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Post-harvest indexes and colour parameters from arugula–beet intercropping under green manuring and population density[1]

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ABSTRACT - In this study, the objective was to determine the post-harvest indexes of arugula leaves and beet roots in intercropping under a biomass mixture of different green manures at diverse arugula population densities in two cropping seasons in a semi-arid environment. The experimental design was a randomised complete block design, with treatments arranged in a 4 × 4 factorial scheme with four replications. Treatments consisted of the combination of equitable amounts of *Merremia aegyptia* and *Calotropis procera* biomass (20, 35, 50 and 65 t ha^{-1} on a dry basis) and arugula population densities (400,000, 600,000, 800,000 and 1,000,000 plants ha^{-1}). The characteristics evaluated in the arugula culture were titratable acidity, pH, and soluble solid and total soluble sugar content. In the beet crop, the same characteristics were evaluated in arugula, in addition to the betalain concentration and the internal colour parameters of the tuberose roots. Arugula showed the best post-harvest indexes when fertilised with green manure biomass amounts of 20, 20 and 65 t ha^{-1} at a population density of 1,000,000 plants ha^{-1}, while beet showed the best indices with green manure amounts of 65, 41, 36 and 40 t ha^{-1} with an arugula density of 1,000,000 plants ha^{-1}. The best colour parameters of beet roots were obtained with green manure amounts of 30 and 32 t ha^{-1} at an arugula density of 400,000 plants ha^{-1}.

Key words: *Beta vulgaris*. *Eruca sativa. Merremia aegyptia*. *Calotropis procera*. Post-harvest quality.

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INTRODUCTION

Beetroot and arugula are two vegetables whose cultivation is increasing in the semi-arid region of northeast Brazil. Beetroot is rich in phenolic compounds, flavonoids and anthocyanins, with biological functions of extreme importance, such as the prevention of cancers and cardiovascular diseases (RAMOS *et al*., 2016). Arugula is an herbaceous vegetable whose leaves are rich in vitamins A and C, fibre, proteins, and minerals, such as potassium, iron and sulphur. The leaves have anti-anaemic, anti-asthmatic, anti-scorbutic, purifying, digestive and diuretic properties and are appetising. In addition, when they are intercropped, these crops are considered companion plants because they do not compete much with each other, sometimes even cooperating in development (GUERRA *et al*., 2021).

Even though beet and arugula are considered companion plants in the intercropping system, one of the questions that has been raised is about the post-harvest quality of their products and whether they are affected. However, it is known that the chemical composition of roots and leaves in vegetables can be influenced by genetic factors and cultivation conditions, such as cropping system, type of fertiliser, amount of fertiliser used and population density of the component crops (GUERRA *et al*., 2022). One way to meet this requirement is the use of green manuring with biomass of spontaneous species from the Caatinga biome, such as *Merremia aegyptia* and *Calotropis procera*. According to Linhares *et al*. (2012), these species have qualities that favour their use as green manure because, in addition to having nutrients in significant amounts, they produce a large amount of biomass and have a low C/N ratio, enabling the faster decomposition and release of nutrients that are supplied to plants.

Manuring, when used in adequate doses, maintains the balance between sugar and acid contents, in addition to improving storage potential, but excess nutrients can reduce the storage potential of the product produced in the post-harvest period (CUQUEL; HADLICH; CALEGARIO, 2004).

Another factor that affects the intercropped vegetable production system is the population density of the component crops, as it induces a series of changes in the architecture of plants, in the growth and development of these plants and in the production and partitioning of photoassimilates. These changes need to be known in greater detail to determine the productive efficiency of the system and the quality of the products produced by the crops (BEZERRA NETO *et al*., 2005). According to Portela *et al*. (2012), the population density of crops can affect the quality of their products, not only in terms of their average size but also in their organoleptic characteristics.

Studying post-harvest indices of the lettuce–beetroot intercropping system as a function of *M. aegyptia* and *C. procera* biomass amounts at different lettuce population densities, Guerra *et al.* (2022) recorded the best post-harvest lettuce indices when using 20 t ha^{-1} of green manure biomass at a lettuce population density between 203,000 and 300,000 plants ha^{-1}. The best beetroot post-harvest indices were achieved with a green manure amount between 20 and 55 t ha^{-1} and lettuce population densities between 150,000 and 300,000 plants ha^{-1}.

In this study, the objective was to determine the post-harvest indexes of arugula leaves and beet roots in intercropping, as well as the colour parameters of these roots under green manuring at different equitable amounts of *Merremia aegyptia* and *Calotropis procera* biomass in diverse arugula population densities in a semi-arid environment.

MATERIAL AND METHODS

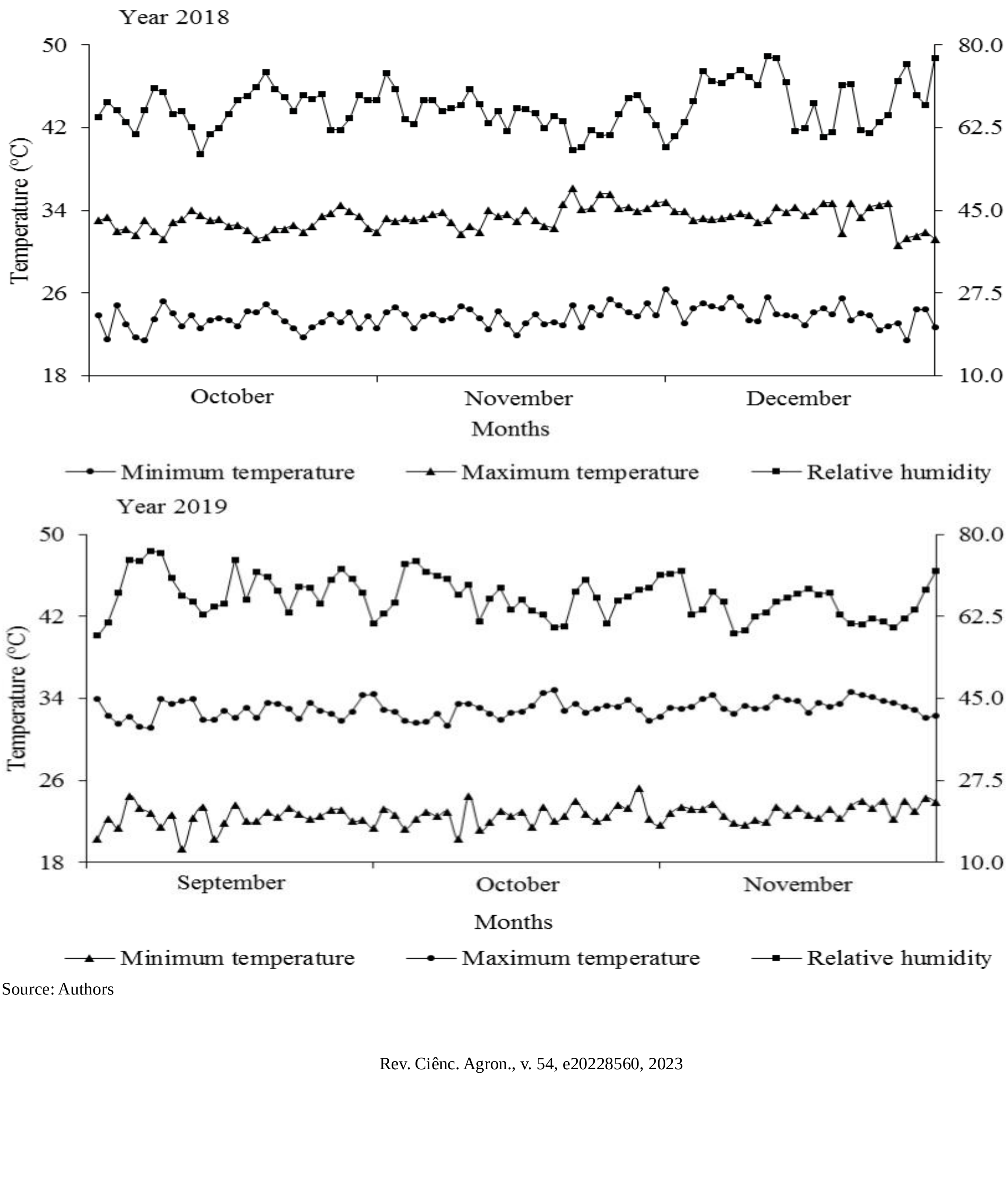
This study was carried out at the Experimental Farm ‘Rafael Fernandes’ of the Universidade Federal do Semi-Árido (UFERSA), located in the district of Lagoinha, 20 km away from the municipality of Mossoró, RN (5° 03’ 37” S, 37° 23’ 50” W Gr, 18 m altitude), the first being from October to December 2018 and the second from September to November 2019. The climate of the region, according to the Köppen classification is ‘BShw’, dry and very hot, with two seasons: a dry season, which generally occurs from June to January, and a rainy season from February to May (ALVARES *et al*., 2014). During the experimental periods, the average values recorded for minimum and maximum temperatures, relative humidity and precipitation for the 2018 and 2019 harvests were 27.8 and 27.1 °C, 33.2 and 32.9 °C, and 66.7 and 67.4%, respectively. There was no record of rainfall in either experimental period (INSTITUTO NACIONAL DE METEOROLOGIA, 2019). Temperatures and relative humidity daily data for cultivation years 2018 and 2019 are shown in Figure 1.

The soils of the experimental areas were classified as Argissolo Vermelho-Amarelo (Acrisol), with a sandy loam texture (SANTOS *et al*., 2018). In each experimental area, simple soil samples were collected from a surface layer of 0–20 cm and then homogenised to obtain a composite sample representative of the area. Subsequently, they were sent to the Laboratory of Analysis of Water, Soils and Plants of the Department of Environmental Sciences at UFERSA for chemical analysis, whose results for 2018 were as follows: pH (H_2O) = 8.10; EC = 0.24 dS m^{-1}; O.M. = 4.97 g kg^{-1}; N = 0.35 g kg^{-1}; P = 22.80 mg dm^{-3}; K = 64.70 mg dm^{-3}; Ca =

3.28 $cmol_c\ dm^{-3}$; Mg = 0.78 $cmol_c\ dm^{-3}$; Na = 32.70 mg dm^{-3}; Cu = 0.10 mg dm^{-3}; Fe = 1.91 mg dm^{-3}; Mn = 11.67 mg dm^{-3}; and Zn = 2.63 mg dm^{-3}. In the 2019 crop, the results were as follows: pH (H_2O) = 7.10; EC = 0.10 dS m^{-1}; O.M. = 5.27 g kg^{-1}; N = 0.28 g kg^{-1}; P = 22.00 mg dm^{-3}; K = 69.47 mg dm^{-3}; Ca = 2.70 $cmol_c\ dm^{-3}$; Mg = 0.50 $cmol_c\ dm^{-3}$; Na = 26.70 mg dm^{-3}; Cu = 0.24 mg dm^{-3}; Fe = 2.71 mg dm^{-3}; Mn = 12.17 mg dm^{-3}; and Zn = 5.27 mg dm^{-3}.

The experimental design used in both experiments was a randomised complete block design, with treatments arranged in a 4 × 4 factorial scheme with four replications. The first factor was constituted by equitable amounts of biomass mixtures of 20, 35, 50 and 65 t ha^{-1} of *M. aegyptia* and *C. procera* on a dry basis, and the second factor was four population densities of 400,000, 600,000, 800,000 and 1,000,000 arugula plants ha^{-1}, corresponding to 40, 60, 80 and 100% of the recommended density in monoculture (RDM), intercropped with 500,000 plants ha^{-1} of beet, corresponding to 100% of the recommended density in monoculture. The recommended population densities for monoculture beet and arugula in the region are 500,000 and 1,000,000 plants ha^{-1}, respectively (ALMEIDA *et al*., 2015; SILVA *et al*., 2018).

Figure 1 - Daily temperature and relative humidity data for cultivation years 2018 and 2019



Source: Authors

The intercropping of beet with arugula was established in alternating strips in the proportion of 50% of the cultivated area for each species. In each experimental plot, the alternating strips consisted of four rows flanked by two rows of arugula on one side and two rows of beetroot on the other side, which were used as borders. The total area of each plot was 2.88 m^2 (2.40 × 1.20 m), with a harvest area of 1.60 m^2 (1.60 × 1.00 m), and the harvest area consisted of two central strips of plants, excluding the first and last plants of each row of the strips, also used as borders. In this cultivation system, the same population density for monoculture beet (500,000 plants ha^{-1}) and arugula was used, at the following densities: 400,000, 600,000, 800,000 and 1,000,000 plants ha^{-1}.

The spacing between the rows of the crops in the cultivation strips was 20 cm, and within the arugula rows, the spacing between holes with two plants varied according to the population densities studied, which were 10, 7.5, 6.0 and 5.0 cm, providing 64, 96, 128 and 160 plants per harvest area, respectively, corresponding to population densities of 400,000, 600,000, 800,000 and 1,000,000 plants ha^{-1}. The beet spacing between holes was 5 cm, with one plant per hole.

In the experimental areas, the soil was prepared, starting with the mechanical cleaning of the areas with the aid of a tractor with a coupled plough, followed by harrowing and mechanical lifting of the beds with a rotating harrow. Subsequently, pre-planting solarisation was carried out with transparent plastic (Vulca Brilho Bril Flex®, 30 microns) for 30 days to combat phytopathogenic microorganisms in the soil based on the methodology of Silva *et al*. (2018).

The biomass of *M. aegyptia* and *C. procera* used as green manure was collected from the native vegetation in the rural area of the municipality of Mossoró, RN, at the beginning of their flowering. After collection, these materials were ground in a conventional forager to obtain fragments of 2–3 cm, which were dried at room temperature until they reached a moisture content of 10% and subsequently subjected to laboratory analysis, whose chemical composition in 2018 was as follows: N = 16.60 g kg^{-1}; P = 2.79 g kg^{-1}; K = 37.80 g kg^{-1}; Mg = 7.07 g kg^{-1} and Ca = 19.35 g kg^{-1} for *M. aegyptia* and N = 21.90 g kg^{-1}; P = 1.92 g kg^{-1}; K = 20.90 g kg^{-1}; Mg = 9.22 g kg^{-1} and Ca = 17.00 g kg^{-1} for *C. procera*. In 2019, these values were as follows: N = 15.30 g kg^{-1}; P = 4.00 g kg^{-1}; K = 25.70 g kg^{-1}; Mg = 7.03 g kg^{-1} and Ca = 9.30 g kg^{-1} for *M. aegyptia* and N = 18.40 g kg^{-1}; P = 3.10 g kg^{-1}; K = 24.50 g kg^{-1}; Mg = 13.50 g kg^{-1} and Ca = 16.30 g kg^{-1} for *C. procera*. Two incorporations of green manure were carried out in each experiment, with 50% of the total biomass of the manure incorporated into the soil 20 days before sowing the cultures and another 50% incorporated at 20 days after sowing the cultures.

The beet cultivar ‘Early Wonder’ and the arugula cultivar ‘Cultivada’ were sown in October in the first cultivation and in November in the second seeding of arugula in 2018. In 2019, both cultivars were sown in September in the first cultivation and in October in the second planting of arugula, in holes of 3 cm of depth, with three to four seeds per hole, and covered with commercial substrate Tropstrato HT. After thinning, two plants per hole for arugula and one plant per hole for beet were left in each intercropping system.

Irrigation was performed daily in the experiments using a micro-sprinkler system with two applications (morning and afternoon). The amount of water supplied was determined from the beet crop coefficients (average Kc: 0.83) (OLIVEIRA NETO *et al*., 2011), with an irrigation depth of 8 mm per day when necessary. Weed control was carried out whenever necessary by manually removing the plants. No chemical methods for pest or disease control were needed. The arugula and beet harvests during the two years of cultivation were carried out at 30 and 70 days after planting (DAP), followed by evaluations. The arugula was harvested at 30 DAP because, after this period, the leaves became more fibrous and burnt, which is not appreciated commercially in the north-eastern semi-arid region. The harvest of organic beet at 70 DAP in the region varies according to the cultivar, but in general, the roots are harvested when they are 8 to 12 cm in diameter and 7 cm in length.

The characteristics evaluated in the arugula culture were titratable acidity (TA), pH, soluble solids (SS) and total soluble sugars (TSS) content. In the beet crop, the same characteristics were evaluated in arugula, in addition to the betalain (B) concentration and the internal colour parameters of the tuberose roots.

In the evaluation of the mentioned characteristics, a multiprocessor (Juicer Compact Philips Walita®) was used. The TA was determined by titration. A volume of 49.0 mL of distilled water was added to 1.0 mL of pulp in an Erlenmeyer flask, and after stirring, it was titrated with a standardised solution of NaOH at 0.1 M using 1% phenolphthalein as an indicator. The results were expressed in grams of citric acid per 100 g of pulp (INSTITUTO ADOLFO LUTZ, 2005), with the data expressed as a %.

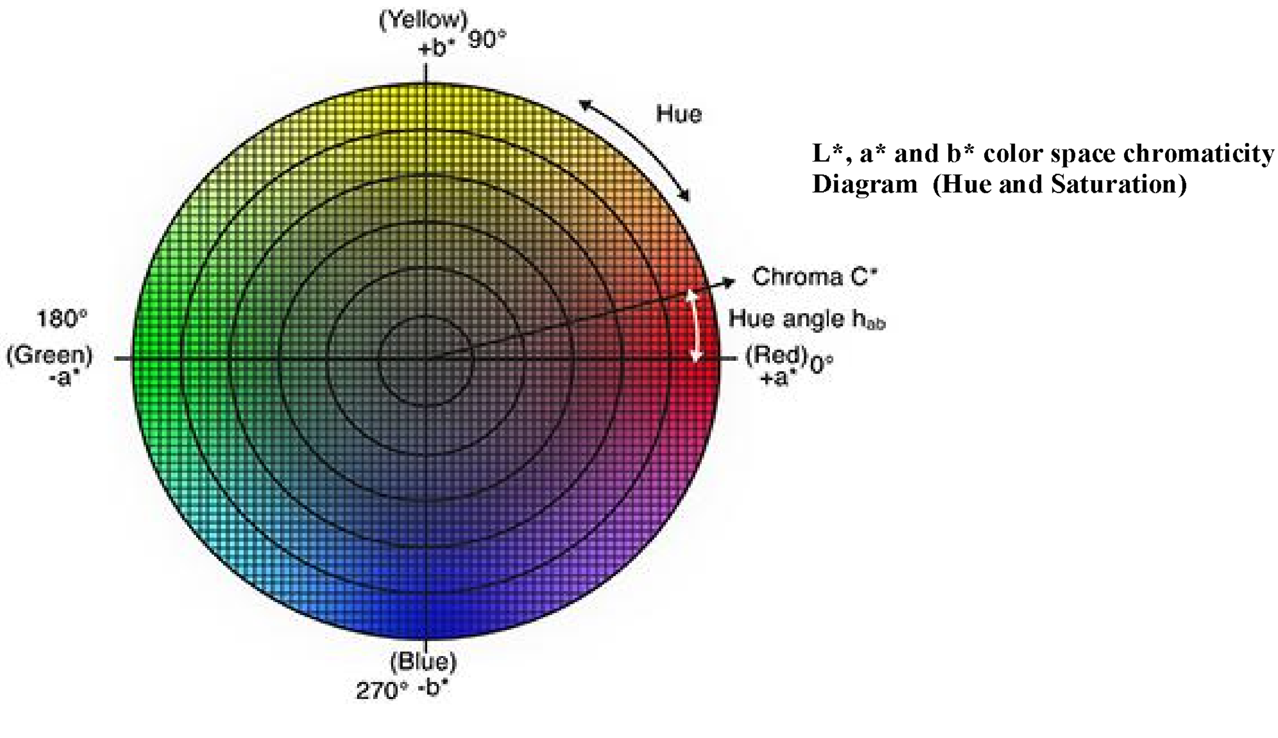
The pH measurement was performed using a benchtop pH metre (Tecnopon mPA 210®). The SS content was determined by refractometry, using a digital refractometer model RTDS-28®, expressing the content in °Brix (ASSOCIATION OF OFFICIAL ANALYTICAL COLLABORATION, 2005). The TSS was evaluated using the anthrone method (%), in which the extract was obtained by diluting 1 mL of pulp juice, from which an aliquot of 0.05 mL was taken and added to 0.95 mL distilled water and 2.00 mL anthrone (9,10-dihiro-9-oxoanthracene). The reaction occurred in a water bath at 100°C for 8 minutes and was cooled in an ice bath. Readings were performed using a spectrophotometer (model SP-2000UV, Spectrum Meter®) at 620 nm (YEMN; WILLIS, 1954).

To determine the concentration of betalain (B) in beet roots, samples (1 g) of beet extract were homogenised in water and transferred to a volumetric flask, where the volume was made up to 100 mL. Then, they were filtered with No. 1 Whatman filter paper. The filtrates were then used for spectrophotometric readings performed in duplicate. The quantification of betalains was performed according to the Beer Lambert–Bougue Law, modified by Tang and Norziah (2007). The calculations to determine the betalain concentration were performed using the following formula: Bc = A x PM x 1000/ε x l, where Bc is the betanin equivalent (mg L^{-1}); A is obtained by λmax at 536 nm; MW is the molecular weight of betanin (550 g mol^{-1}); ε is the betanin excitation molar coefficient (60,000 L $mol.cm^{-1}$); l is the width of the cuvette (1 cm); and 1000 is the dilution factor.

The determination of beet internal colour was performed with the aid of a Minolta colourimeter, model CR-410, calibrated on a white porcelain surface under lit conditions and expressed in the L*, a* and b* modules (Figure 2). The L*, a* and b* coordinates describe the uniformity of colour in three-dimensional space, where the L* value corresponds to how light and how dark the analysed product is (0: black; 100: white). The values of (a*) correspond to the scale from green to red (a* negative; green, a* positive; red), and the values of (b*) correspond to the scale from blue to yellow (b* negative; blue, b* positive; yellow). The Hue angle (hab) is the angle formed between a* and b*, indicating the colour saturation of the object. It can vary from 0 to 360°, with 0° corresponding to red, 90° to yellow, 180° to green, and 270° to blue. According to the CIELAB system, if the angle is between 0° and 90°, the closer to 0°, the more red it is, and the closer to 90°, the more yellow it is (MACDOUGALL, 2002). The roots were cut transversally with a stainless steel knife and read on cut surfaces.

Univariate analysis of variance for a randomised block design in a factorial scheme was used to evaluate the physicochemical characteristics of the arugula leaves and beet roots. Due to the homogeneity of the variances between the cropping seasons, an average of these characteristics was obtained between the cropping seasons. Then, a regression analysis for all physicochemical characteristics was performed, where an adjustment procedure for the response surface of each characteristic was a function of the equitable amounts of *M. aegyptia* and *C. procera* biomass incorporated into the soil and the arugula population density. Analysis was performed using Table Curve 3D software (SYSTAT SOFTWARE, 2021).

Figure 2 - L* (luminosity), a* and b* chromaticity diagram (sensing.konicaminolta.us, 2021)



RESULTS AND DISCUSSION

Arugula crop

The results of the analysis of variance and regression of the characteristics, namely TA, pH, SS and TSS, evaluated in arugula leaves are presented in Table 1. In view of these results, a significant interaction was observed between the studied treatment factors (amount of green manure and arugula population density) only for arugula TA.

However, the response surface was adjusted for all arugula characteristics as a function of these treatment factors, *M. aegyptia* and *C. procera* biomass amounts and population densities of arugula plants intercropped with beetroot. The highest values for TA, pH, SS and TSS of 2.50% malic acid, 5.53, 5.70 °Brix and 3.50%, respectively, were achieved in the combination of equitable amounts of green manure biomass and arugula population density of 20 t ha^{-1} and 1,000,000 arugula plants ha^{-1}; 20 t ha^{-1} and 400,000 arugula plants ha^{-1}; 20 t ha^{-1} and 1,000,000 arugula plants ha^{-1}; and 65 t ha^{-1} and 1,000,000 arugula plants ha^{-1} (Figures 3A to 3D). Factors such as plant nutrition management and crop population densities interfere with the production of sugars and acids in crop products (BATISTA *et al*., 2016; PORTELA *et al*., 2012). Thus, the TA and SS content were more affected by arugula population density, reaching the highest values at the highest population density (1,000,000 arugula plants ha^{-1}) and the smallest amount of green manure incorporated (20 t ha^{-1}) (Figures 3A and 3C). The benefit of these results is the possibility for the producer to obtain quality arugula leaves from the highest population density of the tested arugula, with the smallest amount of biomass from the incorporated green manure. These results partially agree with those obtained by Guerra *et al*. (2022) when intercropping lettuce and beetroot with different amounts of green manure and lettuce population densities, obtaining the same behaviour in the SS content of lettuce leaves at the highest population density of 300,000 lettuce plants ha^{-1} in the smallest amount of the incorporated green manure.

However, the maximum pH value was reached using a combination of a lower amount of green manure and arugula population density, decreasing the value with the increase of these treatment factors (Figure 3B). Leaf acidification of leafy crops decreases with the increasing amount of fertiliser applied, making them less acidic. Therefore, fertilising correctly is very important in obtaining good-quality products from leafy crops. The TSS was affected both by the amount of green manure and by the arugula population density, reaching the maximum value (3.50%) with the combination of 1,000,000 arugula plants ha^{-1} and 65 t ha^{-1} fertiliser (Figure 3D). This increase in the TSS content was partly due to the increase in the amount of green manure since adequate amounts of nutrients provided by the manure increase the amount of TSS in vegetables (CHITARRA; CHITARRA, 2005).

Beet crop

The analysis of variance and regression of post-harvest characteristics, namely TA, pH, betalaine concentration (BC), SS and TSS, evaluated in the beet roots are presented in Table 2. A significant interaction was observed between the treatment factors studied (amount of green manure and arugula population density) for the pH, BC and SS of beet roots.

However, the response surface was adjusted for all beet characteristics as a function of the treatment factors in consortium with arugula. The highest values for TA, pH, BC and TSS of 4.92% malic acid, 6.46, 35.98 mg 100 g^{-1} and 6.99%, respectively, were achieved with equitable amounts of green manure biomass at 65, 41, 65 and 40 t ha^{-1} and arugula population density of 1,000,000 plants ha^{-1} (Figures 4A, 4B, 4C and 4E), while the maximum SS value of 9.38 °Brix was obtained with 20 t ha^{-1} green manure and 400,000 arugula plants ha^{-1} (Figure 4D).

Table 1 - F values for titratable acidity (TA), pH, soluble solids (SS) and total soluble sugars (TSS) in arugula culture intercropped with beetroot with different equitable amounts of *Merremia aegyptia* and *Calotropis procera* biomass incorporated into the soil and diverse population densities of arugula

Sources of variation	DF	Titratable Acidity	pH	Soluble solids	TSS
Blocks	3	1.07^{ns}	0.84^{ns}	2.46^{ns}	1.39^{ns}
Amounts of M. aegyptia and C. procera biomass (A)	3	6.70**	0.79^{ns}	15.42**	0.28^{ns}
Population densities of lettuce (D)	3	5.60**	0.27^{ns}	2.18^{ns}	10.56**
A x D	9	2.18*	0.61^{ns}	1.71^{ns}	1.43^{ns}
Regression (Response surface)	2	7.93**	8.43**	21.09**	54.81**
Error	13	0.01708	0.00263	0.02074	0.05935
CV (%)		8.46	3.36	4.93	27.68

*P < 0.05; ** = P < 0.01; ns = P > 0.05

Figure 3 - Titratable acidity (A), pH (B), and soluble solid (C) and total soluble sugar content (D) of arugula intercropped with beet with different combinations of equitable amounts of *Merremia aegyptia* and *Calotropis procera* biomass and arugula population densities

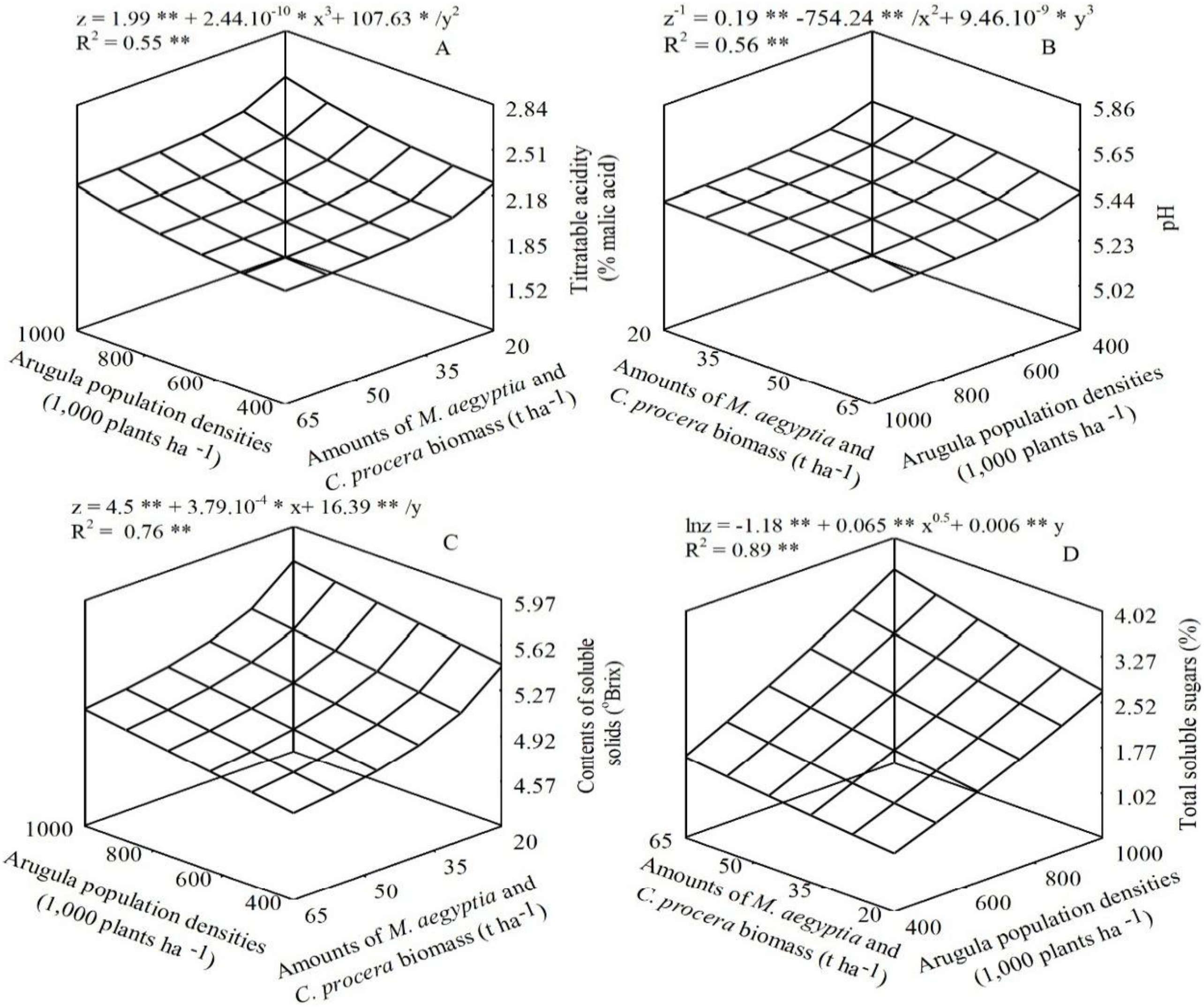
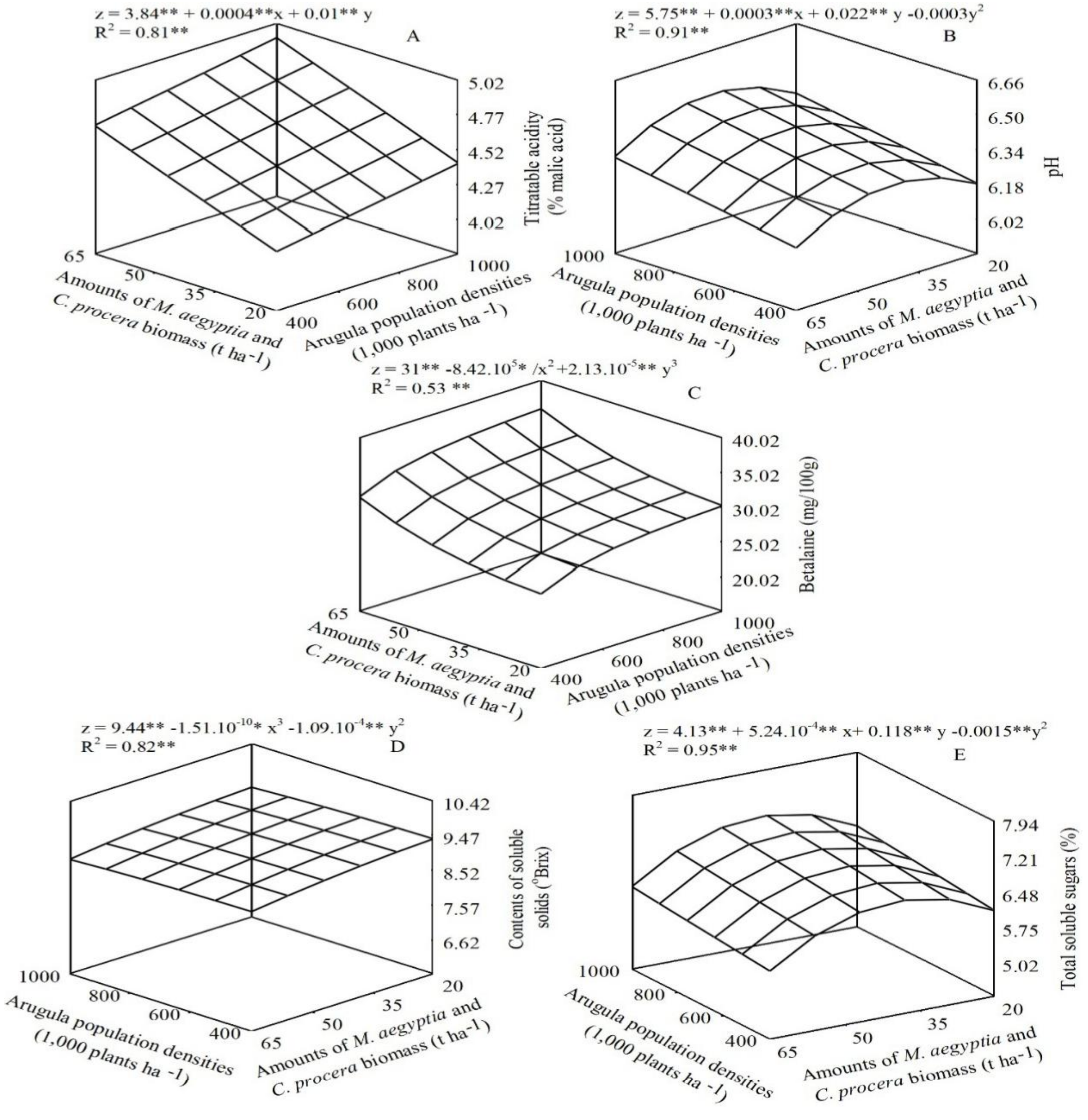


Table 2 - F values for titratable acidity (TA), pH, betalain content (BC), soluble solids (SS) and total soluble sugars (TSS) in beet roots intercropped with arugula with different equitable amounts of *Merremia aegyptia* and *Calotropis procera* biomass incorporated into the soil and diverse arugula population densities

Sources of variation	DF	Titratable Acidity	pH	Betalaine content	Soluble solids	TSS
Blocks	3	0.27ns	1.56ns	6.02**	1.34ns	1.21ns
Amounts of M. aegyptia and C. procera biomass (A)	3	0.43ns	2.14ns	1.49ns	3.88*	3.13*
Population densities of lettuce (D)	3	0.86ns	1.00ns	1.07ns	1.18ns	0.08ns
A x D	9	0.35ns	2.64*	3.14**	2.17*	1.63ns
Regression (Response surface)	2	27.30**	41.77**	7.43**	28.74**	83.18**
Error	13	0.01175	0.00088	8.31547	0.00774	0.00927
CV (%)		15.29	1.86	21.11	5.84	13.54

*P < 0.05; ** = P < 0.01; ns = P > 0.05

Figure 4 - Titratable acidity (A), pH (B), betalaine content (C), soluble solids (D) and total soluble sugar (E) in beetroots intercropped with arugula using different combinations of equitable amounts of *Merremia aegyptia* and *Calotropis procera* biomass and diverse arugula population densities



TA, pH, BC and TSS were affected both by the amount of green manures and by the arugula population density, while SS was affected only by the arugula population density. Factors such as nutrition management and planting densities interfere with the production of sugars and root acids (PORTELA *et al*., 2012), which was also observed in the present work.

However, potassium is a macronutrient that influences SS levels in vegetables, increasing the amount of sugar in beets (OLIVEIRA, 2015). Despite the increasing K content in the treatments with green manure, the greater K availability in the soil will not always promote a greater SS content, indicating that for each characteristic, crop, soil and climate, there are different optimal values.

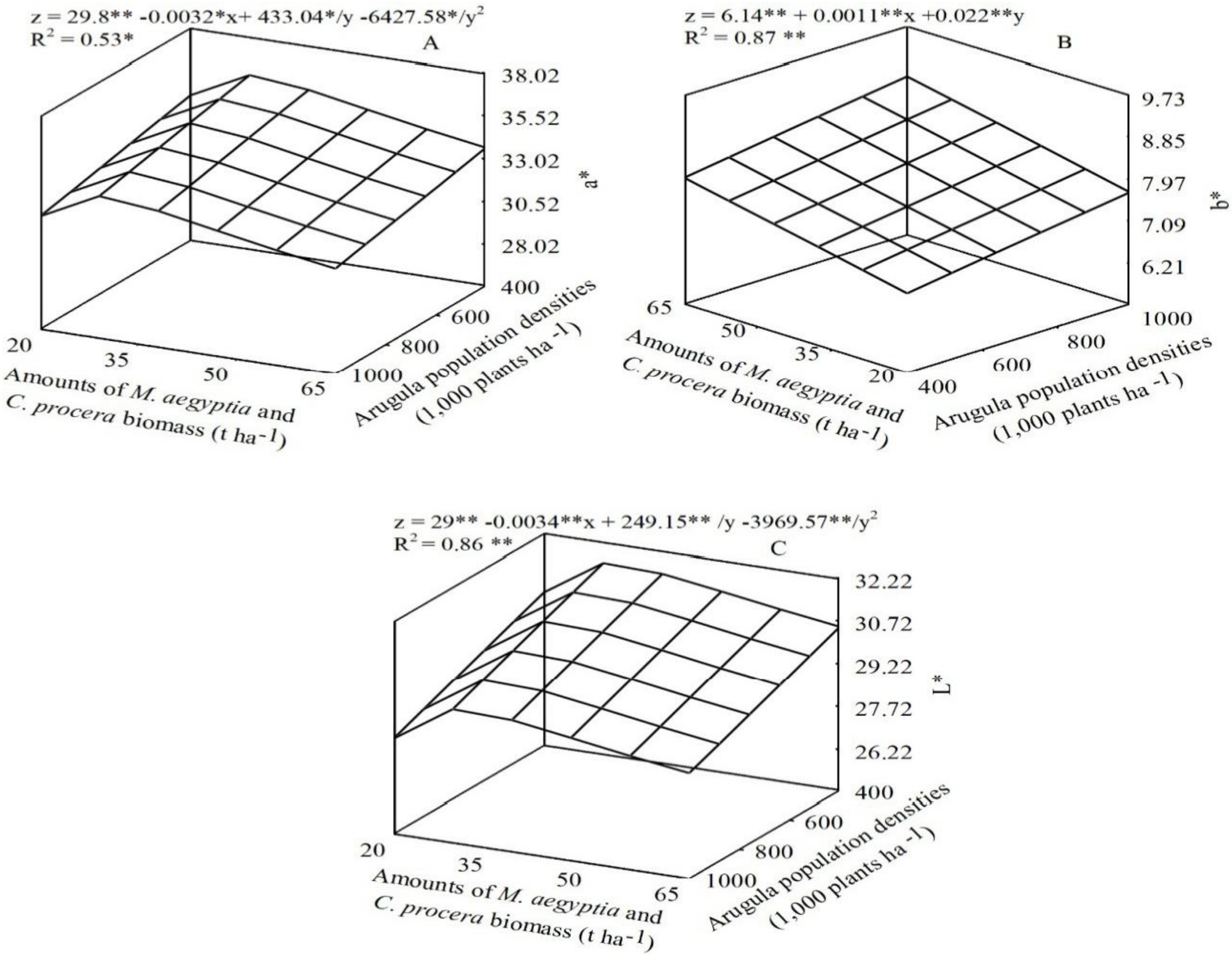
The analysis of variance and regression of the surface colour parameters of the cut beet roots, L* (luminosity), a* and b*, are presented in Table 3. A significant interaction between the factors treatments studied (amount of green manure and arugula population density) was observed only in parameter b* of the beet roots.

Table 3 - F values for the colour parameters, L*, a* and b*, of beet roots intercropped with arugula using different equitable amounts of *Merremia aegyptia* and *Calotropis procera* biomass incorporated into the soil and diverse arugula population densities

Sources of variation	DF	L*	a*	b*
Blocks	3	0.79ns	0.57ns	1.29ns
Amounts of M. aegyptia and C. procera biomass (A)	3	1.66ns	1.00ns	4.07*
Population densities of lettuce (D)	3	1.33ns	3.28*	0.06ns
A x D	9	1.33ns	2.06ns	3.15**
Regression (Response surface)	2	25.35**	4.56*	45.33*
Error	13	0.17631	1.23288	0.03515
CV (%)		6.56	5.30	9.20

*P < 0.05; ** = P < 0.01; ns = P > 0.05

Figure 5 - Colour parameters a* (A), b* (B) e L* (C) (luminosity) in beet intercropped with arugula at different combinations of equitable biomass amounts of *Merremia aegyptia* and *Calotropis procera* and arugula population densities



A response surface was fitted for the beet root colour parameters as a function of the treatment factors. The maximum values for a*, b* and L* of 35.83, 8.69 and 31.54, respectively, were achieved by combining equitable amounts of green manure biomass with arugula population densities of 30 t ha^{-1} and 400,000 arugula plants ha^{-1}, 65 t ha^{-1} and 1,000,000 arugula plants ha^{-1}, and 32 t ha^{-1} and 400,000 arugula plants ha^{-1}, respectively (Figures 5A to 5C).

Working with the beet crop intercropped with lettuce in the same cultivation region of this research, Guerra *et al*. (2022) obtained different values for these parameters (35.43, 9.94 and 32.97) using the combination of different green manure amounts and lettuce population densities of 25 t ha^{-1} and 188,000 plants ha^{-1}, 65 t ha^{-1} and 300,000 plants ha^{-1}, and 65 t ha^{-1} and 280,000 plants ha^{-1}. These differences in the results of the two surveys are due to factors such as plant nutrition management and crop population densities (BATISTA *et al*., 2016; PORTELA *et al*., 2012).

Parameter b* caused the more purple colour in the beets at the highest amount of green manure and arugula population density tested. Compared to the other combinations tested, parameter a* showed a stronger shade of purple/red in the beet roots, using 30 t ha^{-1} green manure and an arugula population density of 400,000 plants ha^{-1}. This colour is well appreciated by consumers. The L* parameter (luminosity) behaved in the same way as the a* parameter, intensifying the colour of the beet roots in the combination of 32 t ha^{-1} green manure with an arugula population density of 400,000 plants ha^{-1} compared to the other combinations tested. Franco *et al.* (2021) worked with beets fertilised with different K doses and demonstrated a behaviour similar to that obtained in this research.

Intercropping has significant advantages over monoculture in terms of increased productivity per area and the more efficient use of land and resources. It also benefits post-harvest products in terms of repelling pests and attracting beneficial insects, adding nutrients to the main harvest, having greater biodiversity and ecological stability, and showing greater returns and guaranteed profits from crop products.

CONCLUSIONS

1. Arugula presented the best post-harvest indexes for TA, SS and TSS when submitted to fertilisation with green manure biomass amounts of 20, 20 and 65 t ha^{-1}, respectively, and a population density of 1,000,000 plants ha^{-1};

2. The beet crop showed the best post-harvest indexes for TA, pH, BC and TSS using green manure biomass amounts of 65, 41, 36 and 40 t ha^{-1}, respectively, and an arugula planting density of 1,000,000 plants ha^{-1};

3. The best colour parameters, in terms of a* and L* of the roots of purple/red beet, which is well appreciated by consumers, were obtained using green manure amounts of 30 and 32 t ha^{-1} and an arugula planting density of 400,000 plants ha^{-1}, while the best b* was obtained using 65 t ha^{-1} and an arugula density of 1,000,000 plants ha^{-1}.

REFERENCES

ALMEIDA, A. E. *et al*. Eficiência agronômica do consórcio alface-rúcula fertilizado com flor-de-seda. **Revista Caatinga**, v. 28, n. 3, p. 79-85, 2015.

ALVARES, C. A. *et al*. Köppen’s climate classification map for Brazil. **Meteorologische Zeitschrift**, v. 22, n. 6, p. 711-728, 2014.

ASSOCIATION OF OFFICIAL ANALYTICAL COLLABORATION – AOAC. **Official Methods of Analysis of AOAC International**. 18th ed., Gaithersburg: AOAC International, 2005.

BATISTA, M. A. V. *et al*. Atributos de solo-planta e de produção de beterraba influenciados pela adubação com espécies da Caatinga. **Horticultura Brasileira**, v. 34, n. 1, p. 12-19, 2016.

BEZERRA NETO, F. *et al*. Qualidade da alface em sistema consorciado com cenoura sob diferentes densidades populacionais das culturas componentes. **Revista Caatinga**, v. 18, n. 3, p. 169-175, 2005.

CHITARRA, M. I. F.; CHITARRA, A. B. **Pós-colheita de frutos e hortaliças**. 2. ed. Lavras: ESAL/FAEPE, 2005. 783 p.

CUQUEL, F. L.; HADLICH, E.; CALEGARIO, F. F. Pós-colheita em fruteiras de caroço. In: MONTEIRO, L. B. *et al*. **Fruteiras de caroço: uma visão ecológica**. Curitiba: UFPR. p. 317-331, 2004.

FRANCO, M. S. F. *et al.* Qualidade de beterraba de mesa (*Beta vulgaris*) em função de fontes e doses de potássio **Research, Society and Development**, v. 10, n. 13, p. 1-13. 2021.

GUERRA, N. M. *et al*. Productive and agro-economic benefits in beet-lettuce intercropping under organic manuring and population densities. **Research, Society and Development**, v. 10, n. 4, e10510413883, 2021.

GUERRA, N. M. *et al.* Post-harvest índice and color parameters in beet roots intercropped with lettuce under organic fertilization and population densities. **Food Science and Technology**, v. 42, e05822, 2022.

INSTITUTO ADOLFO LUTZ. **Métodos Físico-Químicos para Análise de Alimentos**. 4. ed. São Paulo: Instituto Adolfo Lutz, 2005.

INSTITUTO NACIONAL DE METEOROLOGIA – INMET. **Dados meteorológicos**. Brasilia: Ministério da Agricultura, Pecuária e Abastecimento, 2019. Retrieved from https://portal.inmet.gov.br.

LINHARES, P. C. F. *et al*. Amounts and times of decomposition of scarlet starglory on agronomic performance of cilantro. Ciência Rural, v. 42, n. 2, p. 243-248, 2012.

MACDOUGALL, D. B. Colour in food: improving quality. Cambridge: Woodhead Pub., 2002. 388 p.

OLIVEIRA NETO, D. H. *et al*. Evapotranspiração e coeficientes de cultivo da beterraba orgânica sob cobertura morta de leguminosa e gramínea. **Horticultura Brasileira**, v. 29, n. 3, p. 330-334, 2011.

OLIVEIRA, R. J. P. **Adubação para a cultura da beterraba (*Beta vulgaris* l.) na região do Alto Vale do Itajaí**. 2015. 73 p. Tese (Doutorado em Manejo do Solo) - Universidade do Estado de Santa Catarina, Lajes, 2015.

PORTELA, I. P. *et al*. Densidade de plantio, crescimento, produtividade e qualidade das frutas de morangueiro "Camino Real" em hidroponia. **Revista Brasileira de Fruticultura**, v. 34, n. 3, p. 792-798, 2012.

RAMOS, J. A. *et al*. Modificação da composição físico-química de beterrabas submetidas a diferentes tipos de corte e métodos de cocção. **Energia na Agricultura**, v. 31, n. 1, p. 108-120, 2016.

SANTOS, H. G. *et al*. **Sistema brasileiro de classificação de solos**. Brasília: Embrapa, 2018. 356 p.

SILVA, I. N. *et al*. Green manure and spatial arrangement in the sustainability improvement of lettuce-beet intercrops. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 22, n. 7, p. 451-457, 2018.

SYSTAT SOFTWARE INC. **Table curve 3D Academic Edition**. San Jose, CA: Systat Software Inc, 2021.

TANG, C. S.; NORZIAH, M. H. Stability of betacyanin pigments from red purple pitaya Fruit (Hylocereuspolyrhizus): Influence of pH, temperature, metal ions and ascorbic acid. **Indonesian Journal of Chemistry**, v. 7, n. 3, p. 327-331, 2007.

YEMN, E. W.; WILLIS, A. J. The estimation of carbohydrate in plant extracts by anthrone. **The Biochemical Journal**, v. 57, n. 3, p. 508-514, 1954.