmol$_c$ dm^{-3}, Mg^{2+} = 2.0 cmol$_c$ dm^{-3} and Al^{3+} = 0.0 cmol$_c$ dm^{-3}; during the autumn-winter, the values were pH in H_2O (1:2.5) = 6.5, OM = 12.7 g kg^{-1}, P = 20.0 mg dm^{-3}, K^+ = 0.4 cmol$_c$

dm^{-3}, Ca^{2+} = 3.4 $cmol_c$ dm^{-3}, Mg^{2+} = 2.0 $cmol_c$ dm^{-3} and Al^{3+} = 0.0 $cmol_c$ dm^{-3}.

The experimental design was of randomised blocks with three replications. The treatments were arranged in a 4 x 4 factorial scheme, with the first factor comprising four amounts of *C. procera* biomass (5.4, 8.8, 12.2 and 15.6 t ha^{-1} on a dry basis), and the second factor comprising four incorporation times of this fertiliser into the soil (0, 10, 20 and 30 days prior tosowing the coriander).

Each experimental unit had a total area of 1.44 m^2, with a working plot of 0.80 m^2. Six rows were arranged transversely in each plot for planting, spaced 0.20 m apart, with a spacing along each row of 0.05 m between plants. The coriander cultivar used was 'Verdão', recommended for cultivation in the northeast of Brazil. For each experiment, the soil was prepared by raising the beds using hoes.

C. procera was collected from native vegetation at locations near UAST and crushed in a conventional forage maker to obtain fragments of between 2.0 and 3.0 cm which were left to dry until acquiring the condition of hay (10% moisture). The material was analysed, and presented the following results for the nutrient content of the dry matter (after drying at 70 ºC): 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 = 29.0 mg kg^{-1}, Mn = 90.0 mg kg^{-1}, B = 71.0 mg kg^{-1}, Na = 1,640.0 mg kg^{-1}, OM = 764.0 mg kg^{-1} and C/N = 25/1.

The plant biomass was incorporated into the 0-0.20 m soil layer in each experimental plot, as per the treatments. Daily irrigations were carried out in two shifts in order to favour the microbial activity of the soil in the mineralisation process of the organic matter. Irrigation was by micro-sprinkler system, with a daily irrigation shift split into two applications (morning and afternoon), giving a water depth of approximately 8 mm day^{-1}.

In the first growing season (spring), the coriander was planted on 12 November 2011, while in the autumn-winter season, planting was on 1 June 2012. Direct planting was carried out at a depth of 2 cm, using three seeds per hole. Thinning took place ten days after emergence, leaving one plant per hole. Manual weeding was carried out when necessary.

In the spring, the coriander was harvested 38 days after sowing (DAS), and at 40 DAS in the autumn-winter. The productivity for each experimental unit was estimated from the green-matter yield (t ha^{-1}) of the plants in the working area, corrected for 70% of the actual planted area. Economic indicators were used to evaluate the efficiency of the treatments. Production costs were estimated, and were calculated and analysed at the end of the production process. The cost model analysed in this study corresponded to the total expenditure per hectare of cultivated area, which includes services provided by the stable capital, i.e. the contribution of circulating capital and the value of alternative or opportunity costs. Similarly, revenues refer to the production value of one hectare.

The acquisition cost was obtained by multiplying the price of the variable inputs used (seeds, fertilisers, casual labour, etc.) by the amount of the respective input relative to 2012 and to the city of Serra Talhada, Pernambuco. The cost of one ton of *C. procera* green manure was estimated for each quantitive factor, quantifying the labour required for cutting, crushing, drying and bagging the *C. procera*. The prevailing prices in the city of Serra Talhada in December 2011 were considered for the first experiment, and those in July 2012 for the second. The daily rate paid for a rural worker in the region was BRL 25.00 and BRL 30.00 during the first and second growing seasons respectively. The cost of transporting the fertiliser after cutting was also calculated for each amount (BRL 70.00 per load for the spring crop and BRL 80.00 in the autumn-winter).

The final cost of each treatment was therefore determined according to the different amounts incorporated, the time taken for incorporation (variable as a function of the amount) and the other production costs. It should be noted that the treatments corresponding to the incorporation times (0, 10, 20 and 30 days) did not influence the production costs. However, these did participate in combining the factorial to determine the best economic efficiency in the cultivation of coriander fertilised with *C. procera*.

Depreciation, defined as the non-monetary fixed cost that reflects the loss in value of a production good as a function of age, use and obsolescence, was determined by the straight-line or fixed-quota method, which determines the annual depreciation value from the useful life of the durable good, its initial value and as scrap. The latter was not taken into consideration, as the capital goods considered have no residual value. Taxes and fees, as well as fixed labour, were determined by the amount used during the months of crop production. The purpose of the fixed workforce was to manage the productive activity, and corresponded to the payment of one minimum wage per month during each production cycle (BRL 545.00 in 2011 and BRL 622.00 in 2012).

The opportunity cost for fixed-capital items (construction, machinery, equipment, etc.), corresponded to the annual interest rate that reflects the alternate use of the capital. The interest rate chosen was 6% per year, equivalent to that earned with a savings account. For the fixed-capital remuneration, interest was calculated on the present value during cultivation. For the opportunity cost of the land, the lease of one hectare in the region (BRL 200.00) was considered equivalent to the alternative cost of the land used in the research.

Gross income (GI) was measured from the production value per hectare in December 2011 (BRL 5.00 kg^{-1}) and July 2012 (BRL 5.50 kg^{-1}). Whereas net income (NI) was calculated as the difference between gross income (GI) per hectare and the total costs (TC) involved. TC was calculated for each treatment, taking into account the cost coefficients of the inputs and the services used for one hectare of coriander at the experimental level. The rate of return (RR) was obtained from the ratio between GI and TC, corresponding to the amount of BRL obtained for each BRL spent on coriander cultivation as a function of the applied treatment. The profitability index (PI) comprised the ratio between NI and GI, expressed as a percentage (BEZERRA NETO *et al*., 2010).

For each growing season, an analysis of variance was made for the characteristics under evaluation, using the SISVAR 3.01 software (FERREIRA, 2011). A joint analysis was made for any characteristic(s) showing homogeneity of variance between the growing seasons. The procedure to fit the response curves was carried out between the evaluated characteristics and the quantitative factors. Tukey's test ($p<0.05$) was used to compare the mean values of the qualitative treatment.

RESULTS AND DISCUSSION

From the results of the combined analysis of the variables evaluated as a function of the growing season, the amounts of *C. procera* biomass and their incorporation time into the soil, there was an interaction between the three factors for the characteristics of yield, green matter, gross income, net income and rate of return. While for the profitability index there was interaction between the growing season and amount of *C. procera* biomass, and between the amount of *C. procera* biomass and the incorporation time into the soil (Table 1).

Green-matter yield in the coriander reached a maximum value of 4.16 t ha^{-1} in the spring crop, associated with the amount of 12.2 t ha^{-1} *C. procera*, incorporated 10 days prior to sowing (Figure 2A). For the autumn-winter, maximum productivity (4.92 t ha^{-1}) was found with the amount of 8.8 t ha^{-1} *C. procera* for an incorporation time of 20 days (Figure 2B). The estimated incorporation time of 13 days, together with the 12.2 t ha^{-1} dose of *C. procera*, gave the greatest result for green-matter yield in the coriander for the spring crop (4.10 t ha^{-1}) (Figure 2C). For the second growing season (autumn-winter), the association between the optimal time of 23 days and the 8.8 t ha^{-1} dose of green manure (Figure 2D) stood out, giving a maximum yield of 5.11 t ha^{-1}, statistically higher than in the spring.

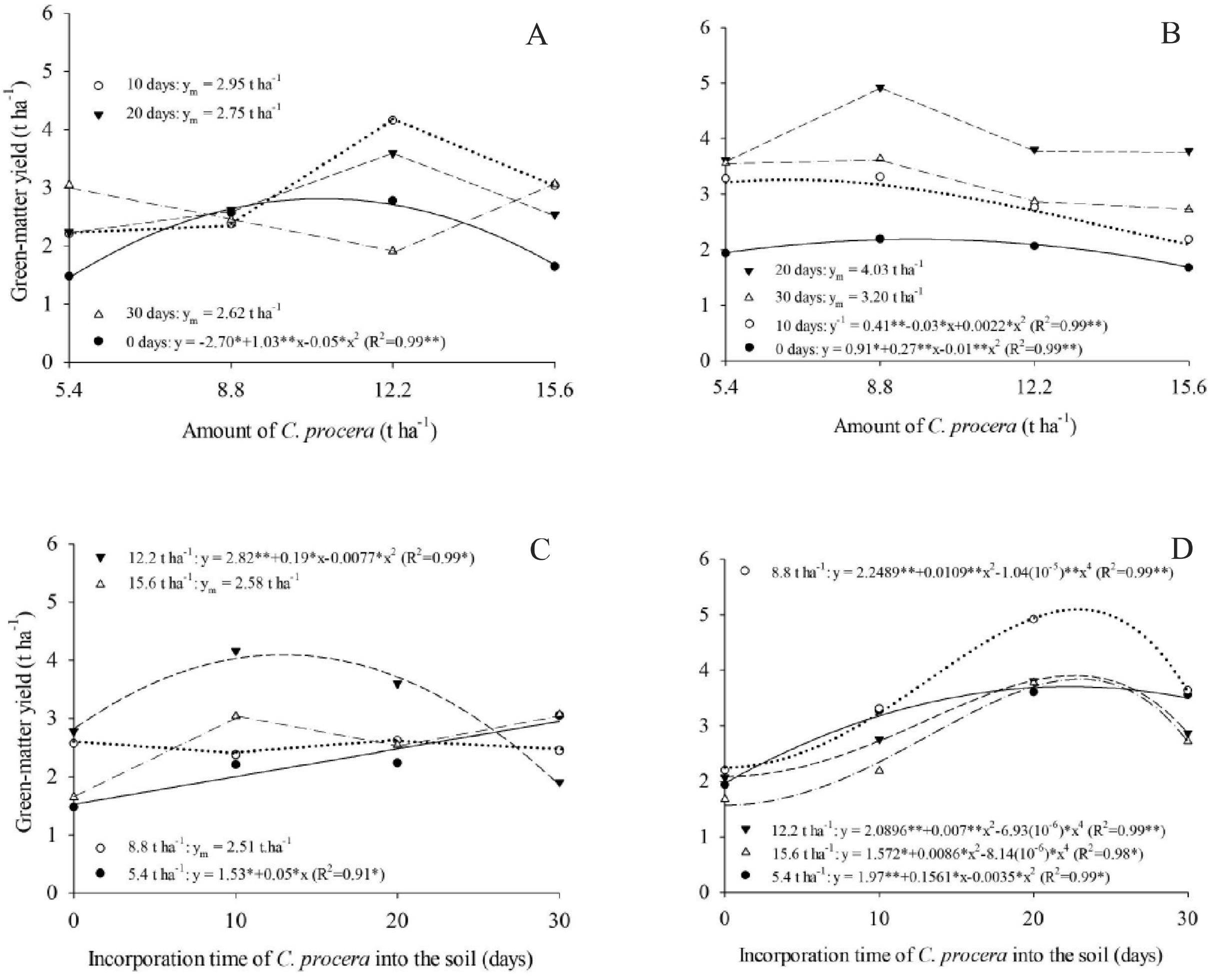
These results are probably due to the milder mean temperatures during the autumn-winter (Figure 1), which may have resulted in greater vegetative growth in the coriander. Similar behaviour was seen in coriander (LIMA

Table 1 - Summary of the joint analysis of variance (F values) for green-matter yield (GMY), gross income (GI), net income (NI), rate of return (RR) and profitability index (PI) in the production of one hectare of coriander fertilised with *Calotropis procera* in two growing seasons

Source of Variation	DF	F				
		GMY	GI	NI	RR	PI
Blocks (Seasons)	4	3.51*	3.62*	3.62*	3.11*	2.72*
Seasons (S)	1	12.77**	33.19**	13.68**	7.23**	0.08^{ns}
Quantities (Q)	3	3.63*	3.51*	7.33**	13.54**	10.08**
Times (T)	3	23.55**	23.51**	23.51**	26.06**	18.02**
S x Q	3	7.05**	6.77**	7.36**	8.87**	3.17*
S x T	3	8.26**	8.95**	8.95**	8.35**	2.36^{ns}
Q x T	9	2.74**	2.47*	2.47*	3.44**	2.36*
S x Q x T	9	2.36*	2.11*	2.11*	2.65*	1.29^{ns}
CV (%)		20.06	20.47	46.24	18.76	46.37
Overall mean		2.81	14,826.67	6,563.31	1.81	37.10

^{ns}; ** and *: not significant, and significant at a level of 1% and 5% probability by F-test respectively

Figure 2 - Green-matter yield (t ha^{-1}) in coriander as a function of the amount of *Calotropis procera* and the incorporation time of the green manure into the soil (A. spring; B. autumn-winter) and the reverse (C. spring; D. autumn-winter), for each growing season



et al., 2007), rocket (SOUZA *et al*., 2016) and radish (SILVA, A. *et al*., 2017) grown under semi-arid conditions during the summer and winter. The greater amounts of *C. procera* may have had a negative effect on seedling emergence, with a reduction in productivity, as coriander is very sensitive to any mechanical resistance caused by the fragments of green manure deposited on the soil surface. On the other hand, the incorporation times showed different moments of synchronisation between the mineralisation of the green manure and the period of maximum nutritional requirement of the coriander, probably due to the differences in air temperature between the growing seasons (Figure 1), with accelerated decomposition of the plant residue in the spring (SOUZA *et al*., 2017).

In relation to gross income, the statistical behaviour is similar to that observed for green-matter yield in the coriander, as this variable reflects the product of the price paid for the vegetables and their productive yield, where the price paid for coriander varied little between growing season, from BRL 5.00 kg^{-1} (spring) to BRL 5.50 kg^{-1} (autumn-winter). According to Figures 3A and 3B, the greatest mean values for gross income were BRL 20,800.00 ha^{-1} (spring: 12.2 t ha^{-1} and a time of 10 days) and BRL 27,041.67 ha^{-1} (autumn-winter: 8.8 t ha^{-1} and a time of 20 days) respectively. For the amounts of 12.2 t ha^{-1} (spring) and 8.8 t ha^{-1} (autumn-winter) of *C. procera*, a maximum gross income of BRL 20,523.04 ha^{-1} and BRL 28,079.42 was estimated respectively for the optimal incorporation times of 13 and 23 days prior to sowing the coriander (Figures 3C and 3D).

Lima *et al*. (2007) reported a price of BRL 5.00 kg^{-1} for coriander 'Verdão' during both winter and spring, in Mossoró, Rio Grande do Norte, reaching a maximum gross income of BRL 26,100.00 ha^{-1}. For the use of *C. procera* as green manure, there are results that show that gross income increased in the organic production of rocket and radish when employing this spontaneous species (SILVA, A. *et al*., 2015; SOUZA *et al*., 2015).

Figure 3 - Gross income (BRL ha^{-1}) in the production of coriander as a function of the amount of *Calotropis procera* and incorporation time of the green manure into the soil (A. spring; B. autumn-winter) and the reverse (C. spring; D. autumn-winter), for each growing season

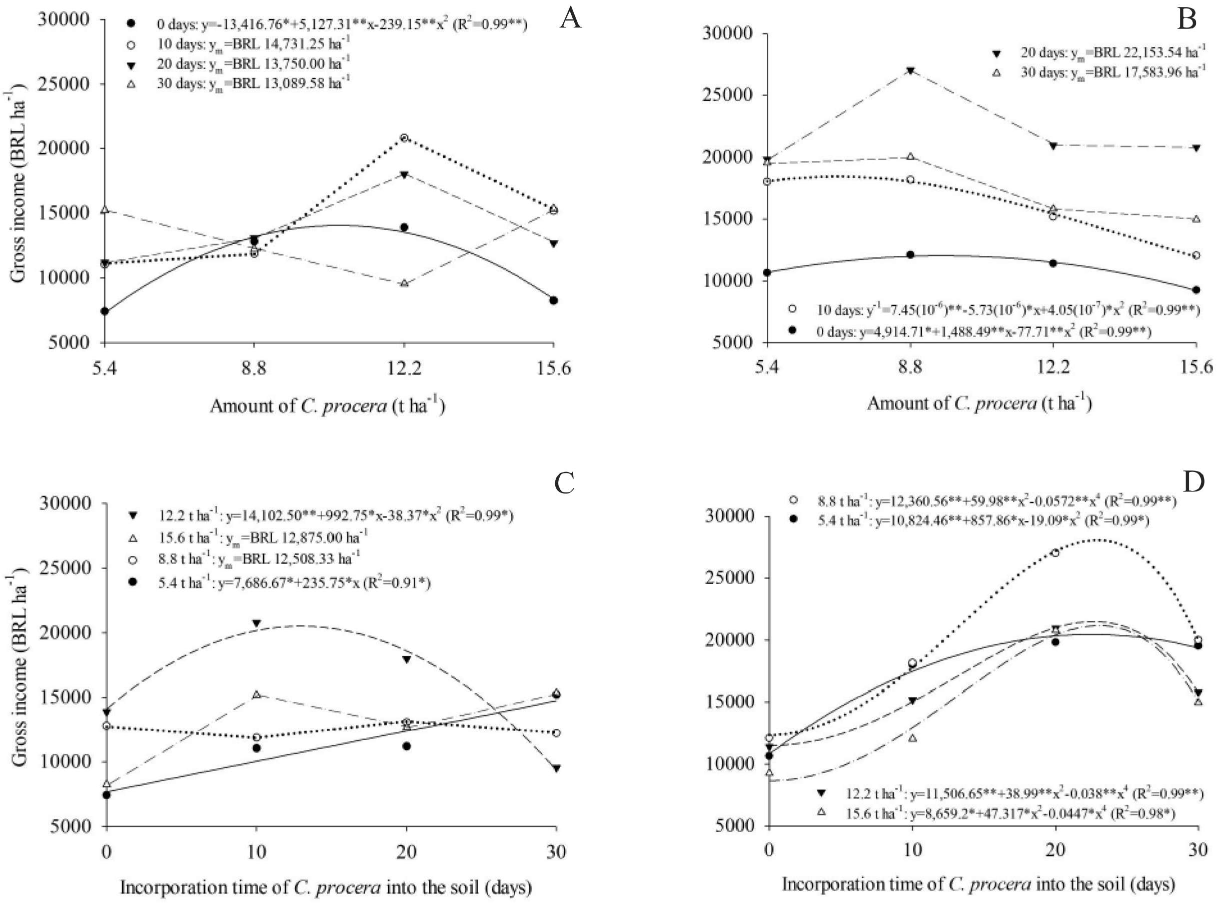


Table 2 shows the sum of the variable, fixed and opportunity costs, ranging from BRL 5,496.58 ha^{-1} (spring) to BRL 6,367.58 ha^{-1} (autumn-winter). The total production cost of one hectare of coriander fertilised with *C. procera* was estimated for each amount of green manure incorporated into the soil (5.4, 8.8, 12.2 and 15.6 t ha^{-1}), corresponding to the following respective values: BRL 6,571.08; BRL 7,272.42; BRL 7,976.28 and BRL 8,677.64 for the spring crop, and BRL 7,648.58; BRL 8,483.42; BRL 9,321.28 and BRL 10,156.14 for the autumn-winter crop (Table 3). It should be noted that the difference between production costs is related to the costs of cutting, transportation, crushing, electrical energy of the forage maker, drying, bagging, distribution and incorporation of *C. procera*, with differences occurring between costs, which increased in relation to the quantitive factor of the green-manure biomass.

Harvesting activities in preparing the green manure accounted for 16.4, 24.6, 31.3 and 36.9% of the total costs relative to the increasing amounts of *C. procera*. The cost became higher during the autumn-winter, mainly due to readjustment of the daily wage paid to the rural worker, which ranged from BRL 25.00 to BRL 30.00. Expenses with daily rates ranged from 65.5 to 72.8% of the total costs between the lowest and highest amounts of *C. procera* biomass (Tables 2 and 3). Some studies of this green manure have obtained results that corroborate those found in the present work, with labour being the most expensive operating cost, corresponding to an average of 68% of the costs in radish cultivation (SILVA, A. *et al.* , 2015) and 69% in rocket production (SOUZA *et al*., 2015). Silva, J. *et al.* (2017) quantified labour costs as 49.2% in relation to the total costs of cultivating coriander 'Verdão' fertilised with 14 t ha^{-1} of *Ipomoea cairica* during the winter in Mossoró, Rio Grande do Norte.

Net income from coriander production reached values greater than BRL 12,500.00 ha^{-1} in the spring crop associated with 12.2 t ha^{-1} *C. procera* and an incorporation time of 13 days prior to sowing the coriander (Figures 4A and 4C). For the autumn-winter, the amount of 7.6 t ha^{-1} fertiliser and an incorporation time of 23 prior to planting the coriander gave a net income of over BRL 19,500.00 ha^{-1}, which was significantly higher than that of the first growing season (Figures 4B and 4D). Net income is the difference between gross income and total production costs, where the superiority of the fall-winter season is mainly due to gross income. According to Bezerra Neto *et al*. (2012), net income better expresses the economic value of cropping systems when compared to gross income, since production costs are already deducted.

Table 2 - Variable, fixed and opportunity cost coefficients in the production of one hectare of coriander as a function of the growing season

COMPONENT	UNIT	AMOUNT	TOTAL (BRL)	
			Spring	Autumn-Winter
Variable Costs			3,640.58	4,335.58
1 - Inputs			120.00	150.00
Seeds: Coriander ‘Verdão’	kg	6.0	120.00	150.00
2 - Labour			3,325.00	3,990.00
Preparing the beds	daily	40	1,.000.00	1,200.00
Sowing the coriander	daily	20	500.00	600.00
Thinning the coriander	daily	10	250.00	300.00
Manual weeding	daily	5	125.00	150.00
Irrigation	daily	15	375.00	450.00
Harvesting the coriander	daily	40	1,000.00	1,200.00
Transporting the coriander	daily	3	75.00	90.00
3 - Energy			195.58	195.58
Energy used for irrigation	kW	889.0	195.58	195.58
Fixed Costs			1,456.00	1,632.00
4 - Depreciation			356.00	378.00
Irrigation pump	month*	2	110.00	115.00
Irrigation piping	month	2	5.00	7.00
Connections	month	2	23.00	26.00
Micro sprinklers	month	2	75.00	80.00
Forage maker	month	1	143.00	150,00
5 - Taxes and fees			10.00	10,00
Rural Territorial Tax	ha	1	10.00	10,00
6 - Fixed labour			1,090.00	1,244.00
Administrative Assistant	salary	2	1,090.00	1,244.00
Opportunity Costs			400.00	400.00
7 - Land remuneration			200.00	200.00
Leasing	ha	1	200.00	200.00
8 - Fixed capital remuneration (0.5% per month)			200.00	200.00
Infrastructure and equipment	BRL 100.00 month^{-1}**	2	200.00	200.00
Total (Variable + Fixed + Opportunity Costs)			5,496.58	6,367.58

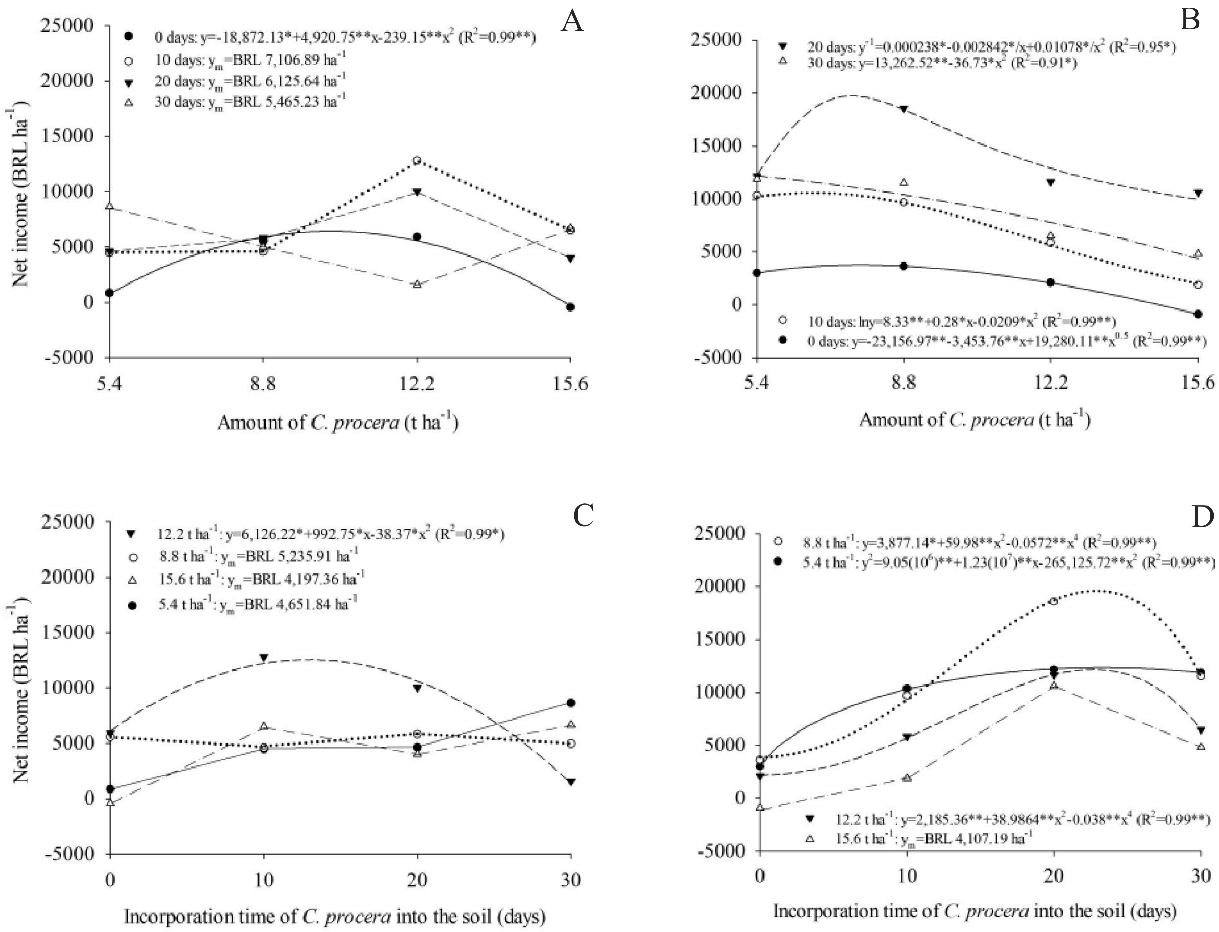
*Ratio between the market value and working life of the equipment, multiplied by the time of use; **Relative to the value of the fixed capital (BRL 20,000.00) multiplied by its remuneration during cultivation

Table 3 - Total costs of producing one hectare of coriander as a function of the amount of *Calotropis procera* incorporated into the soil and the growing season

PRODUCTION COST COMPONENTS	UNIT	AMOUNT	TOTAL (BRL)	
			Spring	Autumn-Winter
1 - 5.4 t ha^{-1} of *C. procera*			6,571.08	7,648.58
Cutting	daily	20.0	500.00	600.00
Transport	load	1.0	70.00	80.00
Crushing	daily	2.5	62.50	75.00
Energy (forage maker)	kW	100	22.00	22.00
Drying	daily	5.0	125.00	150.00
Bagging	daily	1.0	25.00	30.00
Distribution and incorporation	daily	10.8	270.00	324.00
Variable, fixed and opportunity costs			5,496.48	6,378.60
2 - 8.8 t ha^{-1} of *C. procera*			7,272.42	8,483.42
Cutting	daily	32.6	815.00	978.00
Transport	load	2.0	140.00	160.00
Crushing	daily	4.1	102.50	123.00
Energy (forage maker)	kW	162.9	35.84	35.84
Drying	daily	8.1	202.50	243.00
Bagging	daily	1.6	40.00	48.00
Distribution and incorporation	daily	17.6	440.00	528.00
Variable, fixed and opportunity costs			5,496.48	6,378.60
3 - 12.2 t ha^{-1} of *C. procera*			7,976.28	9,321.28
Cutting	daily	45.2	1,130.00	1,356.00
Transport	load	3.0	210.00	240.00
Crushing	daily	5.6	140.00	168.00
Energy (forage maker)	kW	225.9	49.70	49.70
Drying	daily	11.3	282.50	339.00
Bagging	daily	2.3	57.50	69.00
Distribution and incorporation	daily	24.4	610.00	732.00
Variable, fixed and opportunity costs			5,496.48	6,378.60
4 - 15.6 t ha^{-1} of *C. procera*			8,677.64	10,156.14
Cutting	daily	57.8	1,445.00	1,734.00
Transport	load	4.0	280.00	320.00
Crushing	daily	7.2	180.00	216.00
Energy (forage maker)	kW	288.9	63.56	63.56
Drying	daily	14.4	360.00	432.00
Bagging	daily	2.9	72.50	87.00
Distribution and incorporation	daily	31.2	780.00	936.00
Variable, fixed and opportunity costs			5,496.48	6,378.60

The positive results are due to the coriander responding very well to the green manure, with these promising economic indicators being a result of the better use of environmental resources by the plants afforded by the optimal doses and incorporation times of *C. procera*. Differing slightly from the data found in the coriander

Figure 4 - Net income (BRL ha^{-1}) in the production of coriander as a function of the amount of *Calotropis procera* and incorporation time of the green manure into the soil (A. spring; B. autumn-winter) and the reverse (C. spring; D. autumn-winter), for each growing season

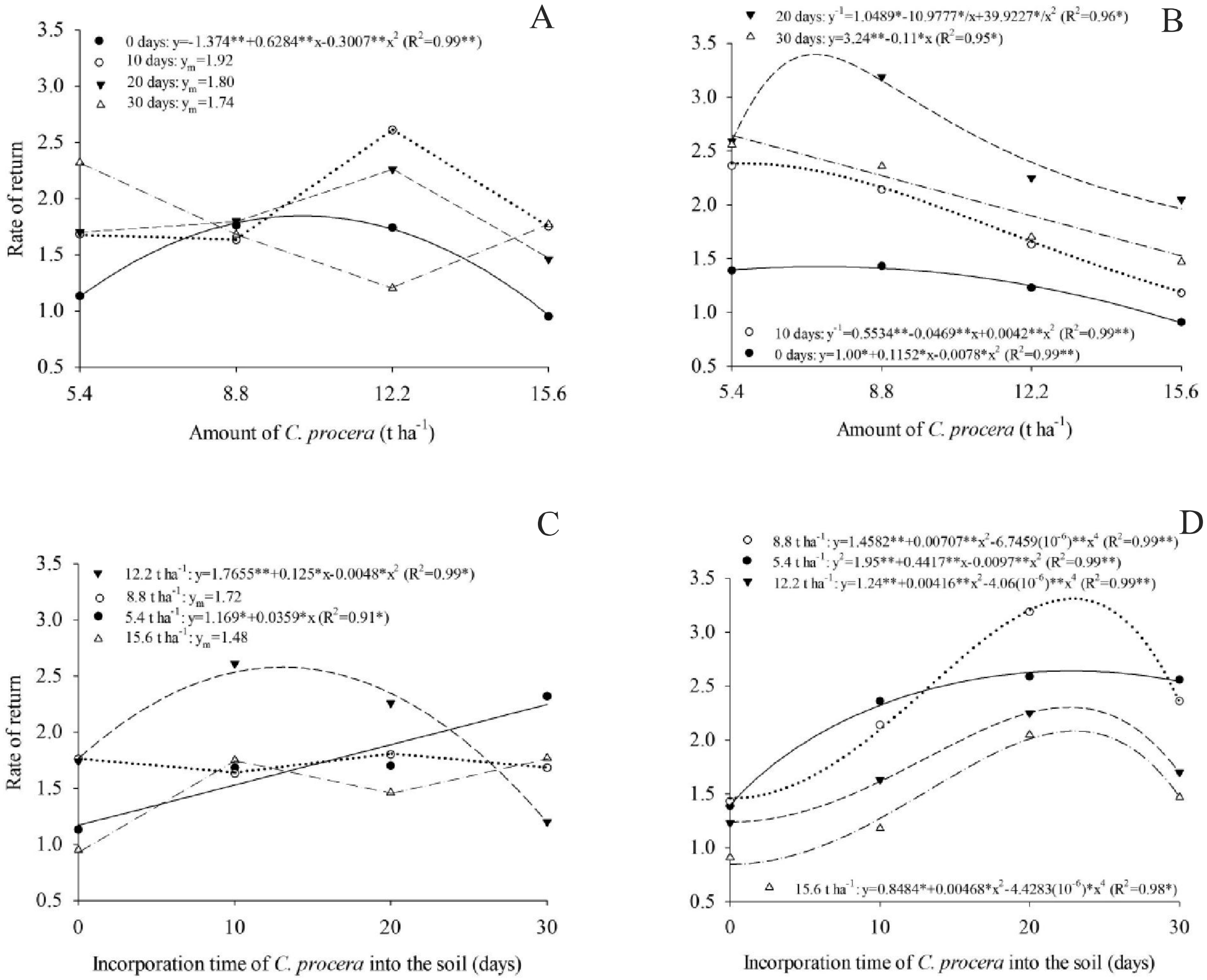


crop, Silva, A. *et al*. (2015) obtained a higher net income in radish production with 15.6 t ha^{-1} *C. procera* added to the soil 22 days prior to sowing, where the fall-winter crop was significantly superior to the spring crop. Similarly, Silva, M. *et al*. (2011) achieved a higher net income from beetroot fertilised with 15.6 t ha^{-1} *I. cairica* at the time the beet was planted. Such differences in results are due to the specific characteristics of each species under study, such as crop cycle and nutritional requirements, among other factors.

In the spring, the highest rate of return (2.57) was found with the use of 12.2 t ha^{-1} *C. procera* added to the soil 13 days prior to sowing the coriander (Figures 5A and 5C). In the autumn-winter (Figures 5B and 5D), the maximum value (3.31) was obtained at a dose of 7.2 t ha^{-1} green manure, 23 days prior to sowing. The superiority of the autumn-winter for a smaller amount of *C. procera*, can be explained by the higher yield of green matter (around 5.0 t ha^{-1}) and the amount paid for the product (BRL 5.50 kg^{-1}), corresponding to gross income, together with the reduced cost of obtaining and incorporating the *C. procera* (BRL 2,104.82 ha^{-1}).

Evaluating the rate of return of Coriander ‘Verdão’ with mineral fertilisers in Mossoró, Rio Grande do Norte, Lima *et al*. (2007) found a maximum value of 3.18. On the other hand, Negreiros *et al*. (2013), studying the residual effect of different amounts and incorporation times of cattle manure on the profitability of coriander, found a rate of return of BRL 4.02 per BRL invested for an amount of 40 t ha^{-1} with incorporation 56 days prior to planting. This result shows that *C. procera* can be used as an option for organic fertiliser, especially as it promotes an economic return similar to that of mineral fertilisers or corral manure.

Figure 5 - Rate of return in the production of one hectare of coriander as a function of the amount of *Calotropis procera* and incorporation time of the green manure into the soil (A. spring; B. autumn-winter) and the reverse (C. spring; D. autumn-winter), for each growing season



Regarding the profitability index, this increased up to 10.6 t ha^{-1} *C. procera* in the spring (43.62%) and 7.3 t ha^{-1} in the autumn-winter (55.3%), and then decreased (Figure 6). However, there was no statistical difference between growing seasons within each amount of green-manure biomass (Table 4). The profitability index is the main economic indicator of the viability of an agricultural activity and is a result of the ratio between gross and net incomes. As such, it also includes the total cost of production.

Figures 7A and 7B show maximum values for the profitability index in the following combinations of treatments: 5.4 t ha^{-1} and a time of 30 days (58.84%), 10.2 t ha^{-1} and a time of 20 days (56.9%), and 12.2 t ha^{-1} and a time of 16 days (59.1%). Lima *et al*. (2007) obtained a maximum profitability index of 67.3% and 80.8% in the 'Verdão' and 'Tabocas' cultivars of coriander respectively under conventional cultivation, which, although greater,

Figure 6 - Profitability index (%) in the production of one hectare of coriander from the interaction of the amount of *Calotropis procera* biomass within each growing season

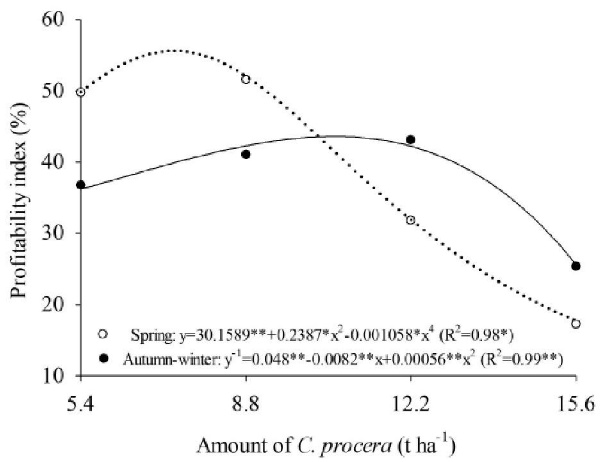
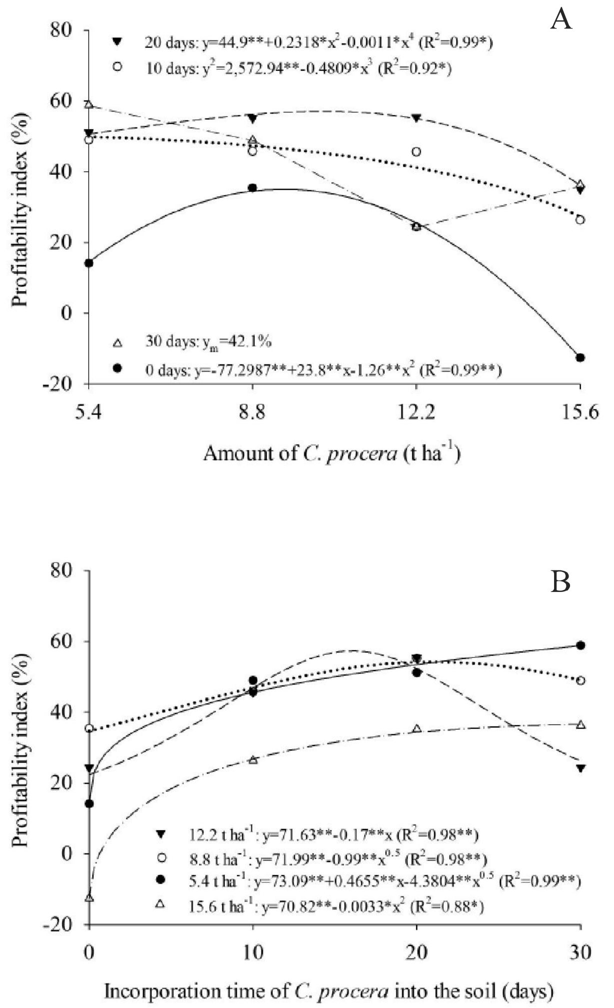


Table 4 - Mean values for the profitability index in coriander from the interaction of the growing season within each amount of *Calotropis procera* biomass

Growing season	Profitability index (%)			
	5.4 t ha^{-1}	8.8 t ha^{-1}	12.2 t ha^{-1}	15.6 t ha^{-1}
Spring	36.79 a[1]	41.07 a	43.12 a	25.37 a
Autumn-winter	49.77 a	51.60 a	31.81 a	17.27 a

[1]Mean values followed by the same letter in a column do not differ by Tukey's test at 5% probability

Figure 7 - Profitability index (%) in the production of one hectare of coriander as a function of the amount of *Calotropis procera* within each incorporation time of the green manure (A), and the reverse (B)



does not invalidate the adoption of green manure as a cropping practice in coriander production, and can be justified by factors that are not measured in an economic assessment, such as the conservation of soil fertility and an improvement in its biological diversity (BATISTA *et al*., 2013, 2016; SOUZA *et al*., 2015).

CONCLUSIONS

1. The amount of 12.2 t ha^{-1} *C. procera* in the spring and 8.8 t ha^{-1} in the autumn-winter resulted in greater productivity and profitability in the production of coriander;
2. The incorporation of green manure, 13 days (spring) and 23 days (autumn-winter) prior to sowing the crop were considered ideal for the economic viability of the activity;
3. The net income (BRL 19,607.10 ha^{-1}) and the rate of return (3.31) for the cultivation of coriander fertilised with *C. procera* were higher when the crop was grown during the autumn-winter.

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