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Scientific Article

Effects of soil amendments with green biomass on quality indices of coriander

Efeitos de adubos de solo na forma de biomassa verde nos índices de qualidade de coentro

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ABSTRACT - This study aimed to evaluate the effects of incorporating green manure, in equal proportions of *Merremia aegyptia* (hairy woodrose) and *Calotropis procera* (roostertree) biomass, at varying rates (16, 29, 42, 55, and 68 t ha^{-1} dry weight) on the quality of coriander shoots grown in a single season under semi-arid conditions. A randomized block design with five treatments and five replicates was employed. A control treatment with coriander without fertilizer was included for comparison. The coriander cultivar ('Verdão') was evaluated for nutritional quality (pH, soluble solids [SS], titratable acidity [TA], SS/TA ratio, total soluble sugar [TSS], vitamin C [VC], and pigment content [chlorophyll 'a' and 'b', total chlorophyll, and carotenoids]). The incorporation of 25.10 and 51.36 t ha^{-1} of the green manure mixture resulted in coriander with the maximum flavor efficiency (10.43 °Brix/% malic acid) and total soluble sugar content (3.71 °Brix). Higher concentrations of vitamin C (69.19 mg 100 g^{-1}), chlorophyll 'a' (0.69 mg g^{-1}), chlorophyll 'b' (0.16 mg g^{-1}), total chlorophyll (0.84 mg g^{-1}), and carotenoids (0.19 mg g^{-1}) were achieved with applications of 48.71, 56.73, 53.52, 57.04, and 42.08 t ha^{-1} of the green manure mixture, respectively.

Keywords: *Coriandrum sativum*. *Merremia aegyptia*. *Calotropis procera*. Green manuring.

RESUMO - Este estudo teve como objetivo avaliar os efeitos da incorporação de adubos verdes, em proporções iguais de biomassa de *Merremia aegyptia* (jitirana) e *Calotropis procera* (flor-de-seda), em doses variadas (16, 29, 42, 55 e 68 t ha^{-1} em base seco) na qualidade da parte aérea do coentro cultivados em uma única estação em condições semiárida. Foi empregado um delineamento em blocos casualizados com cinco tratamentos e cinco repetições. Um tratamento controle com coentro sem fertilizante foi incluído para comparação. A cultivar de coentro ('Verdão') foi avaliada quanto à qualidade nutricional (pH, sólidos solúveis [SS], acidez titulável [AT], relação SS/AT, açúcar solúvel total [SST], vitamina C [CV] e teor de pigmento [clorofila 'a' e 'b', clorofila total e carotenóides]). A incorporação de 25,10 e 51,36 t ha^{-1} da mistura dos adubos verdes resultou em coentro com máxima eficiência de sabor (10,43 °Brix/% ácido málico) e teor de açúcares solúveis totais (3,71 °Brix). Maiores concentrações de vitamina C (69,19 mg 100 g^{-1}), clorofila 'a' (0,69 mg g^{-1}), clorofila 'b' (0,16 mg g^{-1}), clorofila total (0,84 mg g^{-1}) e carotenóides (0,19 mg g^{-1}) foram alcançadas com aplicações de 48,71, 56,73, 53,52, 57,04 e 42,08 t ha^{-1} da mistura dos adubos verdes, respectivamente.

Palavras-chave: *Coriandrum sativum*. *Merremia aegyptia*. *Calotropis procera*. Adubação verde.

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INTRODUCTION

Coriander (*Coriandrum sativum* L.) is a leafy vegetable rich in vitamins A, B complex, and C, and is a source of calcium and iron, which holds significant socioeconomic and nutritional importance. Its consumption is favored due to its use as a medicinal plant and as a condiment in cooking, especially in the North and Northeast regions of Brazil. These regions provide favorable climatic conditions for its cultivation throughout the year (FILGUEIRA, 2013; BRANDÃO et al., 2022).

Cultivation system, as well as the types and quantities of fertilizers used in coriander production, are pre-harvest factors that influence the post-harvest quality of this vegetable. These factors particularly affect appearance, aroma, and flavor attributes, which are influenced by pH, titratable acidity, and soluble solids, among other physicochemical factors (CHITARRA; CHITARRA, 2005; SOUSA et al., 2022). In this context, adopting a cultivation system that enhances the quality of the coriander crop offers productive and economic advantages for the producer and meets the consumer market demand.

Foods from the organic production system have been widely accepted by consumers as they promote greater sensorial and nutritional quality of the crop, ensure human health safety, and support environmental sustainability (YU et al., 2018). Among the organic cultivation practices, green manure is an efficient technique for conserving, preserving, and improving the physical-chemical and biological characteristics of the soil. This contributes to a greater availability of nutrients for plants and, consequently, to a higher productive quality (WUTKE et al., 2023; ABRANCHES et al., 2021).

In the northeastern semi-arid region, the use of spontaneous species from the Caatinga biome, such as roostertree [*Calotropis procera* (Ait.) R. Br.] and hairy woodrose [*Merremia aegyptia* (L.) Urb.] as green manure, has resulted in increased productivity and quality of leafy vegetables. The roostertree and hairy woodrose are promising species for use as green manure in vegetable production, enhancing productivity through their nutrient supply, excellent biomass production, and low carbon/nitrogen ratio, which facilitates rapid decomposition and nutrient release to plants.

Research conducted by Barros Júnior et al. (2010b) observed that the highest amount of fertilizer tested (15.6 t ha^{-1}) resulted in better lettuce quality, with peak values of 5.02 ºBrix (soluble solids), 0.144% citric acid (titratable acidity), 9.49 mg 100 g^{-1} (vitamin C), and 14.36 mg 100 g^{-1} chlorophyll in the leaves.

Barros Júnior et al. (2010a), studying the effects of green manures (hairy woodrose, roostertree, and senna uniflora) on the post-harvest characteristics of coriander in a semi-arid environment, observed an improved quality of the leafy crop when fertilized with 15.6 t ha^{-1} of hairy woodrose. Lino et al. (2023) noted that better physicochemical attributes of arugula intercropped with beetroot are achieved when combined with equitable amounts of 20 and 65 t ha^{-1} of roostertree and hairy woodrose and a population density of 1,000,000 plants of arugula ha^{-1}. Despite existing research, few studies have determined an optimized dose of the roostertree and hairy woodrose fertilizer mixture for coriander cultivation that improves the post-harvest characteristics of this vegetable.

In light of this, the objective of this work was to estimate the post-harvest quality indices of coriander when fertilized with equitable amounts of biomass from the spontaneous species hairy woodrose and roostertree, in a semi-arid environment.

MATERIALS AND METHODS

Location and characterization of the experimental area

Experiments were conducted from December 2020 to January 2021 (Cropping Season 1 - S1) and from September to October 2021 (Cropping Season 2 - S2) at the 'Rafael Fernandes' Experimental Farm of the Federal Rural University of the Semi-Arid (UFERSA). The farm is located in the district of Lagoinha, 20 km from the city of Mossoró, RN, with geographic coordinates at 5° 03' 37" S, 37° 23' 50" W, and an altitude of 80 m.

The region's climate, according to Köppen's classification, is *BShw*-dry and very hot, featuring two distinct seasons: a dry season typically 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).

Table 1. Climatic data during coriander development and growth periods for the 2020 (S1) and 2021 (S2) cropping seasons.

Cropping season	Temperature (ºC)			Air relative humidity (%)	Solar radiation (MJ m^{-2})	Wind speed (m s^{-1})	Rainfall (mm)
	Minimum	Mean	Maximum				
S1	24.77	29.32	35.95	61.08	19.29	2.83–9.91	4.30
S2	23.95	29.40	36.80	58.50	21.13	2.75–0.14	0.30

Figure 1 shows the daily average temperature and air relative humidity after coriander sowing during the two cultivation seasons.

The soils in the experimental areas were classified as typical dystrophic Red Argisols, featuring a sandy-loam texture (SANTOS et al., 2018). Soil samples were collected from the 0-20 cm surface layer in each experimental area during the 2020 and 2021 cropping seasons and underwent chemical analysis (Table 2).

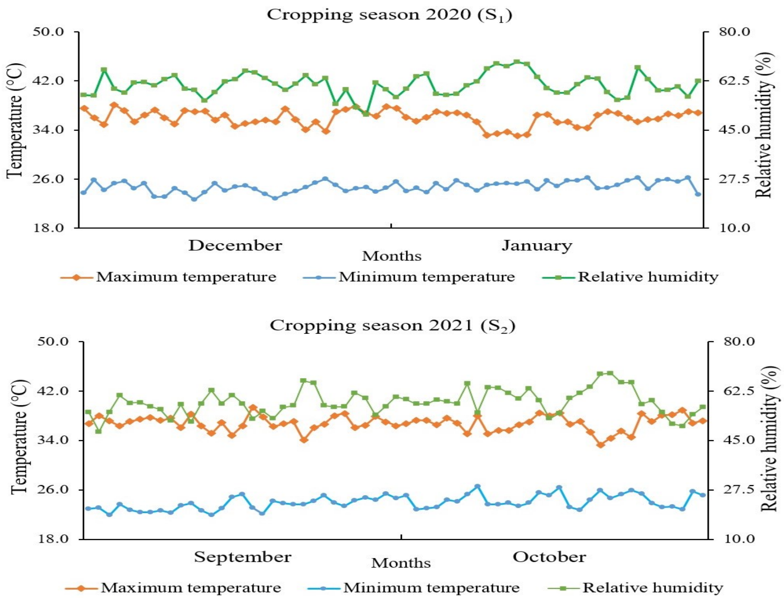

Figure 1. Temperature and relative humidity data during the 2020 and 2021 cropping seasons.

Table 2. Soil chemical analysis before green manure incorporation in the first (S1) and second (S2) cropping seasons.

Season of cropping areas	N*	C	pH	CE	MO	P	K	Na	Ca	Mg	Cu	Fe	Mn	Zn	B
	g kg^{-1}		(H_2O)	ds m^{-1}	g kg^{-1}	mg dm^{-3}		cmol$_c$ dm^{-3}			mg dm^{-3}				
2021 (S_1)	0.60	6.90	6.30	0.44	11.90	24.0	2.36	1.73	2.25	4.80	0.50	5.70	11.20	3.80	0.58
2022 (S_2)	0.65	7.52	6.60	0.56	12.97	32.0	2.59	2.30	2.37	6.50	0.30	4.80	6.10	2.70	0.50

*N: Nitrogen; C: carbon; pH: Hydrogenionic potential; OM: organic matter; EC: electrical conductivity; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; Na: sodium; Cu: copper; Fe: iron; Mn: manganese; Zn: zinc; B: boron.

Experimental design and treatments

For each experiment, the design employed was a randomized complete block, featuring five treatments and five replications. The treatments consisted of equitable amounts of hairy woodrose (*Merremia aegyptia*) and roostertree (*Calotropis procera*) biomass, applied at doses of 16, 29, 42, 55, and 68 t ha^{-1} on a dry basis. Additionally, a control group of coriander plants without fertilizer was included for comparison.

The experimental plot comprised six rows of coriander, each containing 24 plants, planted at a spacing of 0.20 m x 0.05 m (ANDRADE FILHO et al., 2020), resulting in an estimated population of 1,000,000 plants ha^{-1}. The total area of the experimental plot was 1.44 m², with a harvest area of 0.80 m² (Figure 2).

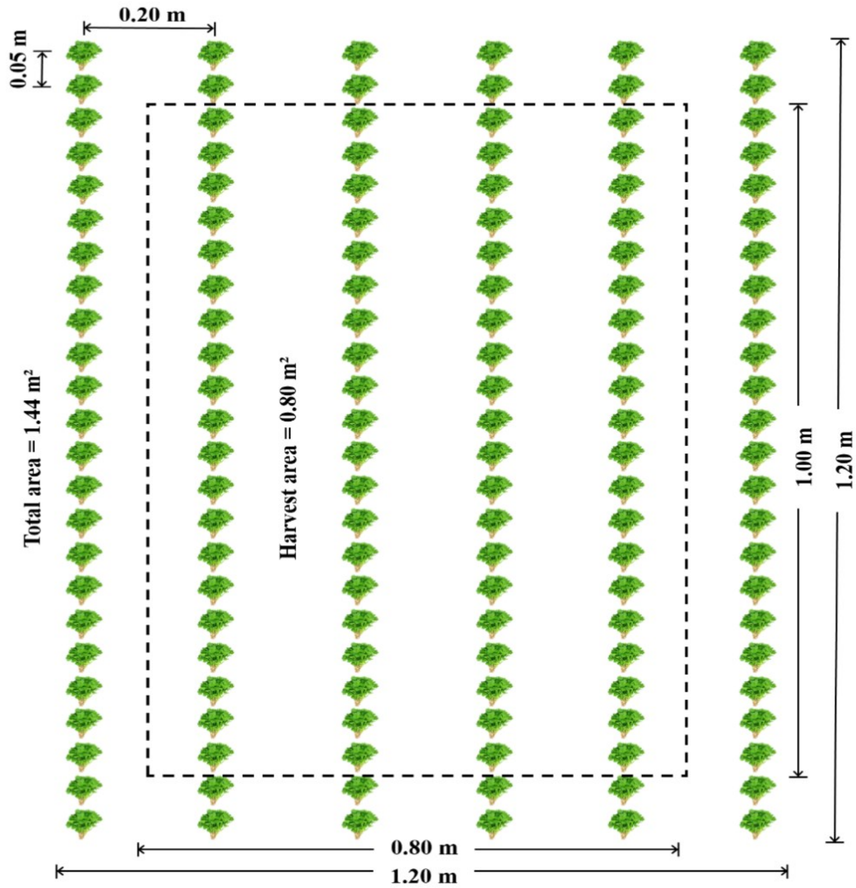

Figure 2. Detail of the experimental plot of coriander in monocropping.

The coriander cultivar used was 'Verdão,' characterized by its vigorous plants, thick stalks, and deeply indented dark green leaves. It features an intense aroma and a pleasant flavor, demonstrating good resistance to elevated temperatures and tolerance to soil diseases (SILVA et al., 2017).

Crop management

Soil preparation for the research involved mechanically clearing the experimental areas using a tractor with a coupled plow, followed by harrowing and mechanized formation of planting beds. Subsequently, pre-planting solarization was carried out for 30 days using 30 µm transparent plastic (Vulca Brilho Bril Fles), according to the methodology recommended by Silva et al. (2017). Solarization is used to reduce the population of phytopathogens in the soil, which could otherwise adversely affect the productivity of leafy crops.

The materials used as green manures for fertilizing the coriander were hairy woodrose (*M. aegyptia*) and roostertree (*C. procera*), collected from native vegetation in various rural areas of Mossoró, RN, prior to the onset of blooming. After collection, the plants were chopped into two to three-centimeter fragments, dehydrated at room temperature until reaching a moisture content of 10%, and then analyzed in the laboratory (Table 3).

Table 3. Chemical analyses of macronutrients in dry biomass of *M. aegyptia* and *C. procera* green manures during the first and second of coriander cropping seasons.

Green manure and cropping season	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, Mg: magnesium and C/N: carbon/nitrogen ratio.

The green manures used in the experiment consisted of equitable amounts of *M. aegyptia* and *C. procera* biomass in a 1:1 ratio. The dry mass of these green manures was manually incorporated using hoes into the 0-20 cm soil layer of the experimental plots 20 days before sowing coriander, following the specified treatment doses. Irrigation was performed daily via a micro-sprinkler system in two shifts-morning and afternoonthroughout the experiment, delivering an 8 mm water depth each day to maintain soil moisture at field capacity and support the needs of microorganisms. This irrigation schedule, combined with the low carbon/nitrogen (C/N) ratio of the green manures, facilitated the mineralization processes of organic matter.

Coriander sowing for the first planting cycle was carried out on December 17, 2020, and for the second cycle on September 24, 2021. In both years, planting was executed by direct sowing into holes two centimeters deep, with two to three seeds per hole. Eight days after sowing, thinning was performed to leave one plant per hole, spaced 0.05 m apart. As a crop treatment, manual weeding was conducted throughout the cycle as needed. No chemical treatments were used against pests and diseases. In the first year, the coriander harvest occurred at 32 days after sowing (DAS), and in the second year, at 31 DAS.

Evaluated characteristics

Post-harvest quality was assessed using a 500-gram sample randomly collected from the useful area of each plot. These samples were sent to the Post-Harvest Laboratory of the Semi-Arid Plant Production Center (CPVSA) at UFERSA. Upon arrival, they were washed in running water and dried in an ambient environment. The plants were then separated into shoots (leaves and stems) and roots, with subsequent analyses performed on the shoots. Three plants from each treatment's sample were set aside for chlorophyll and carotenoid analysis, while the remainder were processed using a Juice Extractor Processor Juiceman 3-in-1 JM3000. The extracted juice was then fractionated for specific analyses, all of which were performed in duplicate.

The hydrogenionic potential (pH) was measured using a benchtop pH meter, model 016A. The total soluble solids (SS) content was determined by refractometry using two drops of juice and a portable digital refractometer, model 104-D, which features automatic temperature correction. Results are expressed in degrees Brix. Titratable acidity (TA) was assessed by titration of a 1 mL aliquot of the juice diluted in 49 mL of distilled water, to which two drops of 1% phenolphthalein were added. Titration continued until the endpoint (clear pink) was reached using a previously standardized 0.1N NaOH solution. Results were expressed as a percentage of malic acid, calculated using Equation 1. Following these determinations, the ratio of SS to TA (SS/TA) was calculated (AOAC, 2012; IAL, 2008).

$$\text{Malic acid \%} = 10 \times \text{acid factor} \times \text{NaOH factor} \times \text{NaOH spent (mL)}/\ \text{sample weight (g)} \qquad (1)$$

Total soluble sugars (TSS) content was determined using the anthrone method, which involves an anthrone solution ($C_{14}H_{10}O$) combined with sulfuric acid (H_2SO_4), as proposed by Yemn and Willis (1954). For this determination, a 1 mL aliquot of the juice was diluted in distilled water in a volumetric flask to a total volume of 100 mL. From this dilution, 50 µL were taken and added to a test tube along with 950 µL of distilled water. The tubes were then placed in an ice bath. While in the ice bath, 2 mL of the anthrone solution was added to each tube, which was then briefly removed for agitation. The tubes were subsequently placed in a boiling water bath for eight minutes and then quickly cooled in ice water. To establish the standard curve, a glucose solution was prepared at concentrations ranging from 0 to 40 µg L^{-1}, in increments of 5 µg L^{-1}. The absorbance was measured using a spectrophotometer at 620 nm. The results were expressed as a percentage, calculated using Equations 2, 3, and 4.

$$\text{Concentration} = (\text{Absorbance} \pm b) \div a\text{, where a and b refer to curve} \tag{2}$$

$$\text{Material mass} = (\text{Sample weight [g]} \times \text{aliquot [}\mu\text{g]}) \div \text{dilution (mL)} \tag{3}$$

$$\text{TSS \%} = (\text{Concentration} \times 100) \div \text{material mass (}\mu\text{g)} \tag{4}$$

The vitamin C content was quantified by titration using the methodology proposed by Strohecker and Henning (1967). For the analysis, a 1 mL aliquot of the juice was taken and transferred to a volumetric flask, which was then filled to 100 mL with 0.5% oxalic acid. From this solution, 5 mL was extracted and diluted in 45 mL of distilled water. Titration was then performed to the endpoint (light pink) using a previously standardized Tillman's solution (2,6-dichlorophenolindophenol sodium 0.2%). The results were expressed in mg of ascorbic acid per 100 g of juice and calculated using Equations 5, 6, and 7.

$$\text{Material mass (g)} = (\text{Sample weight [g]} \times \text{aliquot [mL]}) \div \text{dilution (mL)} \tag{5}$$

$$\text{Concentration (mg)} = (\text{Volume spent in the titration [mL]} \times \text{Tillman factor [}\mu\text{g]} \div 1\text{ mL}) \div 1000 \tag{6}$$

$$\text{Vitamin C (mg 100 g}^{-1}) = (\text{Concentration [mg]} \times 100) \div \text{material mass (g)} \tag{7}$$

To determine chlorophyll 'a', 'b', total chlorophyll, and carotenoids, leaflets from samples of each treatment were cut into discs until 0.6 g of material was collected. These were then transferred to tubes, which were covered with aluminum foil to exclude light, and 6 mL of 80% acetone was added. After refrigerating the mixture for 12 hours at 9ºC, the suspension was filtered through filter paper. The chlorophylls were then quantified by measuring the absorbance of the solution at wavelengths of 470 nm, 645 nm, 652 nm, and 663 nm using a spectrophotometer (model SP 2000 UV). Chlorophyll concentrations were calculated from the absorbance readings and the extinction coefficients, according to Equations 8, 9, 10, and 11 (YANG et al., 1998).

$$\text{Chl 'a'} = 12.25\,(A_{663}) - 2.79\,(A_{645}) \tag{8}$$

$$\text{Chl 'b'} = 21.50\,(A_{645}) - 5.10\,(A_{663}) \tag{9}$$

$$\text{Total Chl} = 7.15\,(A_{663}) + 18.71\,(A_{645}) \tag{10}$$

$$\text{Total Carotenoids} = [1{,}000(A_{470}) - 1.82\text{ Chl 'a'} - 85.02\text{ Chl 'b'}]/198 \tag{11}$$

Statistical analysis

The quality characteristics evaluated were subjected to a univariate analysis of variance using a randomized complete block design, as processed through SAS software (SAS, 2015). Additionally, a joint analysis of each characteristic was conducted to determine the presence of any interactions between the treatments and the growing seasons regarding the physicochemical characteristics. Given the homogeneity of variances for bioactive compounds, an average content of vitamin C, chlorophylls 'a' and 'b', and carotenoids was calculated for each treatment across the coriander cropping seasons. Subsequently, a variance and regression analyses were performed on each compound using the Table Curve software (SYSTAT SOFTWARE, 2022). This analysis included a curve fitting procedure to estimate the behavior of each post-harvest characteristic in response to varying amounts of dry biomass from hairy woodrose and roostertree.

The selection of models was based on several criteria: the biological logic of the variable, specifically the observation that beyond a certain maximum fertilizer amount there is no increase in the variable; the significance of the mean square of the regression residual; a high value of the coefficient of determination; and the significance of the parameters of the regression equation.

RESULTS AND DISCUSSION

Physicochemical characteristics

The results of the analysis of variance for the physicochemical characteristics evaluated in coriander shoots-including pH, soluble solids (SS), titratable acidity (TA), SS/TA ratio, and total soluble sugars (TSS)-are presented in Table 4. These results revealed a significant interaction between the amounts of green manures and the cropping seasons for the characteristics evaluated, with the exception of titratable acidity.

Table 4. Analysis of variance F and mean values of the control treatment (Tc), maximum physical efficiency (MPE), green manure treatments (Tgm) for pH, soluble solids (SS), titratable acidity (TA), SS/TA ratio, and total soluble sugars (TSS) in coriander plants during the 2020 (S1) and 2021 (S2) cropping seasons.

Sources of variation	pH	SS	TA	SS/TA ratio	TSS
(Blocks/Seasons)	0.37^{ns}	0.63^{ns}	0.60^{ns}	1.30^{ns}	1.53^{ns}
Cropping seasons (S)	58.75^{**}	451.50^{**}	58.48^{**}	5.86^{*}	102.22^{**}
Amounts of *M. aegyptia* and *C. procera* and (A)	6.70^{**}	80.42^{**}	8.18^{**}	2.33^{ns}	11.90^{**}
S x A	2.89^{*}	41.34^{**}	2.06^{ns}	5.51^{**}	10.10^{**}
Control x fertilized	0.21^{ns}	1.26^{ns}	3.38^{ns}	7.89^{**}	0.80^{ns}
CV (%)	5.22	3.52	12.47	13.78	15.38

Comparison between mean values	Cropping season			Cropping season		
	2020 (S1)	2021 (S2)	2020-2021 (S1/S2)	2020 (S1)	2021 (S2)	2020-2021 (S1/S2)
	pH			Soluble solids (°Brix)		
Control treatment, T_c	4.75bB	4.85cA	4.80	3.00bB	3.16bA	3.08
MPE value	4.87aB	5.60aA	5.22^{+}	3.30aB	4.23aA	3.73^{+}
Fertilized with green manures, T_{gm}	4.72bB	5.32bA	5.02	3.01bB	3.68bA	3.34
	Titratable acidity (Malic acid %)			SS/TA ratio (°Brix/Malic acid %)		
Control treatment, T_c			0.31	10.17bA	9.88aA	10.03
MPE value			0.40^{+}	13.13aA	9.99aB	10.43^{+}
Fertilized with green manures, T_{gm}			0.34	10.09bA	9.71aA	9.90^{+}
	Total soluble sugars (%)					
Control treatment mean, T_c	1.41bA	1.40cA	1.40			
MPE value	1.53aB	2.54aA	1.95^{+}			
Fertilized with green manures, T_{gm}	1.30bB	2.09bA	1.69^{+}			

** = $P < 0.01$; * = $P < 0.05$; ns = $P \geq 0.05$. $^{+}$ Means followed by the same lowercase letter within the column and uppercase within the row do not differ statistically from each other by the F-test at 5% probability. $^{+}$Means of green manure treatments or MPE is significantly different from the control treatment by the F-test at 5% probability.

The analysis of average values from each cropping season, comparing treatments fertilized with green manures, the control treatment (without fertilization), and the point of maximum physical efficiency (MPE) for each characteristic, revealed notable findings. Specifically, the average values for pH and SS in the second season were significantly different from those in the first season. For the SS/TA ratio, the first season's average significantly differed from the MPE value obtained in the second season. Conversely, the behavior of TSS was reversed at the MPE. In this characteristic, the second growing season's average differed significantly from the first in the treatment fertilized with green manures. No significant differences were observed in the SS/TA ratio between the cropping seasons in both the control and green manure treatments. Similarly, no significant differences were found in the total sugar content between the seasons in the control treatment (Table 4).

The MPE values obtained in all evaluated post-harvest characteristics were significantly higher than those in the control treatment (Tc), with respective increases of 1.09, 1.21, 1.29, 1.04, and 1.38 times the Tc values for pH, SS, TA, SS/TA ratio, and TSS (Table 4). These results highlight the efficacy of green manure in enhancing the post-harvest quality of coriander.

Further analysis of the impact of green fertilizers on the quality characteristics of coriander showed an increasing polynomial behavior as the amounts of *M. aegyptia* and *C. procera* incorporated into the soil increased (Figure 3). The maximum efficiency (ME) values recorded in the S1 and S2 cropping seasons were 4.86 (S1) and 5.61 (S2) for pH; 3.31 (S1) and 4.25 °Brix (S2) for SS; 13.14 (S1) and 9.97 °Brix/% malic acid (S2) for SS/TA; and 1.53% (S1) and 2.56% (S2) for TSS, at respective biomass amounts of 51.80 (S1) and 49.35 (S2); 41.90 (S1) and 55.31 (S2); 21.32 (S1) and 51.17 (S2); and 31.46 (S1) and 54.22 t ha^{-1} (S2) added to the soil. From these points, the efficiency decreased with each subsequent amount of fertilizer biomass added (Figures 3A, 3B, 3D, and 3E).

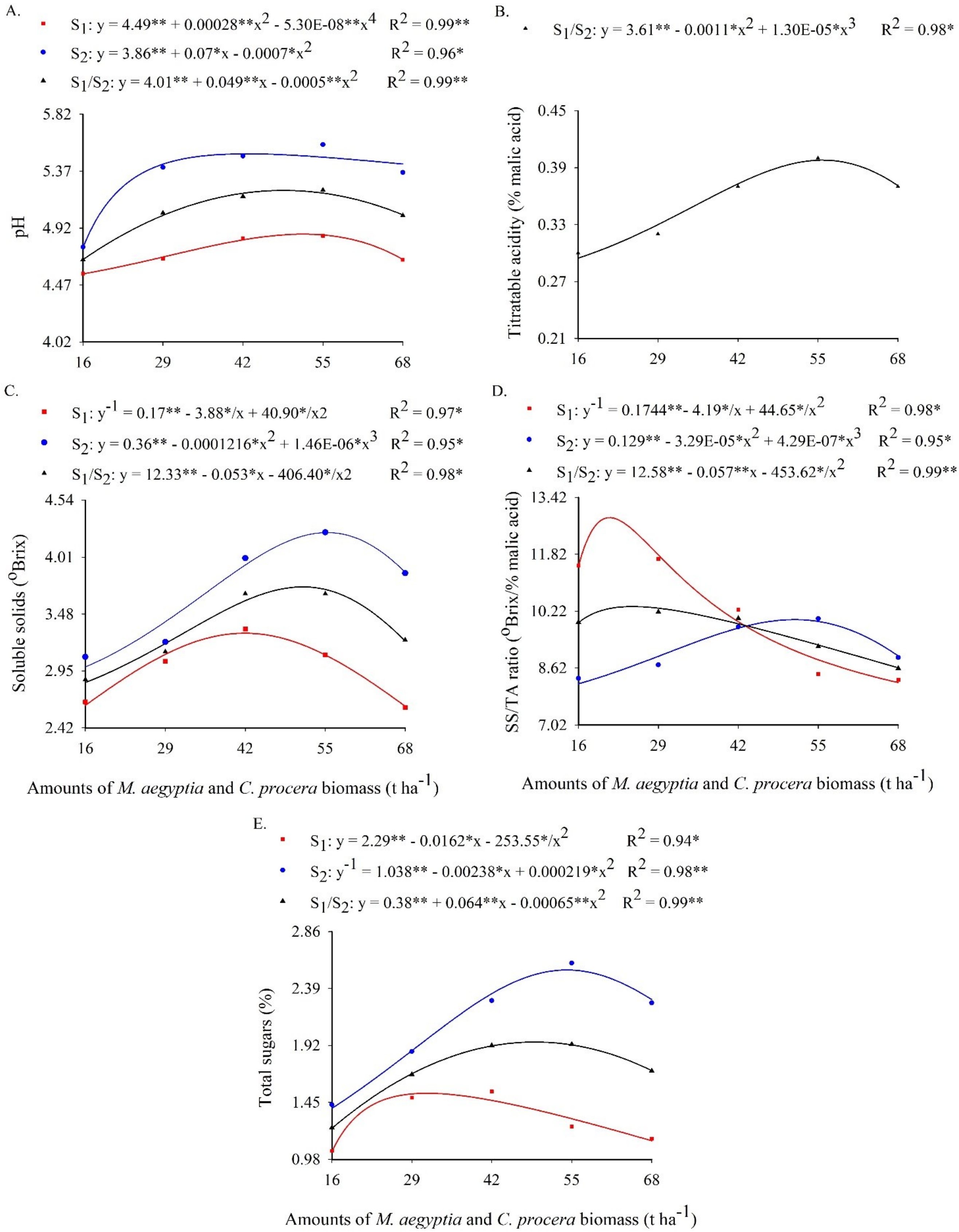

Figure 3. Averages of pH (A), soluble solids (B), titratable acidity (C), SS/TA ratio (D), and vitamin C content (E) in coriander plants as a function of *M. aegyptia* and *C. procera* biomass amounts added to the soil during the 2020 (S1) and 2021 (S2) cropping seasons.

Estimating the maximum efficiency of characteristics such as pH, SS, TA, SS/TA ratio, and TSS over the cropping seasons (S1/S2) revealed a polynomial behavior. This was observed as a function of increasing amounts of green manures up to maximum values of 5.21 for pH, 3.71 °Brix for SS, 0.41% malic acid for TA, 10.43 °Brix/% malic acid for the SS/TA ratio, and 1.95% for TSS at green manure amounts of 48.60, 51.36, 55.79, 25.10, and 49.00 t ha^{-1}, respectively, added to the soil. These values then decreased at the highest amounts of green fertilizers tested (Figure 3). These results were lower compared to those obtained by Santos (2020), who fertilized coriander with different doses of cattle manure in Bananeiras, PB, achieving higher average values (5.88 for pH, 8.67 °Brix for SS, 0.25% malic acid for TA, and 34.50 °Brix/% malic acid).

Reducing acidity generally enhances the flavor of fruits and vegetables. The pH is a flavor indicator, while acidity reflects the presence of organic acids in plant tissues. These acids are either used as substrates in the respiratory process or converted into sugars during ripening (VIANA et al., 2015). However, a decrease in pH after reaching the maximum point could be attributed to an increase in acid concentration during coriander root development, potentially influenced by the potassium (K) content in green manure (COSTA et al., 2017). The levels of organic acids associated with potassium salts regulate enzymatic activity in the vegetable (CHITARRA; CHITARRA, 2005).

Contents of SS are crucial for assessing sweetness, and the SS/TA ratio, reflecting the balance between sugars and organic acids, is indicative of flavor (CHITARRA; CHITARRA, 2005; PACHECO et al., 2021). A higher SS/TA ratio typically suggests a greater sweetness perception.

Regarding TSS, their behavior mirrors that of total SS, as sugars constitute 80 to 90% of the compounds in SS (COSTA et al., 2017). The results observed could also be linked to the potassium (K) and nitrogen (N) contents delivered by the green manure throughout the growing cycle. Potassium aids in sugar formation and translocation, while nitrogen boosts sucrose concentration, affecting amino acid composition (TAIZ et al., 2017), thereby enhancing sugar accumulation and consequently increasing °Brix.

Bioactive compounds

Due to the homogeneity of variances across cropping seasons, an average was calculated for the levels of bioactive compounds evaluated in each treatment over the seasons. The results of the variance and regression analyses for these average levels of compounds in coriander leaves—specifically Vitamin C, chlorophyll 'a', chlorophyll 'b', total chlorophyll, and carotenoids are presented in Table 5.

Table 5. Analysis of variance F and mean values for contents of vitamin C, chlorophyll 'a' and 'b', total chlorophyll, and carotenoids in coriander plants fertilized with different amounts of *M. aegyptia* and *C. procera*.

Sources of variation	DF	Vitamin C (mg 100 g^{-1})	Chlorophyll 'a' (mg g^{-1})	Chlorophyll 'b' (mg g^{-1})	Total chlorophyll (mg g^{-1})	Carotenoids (mg g^{-1})
Blocks	4	1.15^{ns}	4.74*	0.32^{ns}	3.20*	1.53^{ns}
Amounts of *M. aegyptia* and *C. procera*	4	2.50^{ns}	1.93^{ns}	1.19^{ns}	2.04^{ns}	0.54^{ns}
Regression (Polynomial)	2	26.27*	41.78*	43.07*	35.36*	71.40*
Error	16	27.3946	0.0104	0.0014	0.0143	0.0012
CV (%)		8.05	16.57	26.62	15.74	19.80

** = P < 0.01; * = P < 0.05; ns = P ≥ 0.05.

Studying the effect of green manure amounts on bioactive compounds in coriander revealed a polynomial behavior in each compound, correlated with increasing amounts of *M. aegyptia* and *C. procera* biomass incorporated into the soil (Figure 4). The maximum efficiency values were recorded as follows: 69.19 mg per 100 g for vitamin C, 0.69 mg per g for chlorophyll 'a', 0.16 mg per g for chlorophyll 'b', 0.84 mg per g for total chlorophyll, and 0.19 mg per g for carotenoids. These peak values were achieved at green manure amounts of 48.71 t ha^{-1} for vitamin C, 56.73 t ha^{-1} for chlorophyll 'a', 53.52 t ha^{-1} for chlorophyll 'b', 57.04 t ha^{-1} for total chlorophyll, and 42.08 t ha^{-1} for carotenoids, after which they decreased as the amounts of green fertilizers were further increased (Figure 4).

The increase in vitamin C content in coriander, up to the maximum efficiency value, may be linked to the potassium (K) levels provided by the green manure. Depending on growing conditions, K can enhance the synthesis of metabolic intermediates that are precursors of ascorbic acid (CHITARRA; CHITARRA, 2005; TAIZ et al., 2017). The vitamin C levels, ranging from 62.50 to 69.23 mg per 100 g, are comparable to those found by Ferreira et al. (2020) in beet crops fertilized with bovine biofertilizer.

However, the content of chlorophyll and carotenoids was lower than those found by Santos (2020), who noted values of 2.12, 0.77, 2.89, and 3.48 mg per g for chlorophyll 'a', chlorophyll 'b', total chlorophyll, and carotenoids, respectively, in coriander fertilized with various doses of cattle manure. These discrepancies can be attributed to the diverse types and doses of fertilizers used.

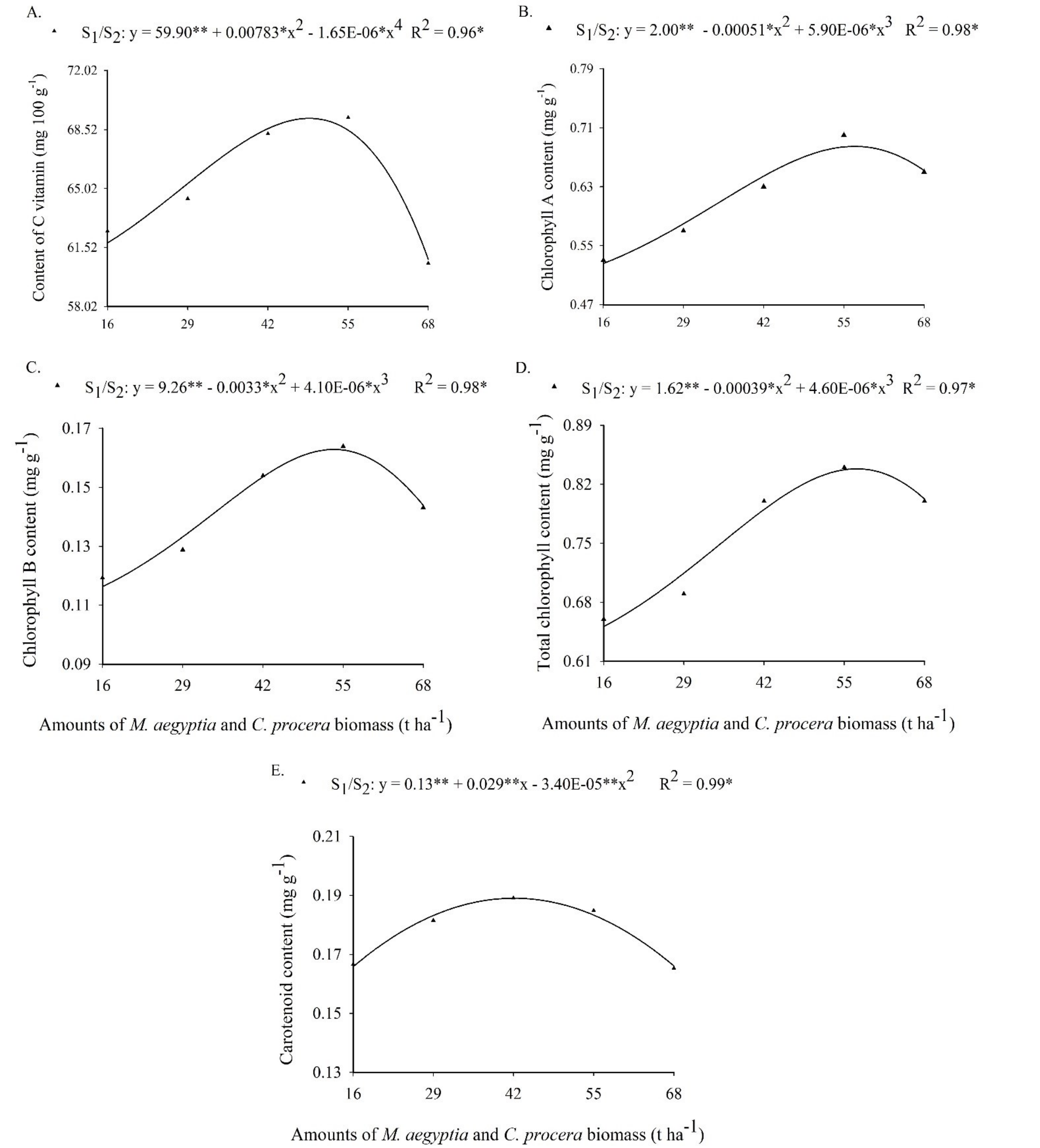

Figure 4. Contents of vitamin C (A), chlorophyll 'a' (B), chlorophyll 'b' (C), total chlorophyll (D), and carotenoids (E) in coriander plants as a function of *M. aegyptia* and *C. procera* biomass amounts added to the soil.

Chlorophyll and carotenoids in coriander, which is widely consumed in northeastern Brazil, are indicators of the plant's photosynthetic potential due to their role in the absorption and transfer of energy. According to Engel and Poggiani (1991), photosynthetic efficiency is linked to chlorophyll content, influencing plant growth and adaptability to different environments. Additionally, carotenoids play essential roles in human health, particularly in vision.

The maximum values for physicochemical characteristics and bioactive compounds achieved in coriander through the use of green manures hairy woodrose and roostertree can be attributed to the positive effects of these manures on soil's physicochemical and biological properties. This includes an increase in organic matter content and maintenance of soil moisture and temperature, which promotes balanced nutrient absorption throughout the crop cycle (ABRANCHES et al., 2021; SILVA, et al., 2017). Sufficient nutrient availability is crucial for the plant's natural physiological processes, impacting biochemical reactions, synthesis of photoassimilates, phytochemical compounds, and enzymatic functions (TAIZ et al., 2017). These factors ultimately reflect in the quality of the cultivated vegetables.

CONCLUSIONS

The maximum flavor efficiency in coriander, measured at 10.43 °Brix/% malic acid, and the highest total soluble sugar content, at 3.71 °Brix, were achieved by incorporating 25.10 and 51.36 t ha^{-1}, respectively, of a mixture of hairy woodrose and roostertree biomass into the soil. Additionally, the highest concentrations of bioactive compounds were recorded as follows: 69.19 mg per 100 g for vitamin C, 0.69 mg per g for chlorophyll 'a', 0.16 mg per g for chlorophyll 'b', 0.84 mg per g for total chlorophyll, and 0.19 mg per g for carotenoids. These peak values were obtained by incorporating 48.71, 56.73, 53.52, 57.04, and 42.08 t ha^{-1}, respectively, of the green manure biomass mixtures.

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