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BIOMASS USE OF *MERREMIA AEGYPTIA* AND *CALOTROPIS PROCERA* IN CORIANDER CULTIVATION IN SEMIARID ENVIRONMENT[1]

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ABSTRACT - Green manuring with spontaneous species from the Caatinga has emerged as a viable alternative to supply vegetables with nutrients and thus increase their productivity. This study aimed to evaluate and estimate the maximum physical and economic efficiencies of coriander productive characteristics as a function of equitable biomass amounts of hairy woodrose [*Merremia aegyptia* (L.) Urban] and roostertree [*Calotropis procera* (Aiton) W. T.] in different cropping seasons. The experimental design was a randomized complete block with five treatments and five replicates. The treatments consisted of green manure amounts (16, 29, 42, 55, and 68 t ha^{-1} on a dry basis). A treatment without fertilization (control) was used in each experiment. The maximum agronomic efficiency (coriander green mass yield) was possible with the incorporation of equitable amounts of 49.56 t ha^{-1} of *M. aegyptia* and *C. procera* biomass, respectively. The maximum economic efficiency of production (evaluated in terms of net income and rate of return) of this leafy vegetable was achieved with the addition to the soil of 42.68 and 41.64 t ha^{-1} of biomass of these green manures, respectively. The net income and the rate of return optimized for these amounts of green manures were 30,243.92 R$ ha^{-1} and 2.79 reais for each real invested in the production of this leafy vegetable. The use of biomass from *Merremia aegyptia* and *Calotropis procera* from the Caatinga biome proved to be a viable technology for producers who practice the cultivation of coriander when monocropping in a semiarid environment.

Keywords: *Coriandrum sativum*. Organic farming. Productive and economic optimization.

USO DE BIOMASSA DE *MERREMIA AEGYPTIA* E DE *CALOTROPIS PROCERA* NO CULTIVO DO COENTRO EM AMBIENTE SEMIÁRIDO

RESUMO - A adubação verde com espécies espontâneas da Caatinga tem se mostrado uma alternativa viável para fornecer nutrientes às hortaliças e, assim, aumentar sua produtividade. O objetivo deste estudo foi avaliar e estimar as máximas eficiências físicas e econômicas das características produtivas do coentro em função de quantidades equitativas de biomassa de jitirana [*Merremia aegyptia* (L.) Urban] e flor-de-seda [*Calotropis procera* (Aiton) W. T.] em diferentes safras. O delineamento experimental foi em blocos casualizados, com cinco tratamentos e cinco repetições. Os tratamentos foram constituídos pelas quantidades de adubos verdes (16, 29, 42, 55 e 68 t ha^{-1} em base seca). Em cada experimento foi utilizado um tratamento sem fertilização (controle). A máxima eficiência agronômica (rendimento de massa verde do coentro) foi possível com a incorporação das quantidades equitativas de 49,56 t ha^{-1} de biomassa de *M. aegyptia* e *C. procera*, respectivamente. A máxima eficiência econômica de produção (avaliada em termos de renda líquida e taxa de retorno) dessa hortaliça folhosa foi alcançada com a adição ao solo de 42,68 e 41,64 t ha^{-1} de biomassa desses adubos verdes, respectivamente. A renda líquida e a taxa de retorno otimizadas para essas quantidades de adubos verdes foram de 30.243,92 R$ ha^{-1} e 2,79 reais para cada real investido na produção dessa hortaliça. A utilização da biomassa de *Merremia aegyptia* e *Calotropis procera* do bioma Caatinga mostrou-se uma tecnologia viável para produtores que praticam o cultivo de coentro em monocultivo em ambiente semiárido.

Palavras-chave: *Coriandrum sativum*. Cultivo orgânico. Otimização produtiva e econômica.

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INTRODUCTION

Coriander (*Coriandrum sativum*) is a leafy vegetable of social and commercial importance, mainly in the northern and northeastern regions of Brazil (ALVES et al., 2020). Its cultivation aims at the production of fresh or green leaves, widely used in cooking due to their characteristic flavor and aroma (PINTO et al., 2018). Coriander is a crop traditionally cultivated throughout the year by small family farmers and produced very rustically, without the use of technologies and scientific information that can contribute to improving the productive efficiency of the crop (SEBRAE, 2016). Despite being widely explored in the Brazilian semiarid region, few studies have been carried out to improve the production techniques used, mainly under organic management. The need to increase yields, improve product quality and reduce production costs, awakens researchers, extension workers, and producers to the idea of evaluating the degree of interference of factors such as type of cultivar, and organic fertilization, among others.

The use of green manuring has been one of the management practices used in organic cultivation and production of crops, including vegetables. According to Silva et al. (2020), green manure incorporates plant biomass, produced in the place of origin or not, to increase the levels of organic matter and nutrients in the soil, in addition to improving the structure, aeration, and water storage capacity in the soil, contributing to the improvement of physical properties, chemical and biological aspects of the soil. The choice of plants to meet these requirements depends on the potential for phytomass production and the ability to absorb and accumulate nutrients.

Leafy vegetables are considered nutritionally demanding since their cycles are relatively fast, and the lack of any essential element affects their growth, yield, and quality (DUARTE et al., 2020). In this context, the use of spontaneous species from the Caatinga biome can significantly contribute to the nutritional supply demanded by these vegetables, being an agroecological and sustainable form of production (SOUZA et al., 2017).

Among these types of green fertilizers are the hairy woodrose (*Merremia aegyptia* L.) and roostertree (*Calotropis procera* Ait.) species, the last one being an exotic plant introduced in Brazil. According to Linhares et al. (2012), these species have “good fertilizer” qualities, as they consist of a good supply of nutrients, excellent biomass production, and a low C/N ratio, which provides for faster decomposition and release of nutrients to the plants.

Studies have shown a positive effect of these green fertilizers from the Caatinga biome in the cultivation of leafy and tuberous vegetables, such as the use of hairy woodrose to increase the productivity of lettuce leaves (BEZERRA NETO et al., 2011), and with the use of roostertree in the green mass yield of arugula (SOUZA et al., 2015). In addition, with the use of hairy woodrose, the commercial productivity of carrot roots (BEZERRA NETO et al., 2014) and beetroot (SILVA et al., 2019) increased, and with the use of roostertree, the commercial yields of carrot roots (MARTINS et al., 2018) and radish (SILVA et al., 2017a) increased.

Therefore, the objective of this work was to optimize, agronomically and economically, the green mass yield of coriander and its components when fertilized with equitable biomass amounts of the spontaneous hairy woodrose and roostertree from the Caatinga biome in two cropping seasons.

MATERIAL AND METHODS

Experiments were carried out from December 2020 to January 2021, and from September to October 2021 at the Experimental Farm 'Rafael Fernandes' of the Federal Rural University of the Semi-Arid (UFERSA), located in the district of Lagoinha and 20 km from the city of Mossoró, RN, at geographic coordinates 5° 03’ 37” S, 37° 23’ 50” W, altitude 80 m.

The climate of the region according to Köppen’s classification is (BShw), dry and very hot, with two seasons: a dry season, which usually occurs from June to January, and a rainy season, from February to May (BECK et al., 2018). The average climate data during the experimental period are presented in Table 1 (LABIMC, 2021).

The average temperature and the relative humidity of the daily air after sowing coriander during the two cultivations are shown in Figure 1.

The soils in the experimental areas were classified as dystrophic red-yellow, with a sandy-loam texture (SANTOS et al., 2018). In each experimental area, soil samples from the 0–20 cm surface layer were collected, and some of their chemical characteristics were analyzed (Table 2).

Table 1. Climatic data during the periods of development and growth of coriander in the cropping seasons of 2020 and 2021.

Cropping seasons	Temperature (ºC)			Relative humidity (%)	Solar radiation (MJ m^{-2})	Wind speed (m s^{-1})
	Minimum	Mean	Maximum			
2020	24.77	29.32	35.95	61.08	19.29	2.83–9.91
2021	23.95	29.40	36.80	58.50	21.13	2.75–0.14

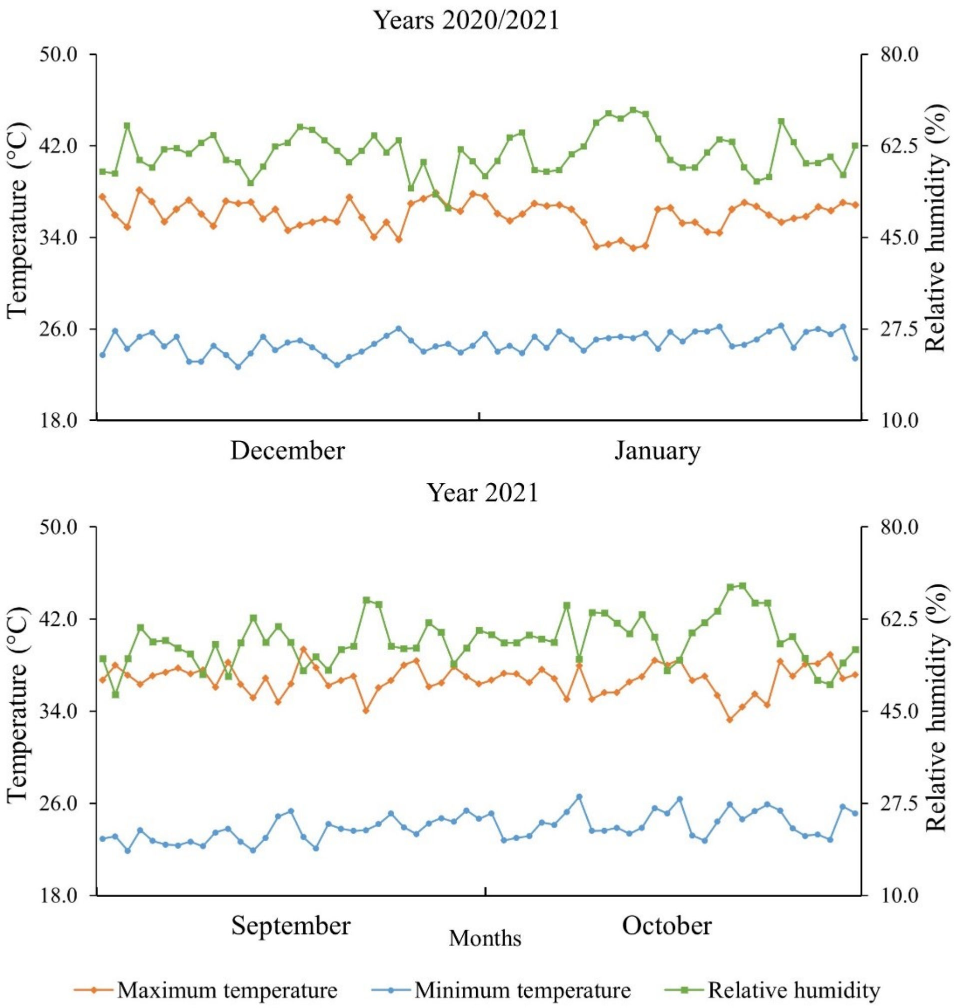

Figure 1. Temperature and relative humidity data in the 2020 and 2021 cropping seasons.

Table 2. Chemical analyses of the soils before the incorporation of the green manures in the first and second cropping seasons.

	N	C	pH	EC	OM	P	K	Na	Ca	Mg	Cu	Fe	Mn	Zn	Bo
	g kg^{-1}			dS m^{-1}	g kg^{-1}	mg dm^{-3}			cmol$_c$ dm^{-3}				mg dm^{-3}		
Soil 1	0.60	6.90	6.30	0.44	11.90	24.0	2.36	1.73	22.5	4.80	0.50	5.70	11.20	3.80	0.58
Soil 2	0.65	7.52	6.60	0.56	12.97	32.0	2.59	2.30	23.7	6.50	0.30	4.80	6.10	2.70	0.50

N: nitrogen; C: carbon; pH (H_2O): hydrogen ionic potential; EC: electrical conductivity; OM: organic matter; P: phosphorus; K^+: potassium; Na^+: sodium; Ca^{2+}: calcium; Mg^{2+}: magnesium; Cu: copper; Fe: iron; Mn: manganese; Zn: zinc; Bo: boron.

The experimental design used was in randomized complete blocks, with five treatments and five replicates. The treatments consisted of equitable amounts of hairy woodrose (*Merremia aegyptia*) and roostertree (*Calotropis procera*) biomass at doses of 16, 29, 42, 55, and 68 t ha^{-1} on a dry basis. In each experiment, a treatment with coriander without fertilizer (control) was planted for comparison purposes. The experimental plot consisted of six rows of coriander with 24 plants per row, planted at a spacing of 0.20 m × 0.05 m (ANDRADE FILHO et al., 2020), making up an estimated population of 1,000,000 plants per hectare. The total area of the experimental plot was 1.44 m^2, with a harvest area of 0.80 m^2 (Figure 2). The coriander cultivar used in the research was 'Verdão', which has vigorous plants, thick stalks, and indented dark green leaves, with intense aroma and pleasant flavor, and showing good resistance to high temperatures and tolerance to soil diseases.

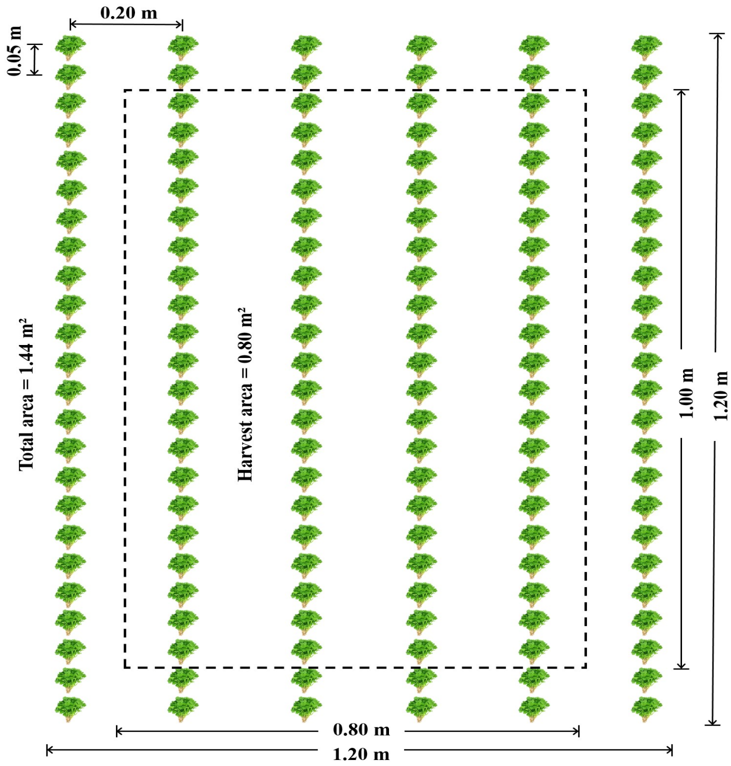

Figure 2. Detail of the experimental plot of coriander in monocropping.

The soil preparation for the research consisted of mechanical cleaning of the experimental areas with the aid of a tractor with a coupled plow, followed by harrowing and mechanized lifting of the beds. Then, pre-planting solarization was performed for 30 days with a 30 µm transparent plastic (Vulca Brilho Bril Fles), following the methodology recommended by SILVA et al. (2017b), whose objective is to reduce the population of phytopathogens in the soil, which would harm the productivity of the leafy crop.

The materials used as green manures in the manuring of coriander were collected from native vegetation in various rural areas of the municipality of Mossoró, RN, before the beginning of their blooms. After collections, the plants were crushed into fragments of two to three centimeters, which were dehydrated at room temperature until reaching a moisture content of 10% and then subjected to laboratory analysis, and the chemical compositions obtained are shown in Table 3.

Table 3. Chemical composition of the *M. aegyptia* and *C. procera* in the first and second cropping seasons.

Growing seasons		Green manures macronutrient content (g kg^{-1})					
		N*	P	K	Ca	Mg	C:N
M. aegyptia	2020	20.56	2.83	37.08	19.35	7.07	25:1
C. procera	2020	15.14	2.96	24.84	17.00	9.20	27:1
M. aegyptia	2021	18.55	1.89	38.68	9.30	7.03	25:1
C. procera	2021	14.09	1.54	22.72	16.30	13.50	27:1

*N: nitrogen; P: phosphorus; K: potassium; Ca: calcium and Mg: magnesium and C/N: carbon/nitrogen ratio.

The incorporation of green manure dry mass was performed manually with the aid of hoes 20 days before sowing coriander in the 0–20 cm soil layer in the experimental plots, following the doses specified in the treatments (OLIVEIRA et al., 2011). Irrigations by the micro-sprinkler system were carried out daily in two shifts, morning and afternoon, during the period of the experiment, providing an 8 mm water layer applied each day, to maintain the soil in its field capacity and supply the need for microorganisms, together with the low C/N ratio of green manures, thus favoring the mineralization processes of organic matter.

The sowing of the first planting cycle of coriander was carried out on 12/17/2020 and the second cycle on 09/24/2021. In both years, planting was carried out by direct sowing in holes two centimeters deep, placing two to three seeds per hole. Eight days after sowing (DAS), thinning was performed, leaving one plant per hole. Manual weedings were carried out throughout the cycle, whenever necessary. No chemical treatment was carried out against pests and diseases. In the first year of cultivation, coriander harvest was carried out at 32 DAS, and in the second year of cultivation at 31 DAS.

The following agronomic characteristics of coriander were evaluated in a sample of 20 plants from the harvest area, chosen at random: plant height (cm), measured from ground level to the tip of the highest leaves; the number of stems per plant; leaf/ stem ratio, obtained from the ratio between the fresh mass of the leaves and the fresh mass of the stems, and the dry mass of shoots, determined by drying in an oven with forced air circulation at 65°C, until constant weight is reached, and expressed in t ha^{-1}. The green mass yield of the plant shoots was obtained from the fresh mass of these plants in the harvest area (80 plants) and expressed in t ha^{-1}, and the number of bunches per m², calculated from the number of bunches of 100 g obtained from the green mass yield.

In addition to these agronomic characteristics, the following economic indicators were quantified. Gross income, expressed in R$ ha^{-1}, was obtained by multiplying the green mass yield of coriander in each treatment by the value of the product paid to the producer (R$ 10.00 per kilogram). The net income was obtained by subtracting from the gross income the production costs, arising from inputs and services performed in each treatment, expressed in R$ ha^{-1}. The prices of inputs and services in effect in October 2021, in the city of Mossoró-RN, were considered. The rate of return per invested real was obtained through the relation between the gross income and the production costs of each treatment, and the profit margin, obtained from the relation between the net income and the gross income, was expressed as a percentage.

Univariate analysis of variance for a randomized complete block design was performed to evaluate the characteristics of coriander using the SISVAR software (FERREIRA, 2011). A joint analysis of these same characteristics was also carried out to find out whether there was an interaction between the treatments tested and the cropping seasons. After that, a regression curve fitting procedure was performed using the Table Curve software (SYSTAT SOFTWARE, 2021) to estimate the maximum physical efficiency (MPE) and maximum economic efficiency (MEE) of each characteristic or index as a function of equitable biomass amounts of *M. aegyptia* and *C. procera* studied. The types of polynomial models tested on the agronomic characteristics of coriander met the selection criteria used to express the behavior of each evaluated characteristic. These criteria were the biological logic (BL) of the variable (that is, when it is found that after a certain dose of fertilizer there is no increase in the variable), the significance of the mean square of the regression residue (MSRR), a high value of the coefficient of determination (R^2), significance of the parameters of the regression equation, and variable maximization. The F test was used to compare the mean values between the cropping seasons, the mean value of maximum agronomic or economic efficiency, and the mean value of the control treatment (non-fertilized).

RESULTS AND DISCUSSION

Agronomic characteristics of coriander

The results of the analysis of variance for plant height, number of stems per plant, leaf/stem ratio, number of bunches per m², green mass yield, and dry mass of coriander shoots are presented in Table 4. Significant interactions were detected between the factors of equitable biomass amounts of *Merremia aegyptia* and *Calotropis procera* and cropping seasons, in all agronomic traits evaluated in the coriander.

Studying the interaction of amounts of green manures within each cropping season (S), an increasing behavior was observed both in the first (S_1) and in the second (S_2) growing season on plant height, the number of stems per plant, and in the number of bunches per m² with increasing equitable amounts of *M. aegyptia* and *C. procera* incorporated into the soil, in a polynomial model (Figure 3). The maximum values were 16.59 (S_1) and 18.65 cm (S_2) in plant height, 5.9 (S_1) and 6.0 (S_2) in the number of stems per plant, and 3.9 (S_1) and 5.6 (S_2) in the number of bunches m^2 (for the biomass amounts of the green manures of 56.62 (S_1) and 50.68 (S_2); 33.66 (S_1) and 35.49 (S_2), as well as 52.52 (S_1) and 50.44 t ha^{-1} (S_2), respectively), decreasing the values up to the last incorporated amount (Figures 3A, 3B and 3D). On the other hand, estimating the maximum physical efficiencies of these characteristics over the cropping seasons (S_1-S_2), a growing polynomial behavior was also observed, as a function of increasing amounts of the green manures up to the maximum values of 17.64 cm (plant height), 6 stems per plant, and 4.7 bunches per m^2 for the amounts of green fertilizers of 52.34; 41.54 and 49.52 t ha^{-1}, then decreasing until the highest amount of fertilizers tested (Figures 3A, 3B and 3D).

Table 4. Mean values for the control (T_{wf}), for the treatment of maximum physical efficiency (MPE), and the fertilized treatments (T_f) of the plant height, leaf/stem ratio, number of stems per plant, number of bunches per m^2, green mass yield and dry mass of shoots of coriander over two cropping seasons.

Comparison treatments	Plant height (cm)			Leaf/stem ratio		
	2020	2021	2020–2021	2020	2021	2020–2021
	(S_1)	(S_2)	(S_1/S_2 mean)	(S_1)	(S_2)	(S_1/S_2 mean)
Control (without fertilization, T_{wf})	9.17a	8.05b	8.61	1.30a	1.34a	1.32
MPE treatment	16.59b$^+$	18.65a$^+$	17.64$^+$	1.12b$^+$	1.28a$^+$	1.20$^+$
Fertilized treatments (T_f)	15.30b$^+$	16.19a$^+$	15.75$^+$	0.98a$^+$	0.99a$^+$	0.99$^+$
CV (%)	5.49	5.53	5.51	3.99	6.28	5.27
	Number of stems per plant			Number of bunches per m²		
Control (without fertilization, T_{wf})	4.31b	7.84a	6.08	0.76a	0.66b	0.71
MPE treatment	5.87b$^+$	6.01a$^+$	5.98$^+$	3.87b$^+$	5.61a$^+$	4.68$^+$
Fertilized treatments (T_f)	5.52b$^+$	5.89a$^+$	5.70$^+$	2.92b$^+$	4.05a$^+$	3.48$^+$
CV (%)	5.63	2.41	4.11	2.93	2.55	2.72
	Green mass yield ($t\ ha^{-1}$)			Dry mass of shoots ($t\ ha^{-1}$)		
Control (without fertilization, T_{wf})	0.76a	0.66b	0.71	0.18a	0.19a	0.18
MPE treatment	3.76b$^+$	5.66a$^+$	4.58$^+$	0.56b$^+$	0.71a$^+$	0.64$^+$
Fertilized treatments (T_f)	2.92b$^+$	4.18a$^+$	3.55$^+$	0.45b$^+$	0.61a$^+$	0.53$^+$
CV (%)	2.94	1.95	2.36	3.42	3.43	3.28

*Means followed by the same small letter in the row do not differ by F test at the 5% probability. $^+$Mean of fertilized treatments or the MPE treatment are significantly different from the control mean by the F test at the 5% probability level.

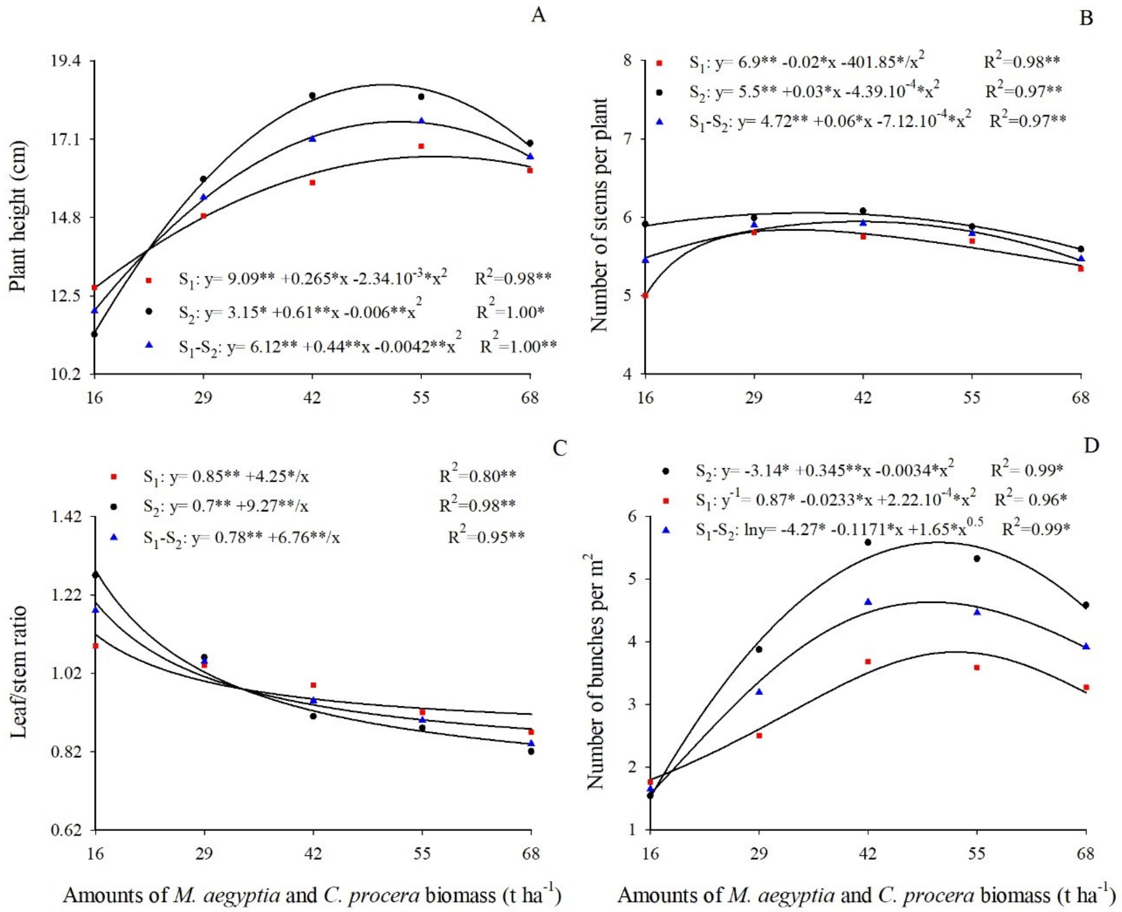

Figure 3. Plant height, number of stems per plant, leaf/stem ratio, and number of bunches per m^2 of coriander as a function of equitable biomass amounts of *M. aegyptia* and *C. procera* incorporated into the soil in the 2020 and 2021 cropping seasons.

For the leaf/stem ratio, a decreasing behavior was registered, both in the first (S_1) and in the second (S_2) cropping season, with the increase of the equitable amounts of *M. aegyptia* and *C. procera* incorporated into the soil, with the maximum values of 1.12 and 1.28 reached in the first and second cropping season in the amount of green manure of 16 t ha^{-1} incorporated into the soil (Figure 3C). Estimating the maximum physical efficiency of this characteristic over the cropping seasons (S_1-S_2), a decreasing behavior was also observed as a function of increasing amounts of green manures. The maximum estimated value of the leaf/stem ratio over the cropping seasons of 1.20 was reached for green manures of 16 t ha^{-1} added to the soil (Figure 3C).

Studying the interaction of amounts of green manures within each cropping season (S) on the green mass yield and dry mass of coriander shoots, a polynomial behavior was observed both in the first (S_1) and in the second (S_2) cropping season with the increase of the equitable amounts of *M. aegyptia* and *C. procera* incorporated into the soil. The maximum values were 3.76 (S_1) and 5.66 cm (S_2) in the green mass yield and 0.56 (S_1) and 0.71 (S_2) in the shoot dry mass, in the amounts of biomass of green fertilizers of 52.54 (S_1) and 50.45 (S_2) and 57.17 (S_1) and 49.07 t ha^{-1} (S_2), respectively, decreasing these values until the last amount of fertilizers incorporated (Figures 4A and 4B).

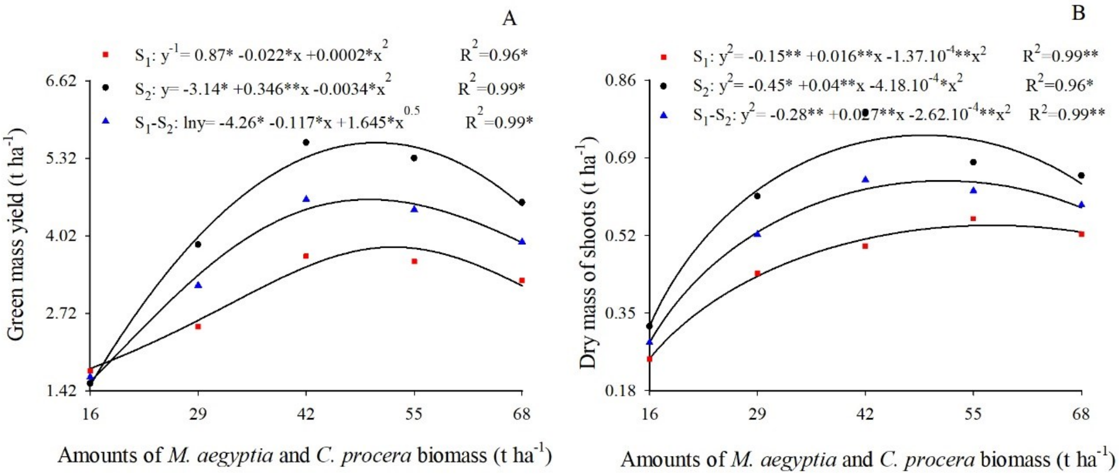

Figure 4. Green mass yield and dry mass of coriander shoots as a function of equitable biomass amounts of *M. aegyptia* and *C. procera* incorporated into the soil in the 2020 and 2021 cropping seasons.

On the other hand, estimating the maximum physical efficiencies of these characteristics over the cropping seasons (S_1-S_2), a polynomial behavior was also observed, as a function of the increasing amounts of green manures. The maximum values of 4.58 (green mass yield) and 0.64 t ha^{-1} (shoot dry mass) were reached in the amounts of green manures of 49.56 and 51.41 t ha^{-1}, decreasing then until the greatest amount of fertilizers tested (Figures 4A, and 4B).

Upward responses and optimizations (MPE values) of coriander agronomic characteristics in polynomial models can be attributed to the Law of Maximum, where the excess of a nutrient in the soil provided by equitable amounts of *M. aegyptia* and *C. procera* can have a toxic effect and/or decrease the effectiveness of other factors, resulting in the reduction of the characteristic under analysis after the maximum point (ALMEIDA et al., 2015). Another factor that may be related to this behavior of the leaf vegetable is the synchrony between the decomposition and mineralization of green fertilizers added to the soil and the moment of greater nutritional demand for the crop (FONTANÉTTI et al., 2006).

The green manures used in this research have C:N ratios between 20:1 and 30:1, which contributed to faster decomposition and release of nutrients, evidenced by the incorporation 20 days before sowing of coriander in the evaluated characteristics. However, it is known that the decomposition rate of organic residues is linked to the carbon: nitrogen (C:N) ratio of the material under this process, which in the case of *M. aegyptia* is 25:1, and 27:1 for *C procera*, and that N mineralization was also strongly influenced by the C:N ratio of the decaying material (VALE et al., 1997).

The mean values of maximum physical efficiency (MPE) of the treatments that received fertilizers (T_f) differed from the control (T_{wf}) in the characteristics of plant height, the number of bunches per m², green and dry mass yields of coriander shoots (Table 4). In these agronomic variables, the MPE values were about 1.8 to 8.5 times the T_{wf} values. On the other hand, the cropping seasons within the MPE treatment differed in all agronomic variables of coriander, with emphasis on the second growing season. In the control treatment, the first season stood out from the second, except for the number of stems per plant, where the behavior was inverse, and for the leaf/stem ratio and shoot dry mass, which were similar (Table 4).

Coriander economic indicators

The results of the analysis of variance for the economic indicators of coriander, gross income, net income, rate of return, and profit margin are shown in Table 5. Significant interactions between the equitable biomass amounts of *M. aegyptia* and *C. procera* incorporated into the soil and cropping seasons were recorded in the coriander economic indicators (Table 5).

Table 5. Mean values for the control (T_{wf}), the treatment of maximum economic efficiency (MEE), and for the treatments fertilized (T_f) in the gross income, net income, rate of return, and the profit margin of the coriander over the growing seasons of 2020 and 2021.

Comparison treatments	Gross income (R$ ha^{-1})			Net income (R$ ha^{-1})		
	2020	2021	2020–2021	2020	2021	2020-2021
	(S_1)	(S_2)	(S_1/S_2 mean)	(S_1)	(S_2)	(S_1/S_2 mean)
Control (without fertilization, T_{wf})	7566.00a	6567.80b	7066.90	-3107.50a	-4105.70b	-3606.60
MEE treatment	38312.31b$^+$	55187.26a$^+$	46002.32$^+$	21048.91b$^+$	40041.59a$^+$	30243.92$^+$
Fertilized treatments (T_f)	29576.60b$^+$	41269.01a$^+$	35422.81$^+$	15390.87b$^+$	23975.28a$^+$	19683.07$^+$
CV (%)	2.70	2.46	2.58	2.65	4.56	4.20
	Rate of return			Profit margin (%)		
Control (without fertilization, T_{wf})	0.71a	0.61b	0.66	-41.13a	-62.68b	-51.91
MEE treatment	2.25b$^+$	3.40a$^+$	2.79$^+$	61.84b$^+$	72.78a$^+$	63.54$^+$
Fertilized treatments (T_f)	1.80b$^+$	2.42a$^+$	2.11$^+$	47.05b$^+$	52.28a$^+$	49.66$^+$
CV (%)	2.51	2.43	2.48	4.95	9.25	7.47

*Means followed by the same small letter in the row do not differ by the F test at the 5% probability.
$^+$Means of fertilized treatments or the MEE treatment are significantly different from the control mean by the F test at the 5% probability level.

Studying the interaction of amounts of green manures within each growing season, an increasing behavior was observed both in the first (S_1) and in the second (S_2) cropping season in the gross income, net income, rate of return, and profit margin as a function of the increasing equitable biomass amounts of *M. aegyptia* and *C. procera* added to the soil in a polynomial model (Figure 5). The maximum values were 38,312.31 (S_1) and 55,187.26 R$ ha^{-1} (S_2) in gross income, 21,048.91 (S_1) and 40,041.59 R$ ha^{-1} (S_2) in net income, 2.25 (S_1) and 3.40 (S_2) for each real invested in the rate of return, and 61.84 (S_1) and 72.78% (S_2), in the biomass amounts of green manures of 52.54 (S_1) and 49.91 (S_2); 48.56 (S_1) and 40.86 (S_2); 42.37 (S_1) and 42.36 (S_2), as well as 56.43 (S_1) and 39.12 t ha^{-1} (S_2), respectively, decreasing the values up to the last incorporated amount (Figures 5A, 5B, 5C and 5D).

In the estimation, the maximum economic efficiencies (MEE) of these indicators over the cropping seasons also registered a polynomial behavior as a function of the green manure amounts (Figure 5). The maximum values were 46,002.32 and 30,243.92 R$ ha^{-1} for gross income and net income, 2.79 and 63.54% for the rate of return and profit margin, in the amounts of green fertilizers of 49.11; 42.68; 41.64 and 44.44 t ha^{-1}, respectively, then decreasing until the highest amount of fertilizers tested (Figures 5A, 5B, 5C and 5D). These results were superior to those obtained by BARROS JÚNIOR et al. (2019), evaluating amounts of *C. procera* incorporated into the soil under organic coriander cultivation in the Sertão do Pajeú microregion, in Serra Talhada, Pernambuco, using polynomial models, where they obtained maximum economic efficiency (MEE) of the gross income of R$ 14,826.67 ha^{-1}, net income of R$ 6,563.31 ha^{-1}, rate of return of 1.81 and profit margin of 37.10%, with optimized amounts of 3.51; 7.33; 13.54 and 10.08 t ha^{-1} of *C. procera* added to the soil, respectively. These differences were due to the green fertilizers, in greater amounts than those used in the research, and due to the climate in Serra where the experiments were carried out.

The ascending responses of the economic indicators evaluated in the coriander in the polynomial model and the economic optimizations as a function of the equitable biomass amounts of *M. aegyptia* and *C. procera* were given because the leafy crop responded very well to green manures.

The environmental resources, provided by the amounts tested, were better used by the coriander plants, whose use translated into economic efficiency. Green manuring is known to improve fertility, increase organic matter content, decrease erosion rates, increase soil water retention and soil microbiota activity, increase nutrient availability, and reduce the number of invasive plants (GRAHAM; HAYNES, 2006).

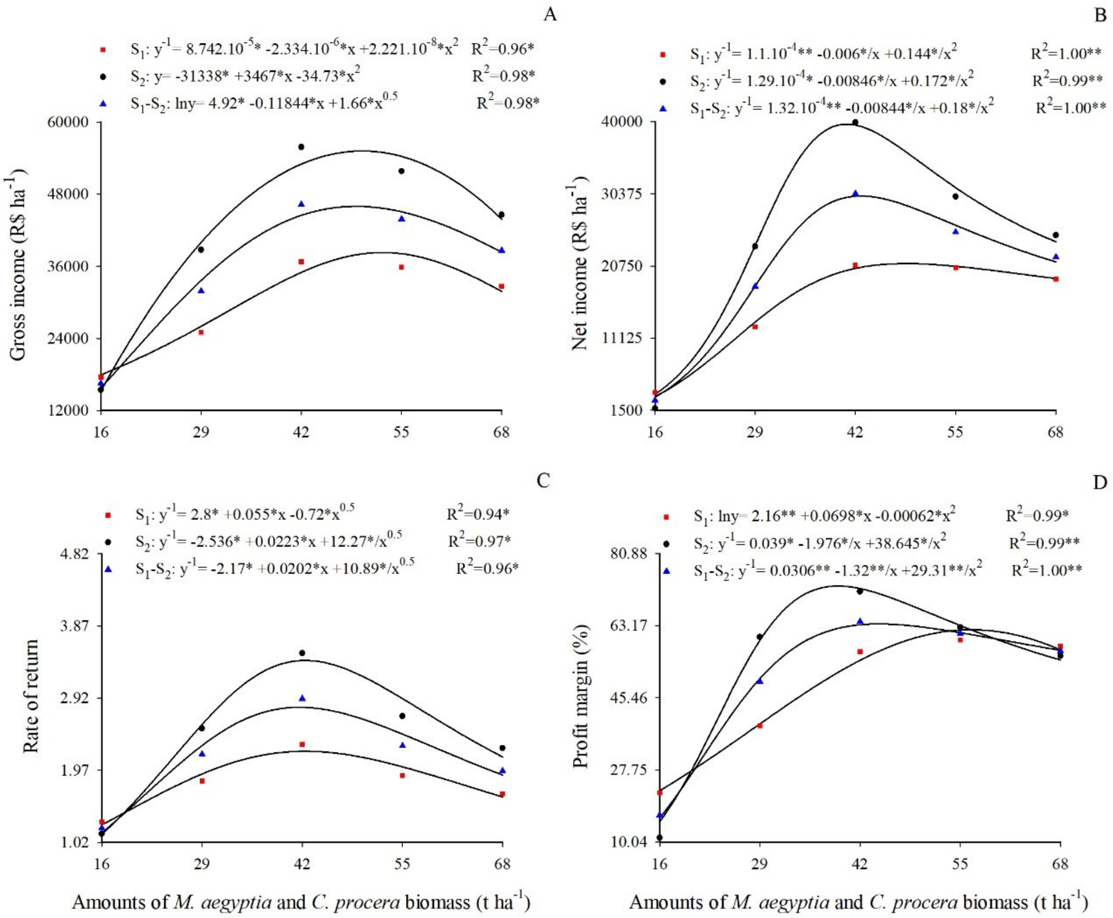

Figure 5. Gross income, net income, rate of return, and profit margin of coriander as a function of equitable biomass amounts of *M. aegyptia* and *C. procera* incorporated into the soil in the growing seasons of 2020 and 2021.

The mean values of maximum economic efficiency (MEE) of the treatments that received fertilization differed from those of the control (T_{wf}) in all coriander indicators (Table 5). On the other hand, the cropping seasons within the MEE treatment differed in all economic indicators, with emphasis on the second cropping season. In the control treatment, the first station stood out from the second in all indicators (Table 5).

The maximum physical efficiency (MPE) of coriander treatments that received green manuring was translated into economic terms in all indicators evaluated, providing an optimized economic efficiency over the cropping seasons (Table 5). This behavior allows the coriander producer to choose the optimal amount of the green manures for incorporation and the economic indicator that best suits him in terms of green mass yield. It is noteworthy that the cultivation of coriander from the combination of two species of green fertilizers provides a financial return compatible with the capital invested, making it a viable alternative, especially for small producers who do not have a very high investment capital (SOUZA et al., 2017). Furthermore, it should be noted that spontaneous species from the Caatinga biome for use as green manure are readily available in the region, in large populations. The hairy woodrose (*Merremia aegyptia*) has fast growth and its average dry mass productivity is 4.00 t ha^{-1} (LINHARES et al., 2008). The roostertree (*Calotropis procera*), in turn, produces throughout the year and allows up to four annual cuts, with dry biomass productivity of 1.00 t ha^{-1} per cut (ANDRADE et al., 2008). Given these amounts, these species have enormous potential to be used as green manure in the production of crops, especially vegetables. The results obtained in these experiments are in agreement with those obtained by Souza et al. (2015) and Bezerra Neto et al. (2011), working with monoculture arugula and lettuce.

CONCLUSIONS

The maximum agronomic efficiency (yield of green mass) and the number of bunches per m² of coriander were possible with the incorporation of equitable biomass amounts of 49.56 and 49.52 t ha^{-1} of *Merremia aegyptia* and *Calotropis procera*, respectively. The maximum economic efficiency of production (evaluated in terms of net income and rate of return) of this leafy crop was achieved with the addition to the soil of 42.68 and 41.64 t ha^{-1} of biomass of these green manures, respectively. The net income and the rate of return optimized for these quantities of green fertilizers were 30,243.92 R$ ha^{-1} and 2.79 reais for each real invested in the production of this leafy crop. The use of biomass from *Merremia aegyptia* and *Calotropis procera* from the Caatinga biome proved to be a viable technology for producers who practice the cultivation of coriander in monocropping and a semiarid environment. This cultivation system should be recommended for family farmers who sustainably produce leafy vegetables in a semiarid environment.

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