

Green manuring with *Calotropis procera* for the production of coriander in two growing seasons

Adução verde com *Calotropis procera* na produção de coentro em duas épocas de cultivo

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ABSTRACT

The use of spontaneous species of the Caatinga biome can contribute significantly to the nutritional demand of vegetable crops, thereby providing an agroecological and sustainable form of production. The objective of this research was to determine the effects of different biomasses of *Calotropis procera* (rooster tree) and times of incorporation into the soil of green manure during two growing seasons on the agronomic performance of coriander cv. Verdão produced in Serra Talhada, a semi-arid region of Pernambuco, Brazil. The experimental design was randomized blocks with three replications. The treatments were arranged in a 4 x 4 factorial scheme, with the first factor consisting of biomass amounts of *C. procera* (5.4, 8.8, 12.2 and 15.6 t ha⁻¹ on a dry basis) and the second by the incorporation times into the soil (0, 10, 20 and 30 days before coriander planting). The evaluated characteristics were plant height, number of stems per plant, yield of green mass and dry mass of shoot. The best productive performance of coriander was observed in amounts of 12.2 (spring) and 8.8 (autumn-winter) t ha⁻¹ *C. procera* added to the soil, with an ideal incorporation time of 13 (spring) and 23 (autumn-winter) days before sowing of the crop and with larger accumulations of green and dry mass of the shoot being obtained in autumn-winter.

Index terms: *Coriandrum sativum* L.; organic cultivation; rooster tree.

RESUMO

O uso de espécies espontâneas do bioma Caatinga pode contribuir de forma significativa no suprimento nutricional demandado pelas hortaliças, sendo uma forma agroecológica e sustentável de produção. O objetivo da pesquisa foi determinar os efeitos de quantidades de biomassa de *Calotropis procera* (flor-de-seda), de tempos de incorporação ao solo do adubo verde e de duas épocas de cultivo sobre o desempenho agrônômico do coentro cv. Verdão produzido em Serra Talhada, semiárido de Pernambuco, Brasil. O delineamento experimental foi em blocos casualizados, com três repetições. Os tratamentos foram arranados em esquema fatorial 4 x 4, com o primeiro fator constituído por quantidades de biomassa de *C. procera* (5,4; 8,8; 12,2 e 15,6 t ha⁻¹ em base seca), e o segundo pelos tempos de incorporação ao solo (0, 10, 20 e 30 dias antes do plantio do coentro). As características avaliadas foram altura de plantas, número de hastes por planta, rendimento de massa verde e massa seca da parte aérea. O melhor desempenho produtivo do coentro foi observado nas quantidades 12,2 (primavera) e 8,8 (outono-inverno) t ha⁻¹ de *C. procera* adicionada ao solo, com um tempo ideal de incorporação de 13 (primavera) e 23 (outono-inverno) dias antes da sementeira da cultura e com maiores acúmulos de massas verde e seca da parte aérea sendo obtidos no outono-inverno.

Termos para indexação: *Coriandrum sativum* L.; cultivo orgânico; flor-de-seda.

INTRODUCTION

The cultivation of coriander (*Coriandrum sativum* L.), a vegetable crop widely consumed and of great socioeconomic importance, has increased exponentially in the Brazilian territory, mainly in the North and Northeast regions of Brazil. Coriander has a short cycle (average of 30 to 40 days), which guarantees a quick return of the invested capital, increasing the income of families in addition to making feasible the use of family labor. Thus, coriander is a species of remarkable social reach (Lira et al., 2015; Pereira et al., 2013).

Most sowing is done in home gardens, which is performed by family farmers using manure (cattle, goats and/or sheep) as a source of organic fertilizer. Thus, the dependence on these inputs makes the producer vulnerable to scarcity, as the farmer may not always have this resource on the property, which increases production costs (Linhares et al., 2012a).

The restitution of nutrients to the soil is an important practice to obtain good productivities in agriculture. In this aspect, green fertilization stands out as a viable and low-cost alternative (Oliveira et al., 2012). The most-used species

for green manure have been legumes. However, in recent years, interest has grown in the use of spontaneous plants in this system due to the potential increase in organic matter and the improvement of the physical, microbiological and nutritional qualities of the soil; through proper management, such additions are being used efficiently in the cultivation of vegetable crops (Favero et al., 2000; Góes et al., 2014; Souza et al., 2016).

Working with spontaneous species of the Caatinga hairy woodrose (*Merremia aegyptia* L.), oneleaf senna (*Senna uniflora* Mill.) and rooster tree (*Calotropis procera* (Ait) R. Br.) for green manuring in the Northeast region of Brazil, Batista et al. (2013) obtained an increase in the productivity of these species with increasing doses of green manures incorporated into the soil. This effect stems from the proportionally higher contribution of soil organic matter to the cation exchange capacity and from the nutrient availability flow from cycling processes by microbial biomass and rapid mineralization of the incorporated material. The use of these species in green manuring increased the production of crops such as lettuce and arugula (Linhares et al., 2008; Linhares et al., 2009a, 2009b; Souza et al., 2016, 2017), whose cultivation cycles are similar to coriander.

Evaluating quantities and times of *M. aegyptia* decomposition in coriander culture, Linhares et al. (2012b) obtained a yield of 7.06 t ha⁻¹ with the 15.6 t ha⁻¹ dose of the green manure added 30 days before sowing, which contributed to the good performance of the crop. Souza et al. (2016) observed maximum production of arugula when they incorporated 15.6 t ha⁻¹ of *C. procera* 20 days before planting, in autumn, in Serra Talhada, Pernambuco

State, Brazil. Under the same soil and climatic conditions, Silva et al. (2017) found that the amount of 15.6 t ha⁻¹ of *C. procera* associated with the 22-day incorporation time was responsible for improved agronomic performance of the radish. *C. procera* stands out for its adaptation, biomass production capacity throughout the year, ease of management and availability in the Brazilian semi-arid region (Almeida et al., 2015).

Therefore, the objective of this study was to evaluate the agronomic performance of coriander as a function of the added biomass of *C. procera*, incorporation times of green manure and the growing seasons (spring and autumn-winter) under the environmental conditions of Serra Talhada, Pernambuco.

MATERIAL AND METHODS

Two field experiments were conducted in two growing seasons: spring (October to December 2011) and autumn-winter (May to July 2012), at the Universidade Federal Rural de Pernambuco (UFRPE), Unidade Acadêmica de Serra Talhada (UAST), located at 7°57'15" south latitude and 38°17'41" west longitude, at 461 m altitude, in the microregion of Sertão do Pajeú, north of Pernambuco. The local climate, by Köppen classification, is Bhw, which is described as semi-arid, hot and dry, with summer rains and annual thermal averages of 24.7 °C and average annual precipitation of 642.1 mm (Medeiros et al., 2005; SUDENE, 1990). The average meteorological data from the period of the experiments are shown in Figure 1.

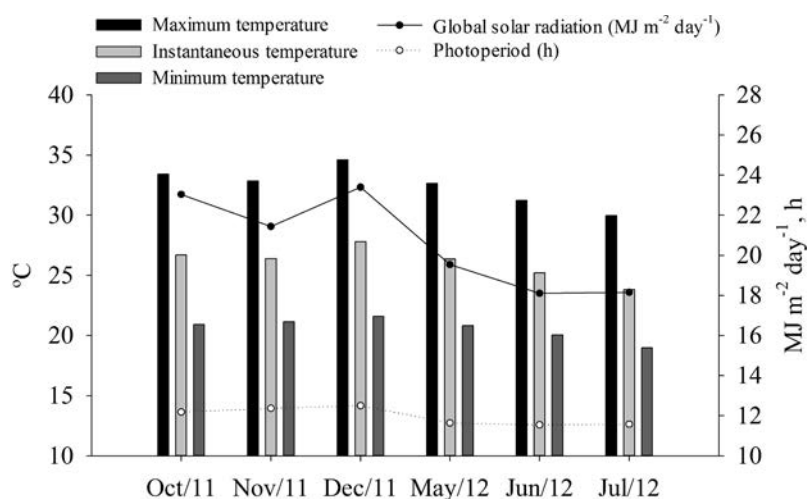


Figure 1: Monthly mean values of instantaneous temperatures (°C), maximum and minimum, global solar radiation (MJ m⁻² day⁻¹) and photoperiod (h) in each time of coriander cultivation fertilized with *Calotropis procera*.

The soil of the experimental area is classified as a *Cambissolo Háplico Ta Eutrófico* (Santos et al., 2013), sandy loam texture (sand = 783.6 g kg⁻¹, silt = 100.4 g kg⁻¹, and clay = 116.0 g kg⁻¹), whose chemical characteristics (Silva, 2009), at a depth of 0-0.20 m before the start of the experiments, in spring, were pH in H₂O (1:2.5) = 6.6, organic matter (OM) = 8.4 g kg⁻¹, P = 15.0 mg dm⁻³, K⁺ = 0.7 cmol_c dm⁻³, Ca²⁺ = 3.4 cmol_c dm⁻³, Mg²⁺ = 2.0 cmol_c dm⁻³, and Al³⁺ = 0.0 cmol_c dm⁻³, and in autumn-winter, were pH in H₂O (1:2.5) = 6.5, OM = 12.7 g kg⁻¹, P = 20.0 mg dm⁻³, K⁺ = 0.4 cmol_c dm⁻³, Ca²⁺ = 3.4 cmol_c dm⁻³, Mg²⁺ = 2.0 cmol_c dm⁻³, and Al³⁺ = 0.0 cmol_c dm⁻³.

The experimental design was in randomized blocks, with three replications. The treatments were arranged in a 4 x 4 factorial scheme, with the first factor consisting of four biomass amounts of *C. procera* (5.4, 8.8, 12.2 and 15.6 t ha⁻¹ on a dry basis), and the second factor, by four times of incorporation into the soil of this fertilizer (0, 10, 20 and 30 days before sowing of the coriander).

Each experimental unit had a total area of 1.44 m², with a harvest plot of 0.80 m². Six rows or planting lines were arranged transversely in each plot, spaced 0.20 m apart, and within row spacing between plants of 0.05 m. The coriander cultivar planted was Verdão, indicated for cultivation in the Northeast region. Soil preparation in each experiment consisted of the raising of the beds using hoes.

The *C. procera* was collected in areas near the experimental area, crushed in a conventional forage machine, with uniform particles of approximately two to three centimeters being obtained. Drying was performed in the shade until the plant particles reached the point of hay (10% of humidity). The material was analyzed and the dry matter exhibited the following nutrient content: 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 fertilizer was incorporated in the 0-0.20 m layer of the soil in the experimental plots, according to the treatments. Daily irrigations were carried out in two shifts for the purpose of favoring the microbial activity of the soil in the organic matter mineralization process.

The planting of the coriander in the first growing season (spring) was performed on November 12, 2011, whereas in autumn-winter, this was done on June 1, 2012. A direct seeding at two centimeters deep was performed, with three seeds being sown per hole. Ten days after emergence, thinning occurred, with one plant being left per hole. Irrigation was performed with a microsprinkler system, with two daily waterings - one in the morning

and another in the afternoon - supplying a water sheet, on average, of 8 mm day⁻¹, pumped from a weir. Weed control was performed whenever necessary.

In the spring, the coriander harvest was conducted at 38 days after sowing (DAS), whereas in autumn-winter, it was at 40 DAS. At harvest, the following characteristics were evaluated: the height of the plants, expressed in cm, obtained by measuring, with a ruler, a sample of twenty plants from the ground level to the end of the highest leaf; number of stems per plant, determined by direct counting of the number of stems in a sample of twenty plants; yield of green mass obtained from the fresh mass of the shoot of all the plants present in the harvest area of the plot and expressed in t ha⁻¹; and the dry mass of the shoot, estimated from the weight of the dry mass of the plants of the harvest area, after oven drying with forced air circulation, at a temperature set at 65 °C, until a constant mass, expressed in t ha⁻¹, was reached.

For each growing season, univariate analyses of variance were performed for the characteristics evaluated through the Sisvar application (Ferreira, 2011). A joint analysis was performed for the characteristic(s) showing homogeneity of variances between the growing seasons (Pimentel-Gomes, 2009). An adjustment procedure for the response curves was done between the evaluated characteristics and the quantitative factors through the program SigmaPlot 12.0 (Systat Software, 2011). Tukey's test (p < 0.05) was used to compare the means of the qualitative treatment.

RESULTS AND DISCUSSION

Joint analysis of variance

According to the results of the joint analysis of the variables evaluated as a function of growing seasons, the biomass of *C. procera* and the times of incorporation of each to the soil showed a double interaction between the growing seasons and the amounts of *C. procera*, as well as between the seasons and the incorporation times of the green manure for the variables of plant height and shoot dry mass (Table 1). Shoot dry mass was significantly influenced by the interaction of the amounts of *C. procera* with their incorporation times. For the number of stems per plant and yield of green mass, an interaction occurred among the three factors.

Plant height (cm)

In autumn-winter, plant height reduced linearly with increasing amounts of *C. procera* (Figure 2A). For each ton added to the soil, decreases of 0.22 cm occurred in this variable relative to green fertilization

with 5.4 t ha⁻¹ (17.28 cm). No regression curve was fitted for the spring cultivation (mean of 9.35 cm). On the other hand, an evaluation of the growing seasons within each amount of *C. procera* biomass showed that greater heights of coriander plants were obtained when the crop was planted in autumn-winter (Table 2).

Increasing values were observed for the plant height in the autumn-winter when the green manure was incorporated 23 days before sowing, in which the coriander reached an estimated maximum height of 18.38 cm and then declined (Figure 2B). For the spring, adjustment of the regression equation (mean of 9.35 cm) was not possible. Evaluation of the growing seasons within each incorporation time revealed that the height of plants in autumn-winter was higher than in the

spring season, regardless of the period of permanence in the soil of the green manure (Table 3).

Shoot dry mass (t ha⁻¹)

The shoot dry mass of the coriander reached a maximum value of 0.55 t ha⁻¹ in the spring season, associated with fertilization with 12.78 t ha⁻¹ of *C. procera* (Figure 3A), whereas no adjustments were made to the regression curve when the plants were cultivated in autumn-winter, when the average dry mass accumulation was 0.60 t ha⁻¹. Coriander dry mass yield in the spring was statistically higher than that of autumn-winter at the doses of 5.4 and 8.8 t ha⁻¹ of *C. procera*, and statistically similar in the dose of 12.2 t ha⁻¹ (Table 4). In the dose of 15.6 t ha⁻¹, the dry mass yield in the autumn-winter cultivation was superior to the spring.

Table 1: Summary of the analysis of variance analysis for plant height (PH), number of stems per plant (NSP), green mass yield (GMY) and shoot dry mass (SDM) of coriander plants fertilized with *Calotropis procera* in two growing seasons.

Sources of variation	df	PH	NSP	GMY	SDM
Blocks (Seasons)	4	2.13 ^{ns}	0.47 ^{ns}	3.51*	0.91 ^{ns}
Seasons	1	241.78**	459.07**	12.77**	75.91**
Amounts	3	1.64 ^{ns}	0.82 ^{ns}	3.63*	5.87**
Times	3	16.80**	13.81**	23.55**	21.47**
Seasons x Amounts	3	3.36*	6.60**	7.05**	11.38**
Seasons x Times	3	8.24**	1.45 ^{ns}	8.26**	14.22**
Amounts x Times	9	0.78 ^{ns}	1.42 ^{ns}	2.74**	3.95**
Seasons x Amounts x Times	9	1.32 ^{ns}	2.09*	2.36*	2.02 ^{ns}
C.V. (%)		14.51	11.97	20.06	14.11
Overall Mean		12.14	6.08	2.81	0.53

^{ns}: Not significant. ** and *: significant at the 1% and 5% probability level, by the F test, respectively.

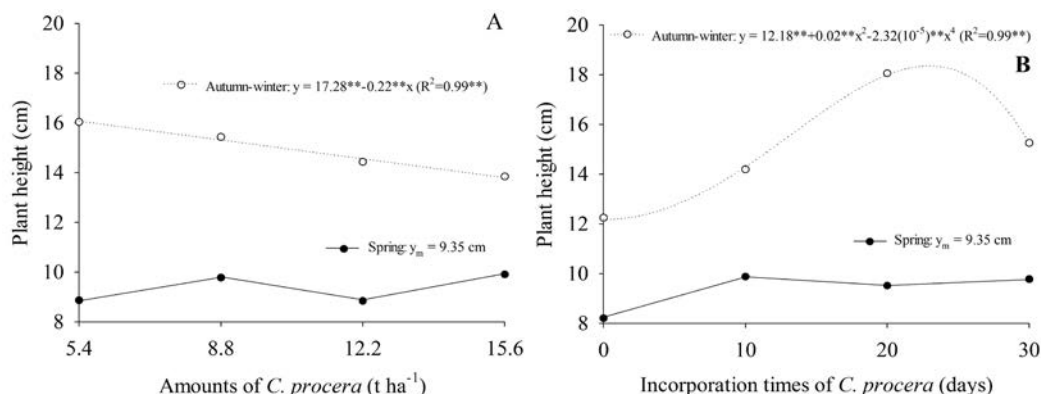


Figure 2: Plant height of coriander as a function of interactions: amounts of *Calotropis procera* and growing seasons (A) and times of incorporation to the soil of the green manure and growing seasons (B).

Table 2: Mean values of coriander plant height from the interaction between growing seasons and biomass of *Calotropis procera*.

Growing seasons	Amounts of <i>C. procera</i> (t ha ⁻¹)			
	5.4	8.8	12.2	15.6
	Plant height (cm)			
Spring	8.87 b ¹	9.78 b	8.84 b	9.91 b
Autumn-winter	16.04 a	15.44 a	14.44 a	13.84 a

¹ Means followed by the same letter in the column do not differ by the Tukey test at the 5% probability level.

Table 3: Mean values of coriander plant height from the interaction between growing seasons and incorporation times into the soil of *Calotropis procera*.

Growing seasons	Incorporation times of <i>C. procera</i> (days)			
	0	10	20	30
	Plant height (cm)			
Spring	8.21 b ¹	9.88 b	9.52 b	9.78 b
Autumn-winter	12.25 a	14.20 a	18.06 a	15.26 a

¹ Means followed by the same letter in the column do not differ by the Tukey test at the 5% probability level.

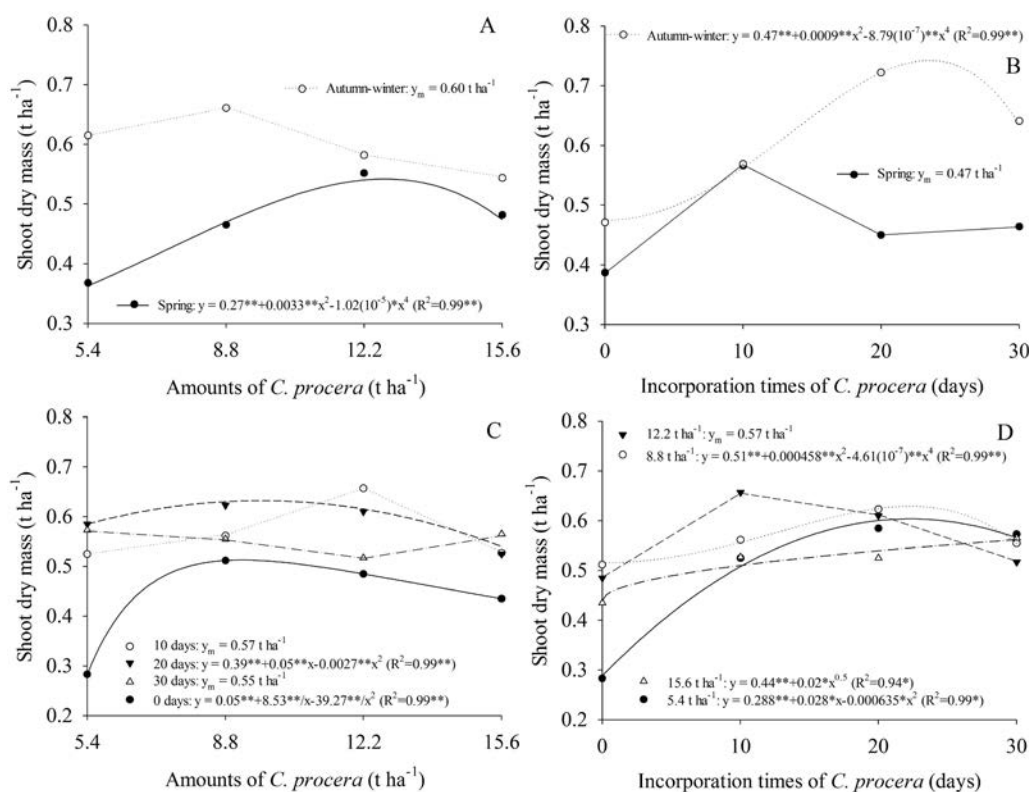
**Figure 3:** Shoot dry mass of coriander as a function of interactions: amounts of *Calotropis procera* and growing seasons (A), times of incorporation to the soil of the green manure and growing seasons (B), amounts of *C. procera* and times of incorporation (C), and the inverse (D).

Table 4: Mean values of dry mass of coriander shoots from the interaction between growing seasons and biomass of *Calotropis procera*.

Growing seasons	Amounts of <i>C. procera</i> (t ha ⁻¹)			
	5.4	8.8	12.2	15.6
	Shoot dry mass (t ha ⁻¹)			
Spring	0.61 a ¹	0.66 a	0.55 a	0.48 b
Autumn-winter	0.37 b	0.46 b	0.58 a	0.54 a

¹ Means followed by the same letter in the column do not differ by the Tukey test at the 5% probability level.

The estimated incorporation time in 23.56 days provided the highest yield of coriander dry mass in autumn-winter (0.74 t ha⁻¹) (Figure 3B). No regression curve was fitted for the spring (mean 0.47 t ha⁻¹). An evaluation of the growing seasons within each incorporation time revealed that the autumn-winter cultivation yielded mean values of dry mass higher than in the spring, except at 10 days (Table 5).

The estimated dose of 9.4 t ha⁻¹ of *C. procera* with an incorporation time of 20 days provided the highest dry mass result of coriander shoot (0.63 t ha⁻¹) (Figure 3C). No adjustment of the regression curves was required for the times of 10 (0.57 t ha⁻¹) and 30 days (0.55 t ha⁻¹), with a greater average value (0.66 t ha⁻¹) being verified for incorporation time of 10 days associated with the dose of 12.2 t ha⁻¹ of *C. procera*. The dry mass yield also increased in a biquadratic manner with the incorporation times of the green manure to the soil, where the amount of 8.8 t ha⁻¹ of *C. procera*, associated with the estimated time of 22.29 days, reached a maximum value of 0.63 t ha⁻¹, then decreased until the last incorporation time (Figure 3D).

Number of stems per plant

Regarding the number of stems per coriander plant as a function of the interaction of *C. procera* amounts and incorporation times, no adjustments were required for the regression curves for the spring cultivation, with the highest average value observed for the time of 20 days (8.26 stems per plant) (Figure 4A). In general, the coriander produced in the autumn-winter showed a reduction in the number of stems per plant with the increase in green manure, for which the amount of 5.4 t ha⁻¹ of *C. procera* combined with the time of 20 days obtained the maximum average of 5.81 stems per plant (Figure 4B).

An evaluation of the incorporation times as a function of the *C. procera* amounts, in the coriander spring crop, an optimum time association of 19.53 days with 12.2 t ha⁻¹ of green manure was highlighted, with a

maximum number of 8.00 stems per plant being obtained (Figure 4C). No adjustment of the regression curves was required for the treatments for the amounts of 5.4, 8.8 and 15.6 t ha⁻¹. In autumn-winter (Figure 4D), the highest number of stems per coriander plant (5.70 stems) was reached with the amounts of 5.4 and 8.8 t ha⁻¹ of *C. procera* with an incorporation time of 23 days.

Green mass yield (t ha⁻¹)

The green mass yield of 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 of *C. procera* fertilized 10 days before the crop was sown (Figure 5A). In autumn-winter, a maximum yield (4.92 t ha⁻¹) was observed in the amount of 8.8 t ha⁻¹ of *C. procera* with an incorporation time of 20 days (Figure 5B). The estimated incorporation time at 13 days, along with the 12.2 t ha⁻¹ dose of *C. procera*, provided the highest yield of coriander green mass in spring (4.10 t ha⁻¹) (Figure 5C). In the second growing season (autumn-winter), the association of the optimized time of 23 days with the 8.8 t ha⁻¹ dose of green manure (Figure 5D) was highlighted, with a maximum yield of 5.11 t ha⁻¹ being obtained, which was superior to that obtained in the spring.

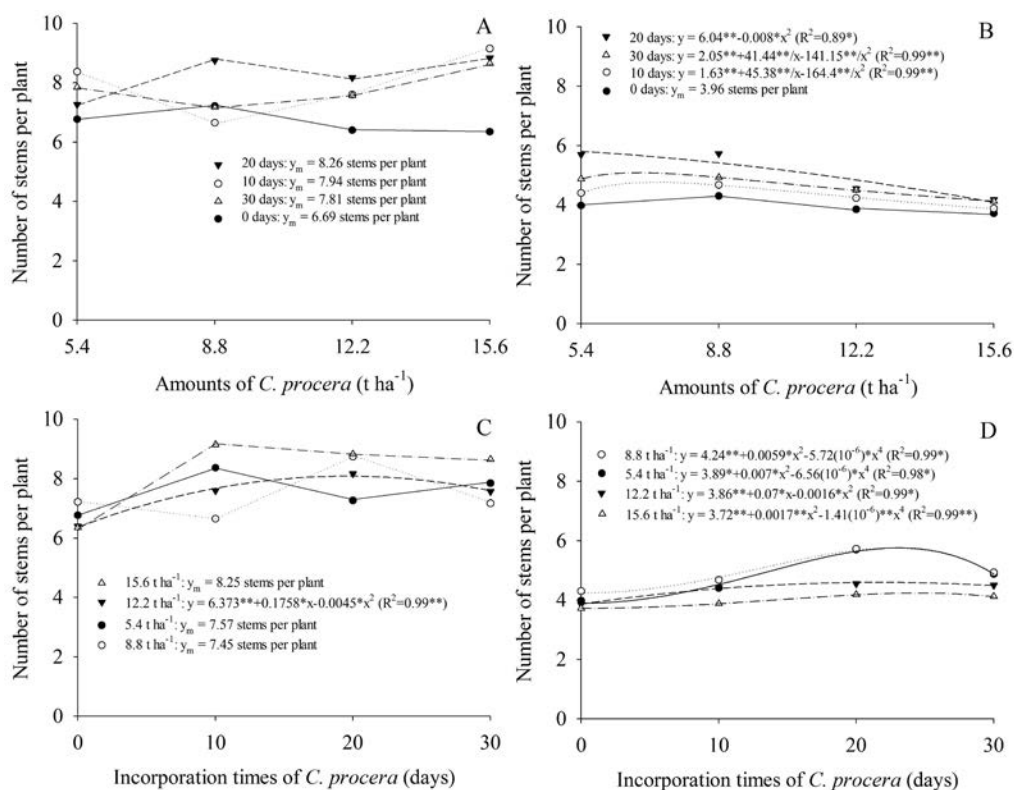
Effects of *C. procera* amounts

The green and dry mass yields of coriander shoots fertilized with *C. procera* increased with the increasing amounts of green manure, reaching maximum values of 12.2 (spring) and 8.8 t ha⁻¹ (autumn-winter), then decreasing up to the last amount of biomass evaluated. Most likely, these doses promoted a better balance between the nutritional demand of the crop and the nutrient supply by the soil, since green fertilization with *C. procera* provides macro- and micronutrients to the soil, besides favoring the development of actinomycetes, fungi and bacteria beneficial to plant growth (Batista et al., 2013, 2016).

Table 5: Mean values of dry mass of coriander shoots from the interaction between growing seasons and incorporation times to the soil of *Calotropis procera*.

Growing seasons	Incorporation times of <i>C. procera</i> (days)			
	0	10	20	30
	Shoot dry mass (t ha ⁻¹)			
Spring	0.39 b ¹	0.57 a	0.45 b	0.46 b
Autumn-winter	0.47 a	0.57 a	0.72 a	0.64 a

¹ Means followed by the same letter in the column do not differ by the Tukey test at the 5% probability level.

**Figure 4:** Number of stems per coriander plant as a function of the interaction of the amounts of *Calotropis procera* biomass and the time of incorporation into the soil of the green manure (A. spring, B. autumn-winter) and the inverse (C. spring, D. autumn-winter) in each growing season.

However, the higher amounts of *C. procera* biomass may have had a negative effect on seedling emergence, with a reduction in productivity, as the coriander is very sensitive to the possible mechanical resistance caused by fragments of green manure deposited on the soil surface. To avoid such a problem, a deeper incorporation of *C. procera* biomass is critical, especially in autumn-winter.

Different results were observed by Linhares et al. (2014), who did not report problems with emergence

of the coriander fertilized with the highest amount of *C. procera* (15.6 t ha⁻¹) in the spring in Mossoró-RN, where plants reached 18.20 cm in height, had 9.00 stems per plant, presented 4.40 t ha⁻¹ of fresh yield and produced 0.85 t ha⁻¹ of accumulated dry mass. Most likely, the better management in the incorporation of *C. procera* in this work avoided problems with the emergence of coriander plants. Under these same environmental and soil conditions, Linhares et al. (2012b) obtained

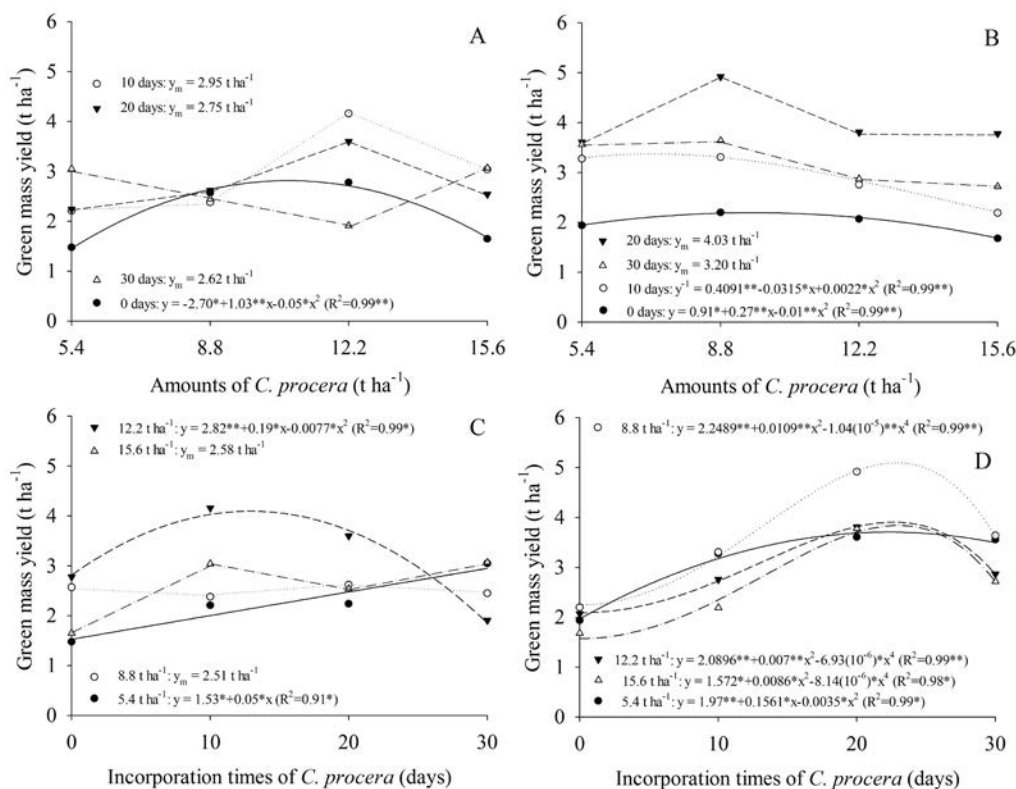


Figure 5: The green mass yield of coriander as a function of the interaction of the biomass amounts of *Calotropis procera* and the times of incorporation into the soil of the green manure (A. spring, B. autumn-winter) and the inverse (C. spring, D. autumn-winter) in each growing season.

maximum yields of green (7.01 t ha⁻¹) and dry (0.72 t ha⁻¹) mass of coriander with 15.6 t ha⁻¹ of *M. aegyptia*, justifying the superiority of this species over *C. procera* in the functioning of the higher content of nutrients, mainly N (25.6 g kg⁻¹).

In conventional production systems, the green mass yield of coriander showed increasing agronomic responses, with N doses of 94 (Angeli et al., 2016) and 213 kg ha⁻¹ (Oliveira et al., 2003) providing productivity results of 20.30 (cv. Vedete) and 37.66 t ha⁻¹ (cv. Verdão), respectively. In the study by Oliveira et al. (2003), organic (5 kg m⁻² of bovine manure) and chemical fertilizations (doses of N evaluated in the form of ammonium sulfate) were used, whereas Angeli et al. (2016) used only mineral sources of N: monoammonium phosphate (MAP) and urea. In addition to the effect of these high doses of N, the high yields of coriander green mass can be explained by the occurrence of average temperatures below 25 °C in both experiments, which increased the cycle of coriander vegetative development (46 to 50 days).

Effects of soil incorporation times of *C. procera*

In the spring and autumn-winter, the productive behavior of coriander also increased with the times of incorporation to the soil of *C. procera*, until approximately 13 and 23 days, respectively, with a subsequent decrease. Similar results were observed by Souza et al. (2017), where the ideal time for the incorporation of *C. procera* was 10 (spring) and 20 (autumn-winter) days before lettuce transplanting in Serra Talhada-PE. On the other hand, Linhares et al. (2014) recommend incorporating *C. procera* 30 days before planting coriander in the spring in Mossoró-RN. These results show that environmental conditions directly influence green manuring and crop performance.

The study of the time of incorporation into the soil of the green manure allows identification of the moment of synchrony between the mineralization of the vegetal residue and the period of maximum nutritional requirement of the coriander (Myers et al., 1994); that is, organic fertilization at the ideal moment for each condition allows the vegetal material to make the nutrients present in its chemical

composition available in the soil solution, thus favoring the absorption and accumulation of biomass by the plants.

According to Grangeiro et al. (2011), the greatest nutrient demands by coriander occur in the period between 30 and 35 days after sowing, thus providing the highest availability of nutrients at 45 (spring) and 55 (autumn-winter) days after incorporation of the green fertilizer.

Torres et al. (2005) verified that the greater mineralization of N in cultures using green manures occurred in the first 42 days after being desiccated, relating this mineralization to the low C/N ratio of the vegetable material (20-25/1). This proportion is similar to that observed in the chemical composition of the *C. procera* (25/1). Thus, the recommended time changed between the growing seasons, perhaps because the variation in temperature and solar radiation promoted changes in the speed of the reactions between the microbiota and the soil organic matter, with higher microbial activity being probable in the spring (Lourente et al., 2011).

Effects of growing seasons

In general, in the coriander autumn-winter planting, the plant height, shoot dry mass and green mass yield were higher than the values obtained in the spring crop. These results are due to milder average temperatures (close to 25 °C), lower solar radiation and a photoperiod of less than 12 h in autumn-winter (Figure 1), which probably favored the vegetative growth of the crop. On the other hand, in the spring, the average maximum temperatures were above 34 °C, and the days had more than 12 h of light (Figure 1), possibly promoting a negative effect on coriander growth.

These data corroborate the findings of Lima et al. (2007), who, while working with the same cultivar of coriander cv. Verdão in the soil-climatic conditions of Mossoró-RN, observed a higher agronomic yield of this vegetable crop when cultivated in the winter (5.00 t ha⁻¹) compared to in spring (3.39 t ha⁻¹) and justified such results with the meteorological information of the planting periods, which was similar to that of the present research. Similar results were also observed in arugula and radish fertilized with *C. procera* in two growing seasons in the municipality of Serra Talhada-PE (Silva et al., 2017; Souza et al., 2016).

The coriander plant presented a higher number of stems in the spring (Figure 4), associated with a lower yield of green mass (Figure 5), indicating that a high percentage of stems relative to the formation of leaves confers a lower quality on the coriander. The planting of leafy vegetable crops in periods characterized by maximum temperatures above 30 °C can promote a short vegetative cycle, reduction

in the leaf numbers, and early flowering, with consequent depreciation of quality (Feltrim et al., 2005). Because the harvesting point of the coriander consists of the period immediately prior to the tasseling, these characteristics associated with maximum temperatures can be confirmed by the differences observed between the cultural cycles in the spring (38 DAS) and autumn-winter (40 DAS).

Therefore, the cultivation of coriander cv. Verdão manured with *C. procera* is recommended for both growing seasons. However, in the autumn-winter planting with 8.8 t ha⁻¹ of the green manure added to the soil at 23 days before planting the crop, an 18% increase can be obtained in the yield of green mass relative to the cultivation in the spring.

CONCLUSIONS

The cultivation in autumn-winter promoted greater accumulations of green and dry mass in the coriander shoot fertilized with *C. procera*. The best productive performance of coriander was observed with the addition of *C. procera* to the soil in the amounts of 12.2 t ha⁻¹ (spring) and 8.8 t ha⁻¹ (autumn-winter). The ideal incorporation time of the green manure consisted of 13 (spring) and 23 (autumn-winter) days before planting of the coriander.

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