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Different sources of nutrients in the production and quality of "Veneranda" curly lettuce

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ABSTRACT

Driven by the growing demand for good quality food, agriculture is changing the way of cultivation to attend consumer's expectations. In addition to the nutritional value, the production system has been an important factor in the consumer's intention to purchase products. In this scenario, this work aimed to evaluate the effects of different nutrient sources on production characteristics and nutritional quality of 'Veneranda' lettuce. The experiment was conducted in randomized block design, with seven treatments (control, bokashi, organic compost, mineral fertilizer, mineral fertilizer + organic compost, foliar biofertilizer and soil biofertilizer), and five replications. In commercial vegetative stage, lettuce was harvested and evaluated for physical, physicochemical, bioactive compounds and mineral composition. Lettuce produced with mineral and organomineral fertilizers showed the highest yield of physical characteristics, which is related to the highest nitrogen content in their leaves. The use of organomineral fertilization, organic and mineral compost and biofertilizer via leaf application presented a positive effect on lettuce cultivation, with better nutritional quality and productivity.

Keywords: *Lactuca sativa*, phenolic compounds, plant nutrition, organic production.

RESUMO

Diferentes fontes de nutrientes na produção e qualidade de alface crespa "Veneranda"

Impulsionada pela crescente demanda por alimentos de boa qualidade, a agricultura está mudando a forma de cultivo para atender às expectativas dos consumidores. Além do valor nutritivo, o sistema de produção tem sido um fator importante na intenção de compra dos consumidores. Diante desse cenário, este trabalho teve como objetivo avaliar os efeitos de diferentes fontes de nutrientes nas características de produção e qualidade nutricional da alface Veneranda. O experimento foi conduzido em delineamento em blocos casualizados, com sete tratamentos (controle, bokashi, composto orgânico, fertilizante mineral, fertilizante mineral + composto orgânico, biofertilizante via foliar e biofertilizante via solo) e cinco repetições. No estádio vegetativo comercial, a alface foi colhida e avaliada quanto a aspectos físicos, físico-químicos, compostos bioativos e composição mineral. As alfaces produzidas com fertilizantes minerais e organomineral apresentaram o maior rendimento das características físicas, o que está relacionado ao maior teor de nitrogênio em suas folhas. A utilização de adubação organomineral, composto orgânico e mineral e biofertilizante via foliar apresentou efeito positivo no cultivo da alface, com melhor qualidade nutricional e produtividade.

Palavras-chave: *Lactuca sativa*, compostos fenólicos, nutrição vegetal, produção orgânica.

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A new perspective on people's lifestyles has opened up a field for researching alternatives for the production of nutritionally rich food, in sufficient quantity. In addition to nourishing, consumers are looking for foods rich in functional components that bring health benefits, as well as the origin of the product and the production system has become an important purchase criterion (Banwo *et al.*, 2021).

As a consequence of consumer's awareness about the importance of eating healthy foods, and the relationship between the consumption of vegetables and the reduced risk of cancer occurrence and degenerative diseases, the demand for vegetables has increased resulting that the world value of the vegetable trade has surpassed that of cereals (Chakraborty & Chattopadhyay, 2018; Miceli *et al.*, 2019).

Among these, lettuce (*Lactuca sativa*) is one of the most cultivated and consumed leafy vegetables in the world, appreciated for its sensory properties and good source of minerals, vitamins, terpenoids, in addition to carotenoids, phenolic acids and flavonoids, which promote the provision of beneficial components for human health (Giordano *et al*., 2019; Kyriacou *et al*., 2019; Gutierrez-del-Río *et al*., 2021).

Driven by these emerging trends in human nutrition connected to physical well-being and nature's legacy as a provider of healthier and more nutritious food, agriculture is changing the way of cultivation to more sustainable and healthier food production (Nakhel *et al*., 2020). The systematic use of mineral fertilizers and pesticides in agriculture is increasingly questioned because of their negative impacts on ecosystems. Other production methods (organic and sustainable agriculture) limit or exclude applications of synthetic chemicals to ensure high quality food in an ecologically sound way (Diallo *et al*., 2019).

Organic agriculture promotes the use of certain organic waste products as an alternative to mineral fertilizers. According to Skinner *et al*. (2019), organic agriculture provides immediate fertilization of crops, while ensuring improvement in the physical, chemical and biological properties of the soil, resulting in long-term differential management of the agricultural system. Its residual effects increase productivity after several cropping cycles, unlike soils on which mineral fertilizers are often used to obtain higher yields of the crop in question (Bai *et al*., 2020).

Thus, this study aimed to evaluate the effects of different nutrient sources on production characteristics and nutritional quality of “Veneranda” lettuce.

MATERIAL AND METHODS

Conducting the experiment

The experiment was conducted in 2017, under natural light conditions, in the municipality of Bananeira (6°45'10"S, 35°37'41"W, 524 m altitude), Paraíba, Brazil. The local climate is classified as type A (tropical rainy), hot and humid.

Seeds of the looseleaf lettuce group, cv. Veneranda were sown in 200-cell polyethylene trays with Plantmax® commercial substrate. Seed germination occurred during a period of 20 days, where, at the end of the period, the plants had two to three definitive leaves, ideal for transplant.

The plants were transplanted into an experimental area of 548.9 m². The experimental plots were 1.2 m wide by 3.3 m long (3.96 m²), adopting a spacing of 0.3 m between ranks by 0.3 m between plants, totaling 44 plants per plot. The useful area of the plot was 1.98 m², consisting of the two central rows, with 18 useful plants.

Lettuce was harvested when the plants were at a commercial vegetative stage, occurring 45 days after transplanting. The cutting of the plants was carried out disregarding the effect of the edges, being used only the useful plants to evaluate the effects of the treatments on the production and nutritional quality of the lettuces.

Application of treatments

The experiment was conducted in a randomized blocks design, with seven treatments and five repetitions, totalizing thirty-five experimental plots: 1) Control (without fertilization); 2) Bokashi via leaf; 3) Organic compound; 4) Organomineral (50% mineral, 50% organic compound); 5) Mineral; 6) Biofertilizer via leaf; 7) Biofertilizer via soil.

Bokashi

The liquid fertilizer Bio Bokashi® was applied via leaf to the plants. The product contains nitrogen and organic carbon in the formulation, used in organic agriculture to optimize the physical, chemical and biological conditions of soil and plant, providing conditions for ideal development of plants. Fertilization with bokashi was carried out by spraying in the late afternoon, using a proportion of 5:1000 mL of water, per plot.

Organic, organomineral and mineral compound

Organic compost was produced by composting. In this process, plant residues (leaves) and rabbit manure were used. The compostage was monitored periodically regarding the control of temperature (50 °C) and humidity (55±5%), for 120 days, where posteriorly the organic matter was later sieved and stored in plastic packaging until the moment of application in the experiment. The organic compound obtained had in its composition high concentrations of phosphorus (298.25 mg/dm^3), potassium (750.00 mg/dm^3), calcium (12.00 cmolc/dm^3), magnesium (6.50 cmolc/dm^3) and organic matter (81.37 g/kg).

Fertilization with organic compost, as well as organomineral and mineral, were applied in the transplanting holes of the seedlings as indicated by the treatments. The amounts of mineral fertilizers (1.52 g before planting and 2.03 g of ammonium sulfate in top dressing, 4.55 g of simple superphosphate and 0.95 g of potassium chloride) were calculated following the recommendations proposed by the Instituto Agronômico of Pernambuco (IPA, 2008).

For mineral fertilization, ammonium sulfate was used as a source of nitrogen (N), simple superphosphate (P_2O_5) and potassium chloride (K_2O), at doses of 30.0, 90.0 and 60.0 kg/ha, respectively. The application of fertilizer on top dressing was carried out next to the plants, at a dose of 40 kg/ha of ammonium sulfate.

Biofertilizer

The biofertilizer used in the fertilization was produced from the aerobic fermentation of the mixture of cattle manure, water, banana stem, foliage from other crops and bakery ash. The biofertilizer elaborated had in its composition N, P, K, Ca, Mg and S in concentrations of 21.44, 40.35, 15.64, 59.47, 14.48, 14.13, g/L, respectively; Cu, Zn, Fe, Mn and B in concentrations of 2.92, 209.44, 2978.58, 657.80 and 19.25 mg/L, respectively. Fertilization with the biofertilizer was carried out via leaf and soil. For the application of biofertilizer via leaf, dilution was made with 5 mL of biofertilizer in 1000 mL water for each plot, which was sprayed weekly. The application via soil was performed using a 0.12 mL biofertilizer solution per plant with the aid of a graduated cylinder.

Physical and physicochemical analyzes

The chlorophyll a, chlorophyll b and total chlorophyll indices were determined in three fully expanded healthy leaves per plant, in each plot using a portable chlorophyll (ClorofiLOG CFL1030). Chlorophyll indices were monitored during the experiment period, at 7 days intervals, between 09:00 and 10:00 am.

During the period of conducting the experiment, the diameter of the aerial part (cm), the height of the plant (cm), were also determined, obtained by the vertical distance from the soil surface to the top of the plant, and the leaf number per plant with a size greater than 3 cm in length.

Harvested lettuces were immediately evaluated for commercial fresh mass (g); fresh mass (g); dry mass (g). To determine the dry mass, plants were dryed in an oven at 60 °C until constant mass; leaf color was determined using a Delta Color Colorimeter (Delta Vista d.0), which was previously calibrated, with a light source of D65 and an observation angle of 10°. The color expression was performed in the parameters: L* (luminosity), a* (+a* red and -a* green), b* (+b* yellow and -b* blue), C* (chromaticity) and hº (hue angle).

The physicochemical characteristics of the harvested lettuces were evaluated regarding the parameters water content (% b.u.) by the 932.12 method, ash (%) by the 938.08 method, titratable acidity (% malic acid) by the 942.15 method and pH by the 981.12 method, according to the analytical methods of the AOAC (1997).

The ascorbic acid content (mg/100 g) was determined by the method reaction of ascorbic acid with 2,6-dichlorophenol indophenol. Absorbance reading was performed using a spectrophotometer at 520 ηm. The content of total polyphenols (mg EAG/100 g) was determined according to the method of Waterhouse (2002). Peroxidase activity (UAE min/g) was determined according to the methodology proposed by Matsuno & Uritani (1972) and Wissemann & Lee (1980).

Mineral composition

The evaluation of mineral composition was carried out at 45 days after transplant on dry leaves. The macro and micronutrients of the samples were determined using the methodology proposed by Malavolta *et al.* (1997). The levels of potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), manganese (Mn), zinc (Zn) and iron (Fe) were measured by flame atomic absorption spectrometry and, total nitrogen (N) by micro-Kjeldahl method, phosphorus (P) by spectrophotometry and sulfur (S) by gravimetric analysis.

Statistical analysis

The data were tested by performing a two-way ANOVA ($p \leq 0.05$). For the quantitative factor (periods after fertilization), non-linear regression analysis was applied, and the polynomial equation was adjusted, assuming a coefficient of determination (R^2) greater than or equal to 60%. The parameters of the equation were evaluated using the t test at 5% probability. For the qualitative factor (fertilization), the means were subjected to analysis of variance and the means were compared by Tukey test ($p \leq 0.05$) using Statistica 7.0 Tursa, OK, USA (www.statsoft.com).

RESULTS AND DISCUSSION

Formation of plant biomass

There were statistically significant effects of the interaction between treatments applied with different nutrient sources. The effects of these treatments can be seen in Figure 1. We verified that treatments 4 and 5, corresponding to organomineral and mineral fertilization, respectively, presented high efficiency for plant development, obtaining high values for the parameters head diameter (106.07 and 111.27 cm), plant height (20.25 and 21.03 cm) and leaf number (25.47 and 26.20).

The effect of organomineral and mineral fertilizers on the development of lettuce was superior to the other studied fertilizers. Similar responses to our work were reported by Monteiro Filho *et al.* (2017), when they evaluated the effect of fertilizers, minerals and organomineral on the growth of looseleaf lettuce group 'Thaís', 'Verônica' and 'Vanda'; these authors observed similar values of head diameter, plant height and leaf number. However, variations in the development of different cultivars can be observed, since the genotype can interact with environmental factors such as soil fertility, temperature, humidity and light intensity, which can directly affect crop performance (Blind & Silva Filho, 2015). As observed in the work carried out by Lee *et al.* (2021), in which butter lettuce plants with 16.9 cm height were reported, whose values were higher than those obtained in this study; the results found point to a better quality of lettuce for commercialization and greater resistance to bolting.

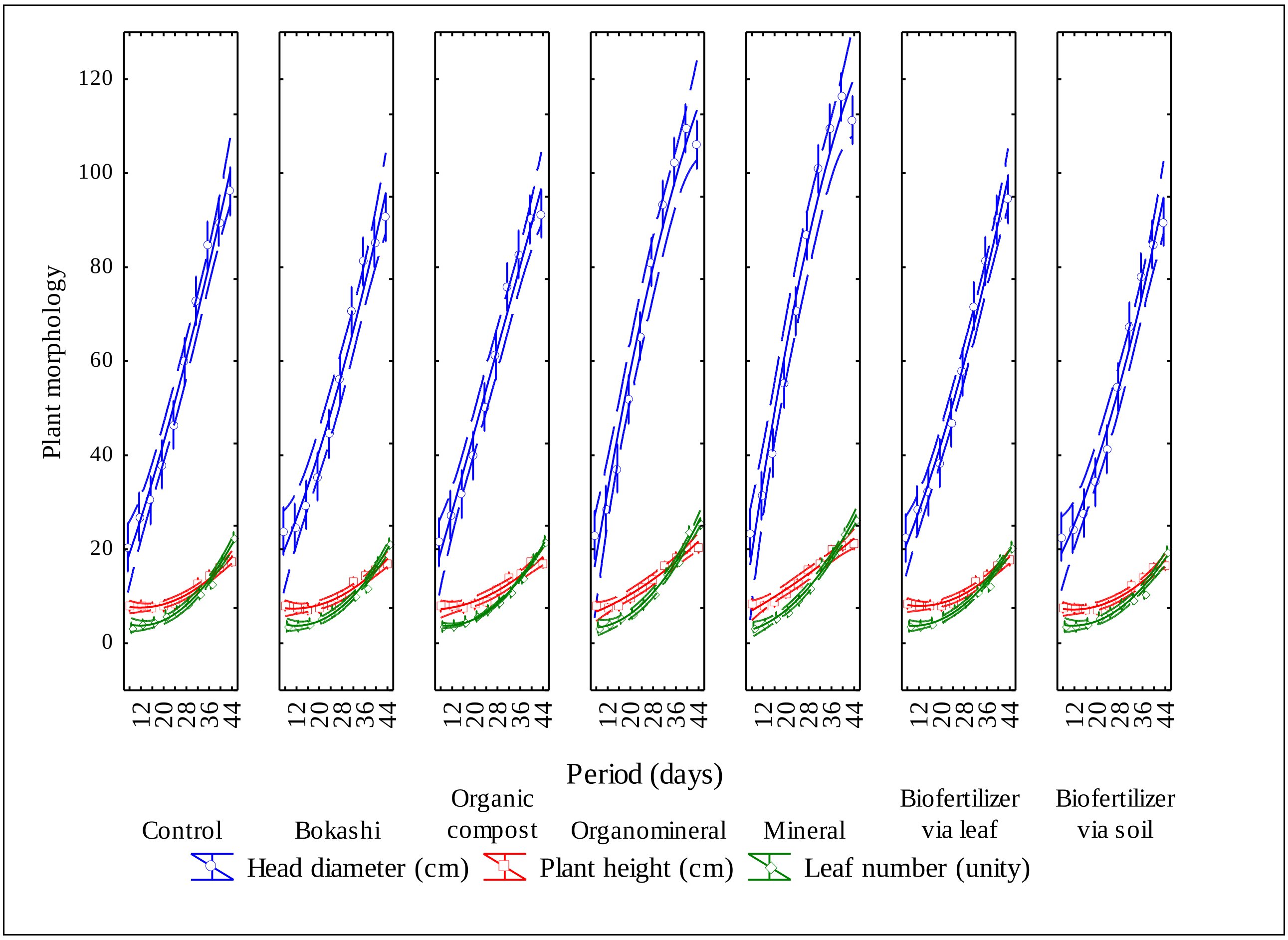

Figure 1. Head diameter, plant height and leaf number with the adjustment of the equations: head diameter = 12.1673 + 6.7467*×D + 0.2245*×D², R^2 = 0.99; plant height = 8.177 – 0.6176*×D + 0.1631*×D², R^2 = 0.93 and leaf number = 4.7501 – 1.018*×D + 0.2644*×D², R^2 = 0.94, where P is the period in days. The center line is the fitted nonlinear function, the dashed outer lines define the range with 95.0% confidence. Bananeiras, UFPB, 2017.

The head diameter, the plant height, as well as the leaf number, are parameters directly related to productivity and consequent increase in profitability with the accumulation of lettuce biomass, since these parameters can indicate how much the genetic material is adapted to the environment and indicate its potential commercial success (Diamante *et al*., 2013; Zhao *et al*., 2022). The greater leaf number also indicates greater leaf area, greater fresh weight, and consequently, greater productivity, considered one of the most important attributes, since the leaves constitute the commercial part, factors observed by the consumer in the purchase of the product.

Fresh, dry and marketable mass were significantly influenced by treatments (Figure 2). A higher yield of fresh mass was observed in the treatment with mineral fertilization, followed by organomineral fertilization and other treatments.

The use of mineral and organomineral fertilization provided higher lettuce yield and higher quality production. The mixture of organic and mineral fertilizer sources resulted in a positive effect on the development of the lettuce, which is directly linked to its composition, as it presents in its formulation fulvic and humic acids, present in organic fractions which, in general, have the function of increasing growth, capacity of water and nutrient retention and absorption, and disease suppression (Guo *et al*., 2019). These results are observed through the evaluation of fresh mass, dry mass and commercial mass of the harvested plants (Figure 2). Architecture and leaf’s dimensions, imply better packaging and transport of plants, reflecting on the quality of the product.

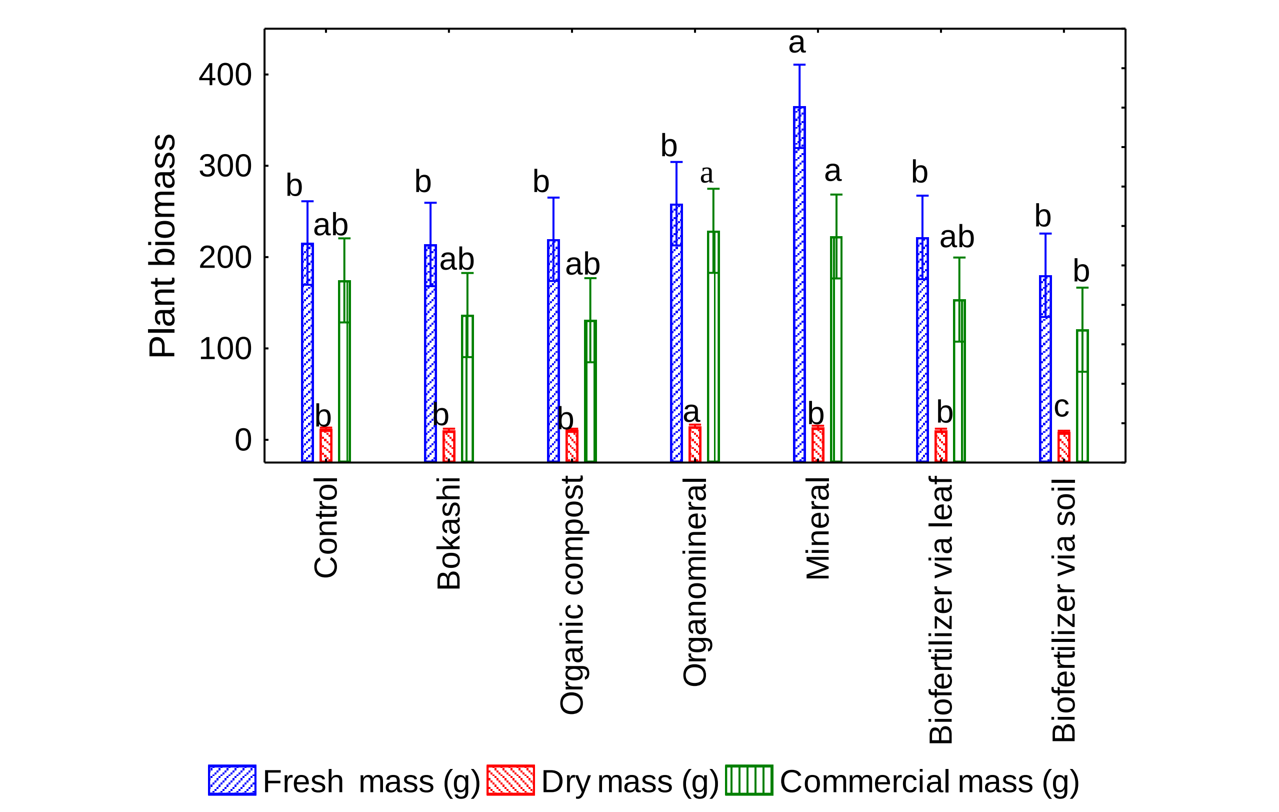

Figure 2. Weight of fresh mass, dry mass and commercial mass with error under the effect of the application of different fertilization. Equal letters between treatments do not differ by Tukey test at 5% probability. Bananeiras, UFPB, 2017.

The lettuce treated with mineral fertilizer showed higher fresh mass yield (365.07 g/plot) compared to the other fertilizers applied to the lettuce. The fresh mass of lettuce is associated with commercial value, being one of the main traits that influence the choice of lettuce by the consumer. Therefore, the cultivars that present greater fresh mass are preferred by the consumer. This occurs because mineral fertilization provides nutrients to lettuce, which are immediately available to the plants, promoting rapid growth and providing high productivity (Hernández *et al*., 2016). Similar results were reported by Silva *et al*. (2010) and Aquino *et al*. (2014), with 318.2 g of fresh mass of the lettuce treated with nitrogen fertilization. On the other hand, using different organic compounds, these authors reported 335.0 g of fresh mass per plant.

Fertilization with biofertilizer via soil resulted in plants with low values of dry mass. The superior results of organomineral fertilization for the production of the lettuce are due to the advantages directed to this type of fertilization, such as the increase of microbial activity in the soil; reduced leaching; increased availability of nutrients; improved soil properties; increased cation exchange capacity; improved water and nutrient retention, and contribution to the addition of organic matter to the soil (Smith *et al*., 2020; Choudhary *et al*., 2021), through changes in morphological and physiological indices, which in turn contribute to biomass increase (Zhao *et al*., 2022).

The treatments did not exert significant effects on the levels of photosynthetic pigments (chlorophyll a, b and total). However, the average index of chlorophyll a (128.08 mol/L), chlorophyll b (28.59 mol/L) and total chlorophyll (157.61 mol/L) increased throughout the lettuce growth period (Figure 3). Chlorophyll, as the primary pigment of leafy green vegetables, plays a major role in assessing the health status of vegetables. Chlorophyll, as the primary pigment of green leafy vegetables, plays an important role in the nutritional status of leafy vegetables as it contains N, an essential nutrient for plant growth and development (Lu *et al*., 2019).

The different fertilization met the needs of the vegetable, confirmed by the index of the chlorophyll a, b and total, since the degradation of these pigments was not observed, satisfactory result, since the loss of chlorophyll is a relevant factor in the quality of lettuce. The chlorophyll present in leaves is responsible for light absorption, excitation energy transfer and charge separation within photosynthetic complexes, because the composition of the content of photosynthetic pigments (chlorophyll a and chlorophyll b) directly affects the photosynthetic rate of leaves (Wang & Grimm, 2021).

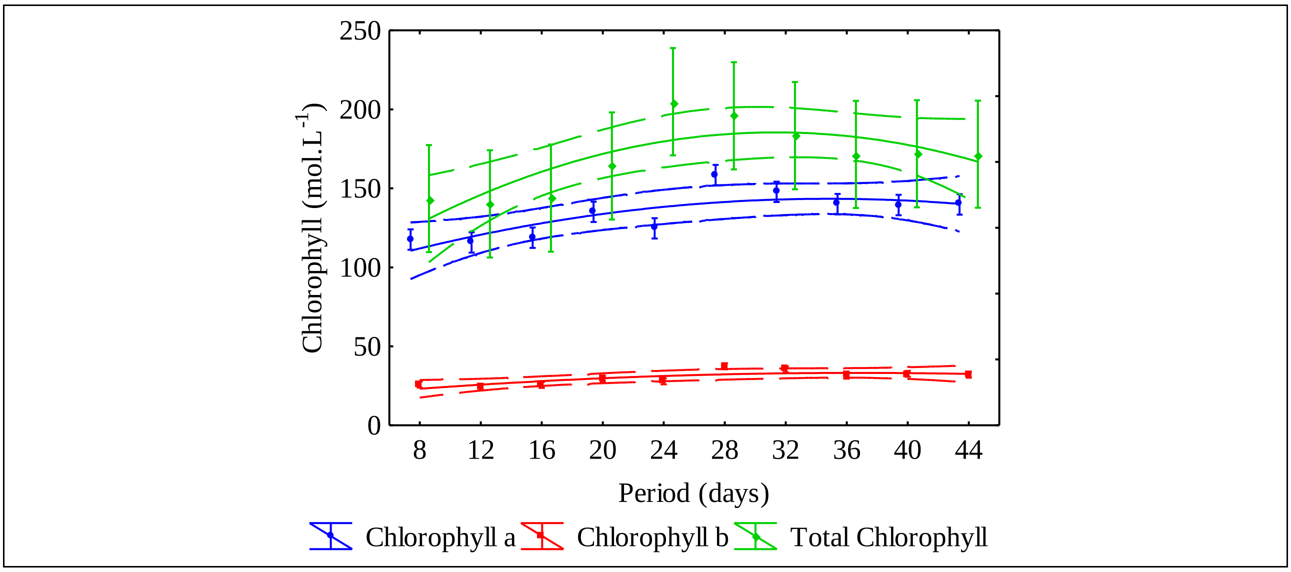

Figure 3. Chlorophyll index and error with the equation fitting: chlotophyll a = 101.8485 +10.7867*×D - 0.7001*×D², R^2 =0.69; chlorophyll b = 20.1086 + 3.2059*×D – 0.1965*×D², R^2 = 0.69; and total chlorophyll = 106.4305 + 23.1011*×D - 1.6895*×D², R^2 = 0.71, where P is the period in days. The center line is the fitted nonlinear function, the dashed outer lines define the range with 95.0% confidence. Bananeiras, UFPB, 2017.

The high photosynthetic efficiency can lead to increased agricultural productivity, and this relationship is directly related to the use of radiation available by these pigments (Silva *et al*., 2014). Chlorophyll a is present in all photosynthetic organisms; it is the pigment used to carry out the photochemical phase, while the other pigments help to absorb light and transfer energy to the reaction centers, being called accessory pigments (Taiz *et al*., 2017).

Vegetable quality

The treatments do not show significant influence for the color parameter: L*, b*, C* and h°, and the peroxidase activity (Table 1).

Table 1. Effect of treatments over color traits and physics and physicochemical of the lettuces. Bananeiras, UFPB, 2017.

Variables	Treatments						
	1	2	3	4	5	6	7
L*	55.84a	54.30a	56.43a	52.61a	52.59a	56.64a	57.72a
a*	-8.24ab	-6.52b	-8.03ab	-9.17ab	-9.50ab	-9.73a	-9.65a
b*	29.13a	30.67a	30.85a	31.54a	31.83a	32.62a	32.93a
C*	30.40a	31.43a	31.97a	32.86a	34.30a	33.29a	34.03a
h°	106.44a	102.12a	104.61a	106.14a	106.05a	107.00a	106.50a
Water content (%)	92.80cd	92.82cd	92.16c	98.07a	93.57bd	93.93b	93.17bd
Ash (%)	0.84c	0.96a	0.83c	0.81bc	0.83c	0.75b	0.85c
Titratable acidity (%)	0.07ab	0.04d	0.04d	0.06bc	0.05cd	0.04d	0.09a
pH	5.47b	5.63ab	5.51b	5.50b	5.63ab	5.76a	5.56b
Ascorbic acid (mg/100 g)	9.53ab	9.36b	9.48ab	9.54ab	9.65a	9.41b	9.54ab
Total polyphenols (mg GAE/100 g)	56.71a	54.81ab	57.55a	48.44cd	50.11bd	54.72ab	43.76d
Peroxidase activity (UAE min/g)	0.18a	0.41a	0.45a	0.27a	0.25a	0.20a	0.50a

*Treatments: 1) Control, 2) Bokashi, 3) Organic compost, 4) Organomineral, 5) Mineral, 6) Biofertilizer via leaf and 7) Biofertilizer via soil. **Means followed by the same letter in the line do not differ statistically from each other by Tukey test (p>0.05).

The treatments with mineral fertilization, biofertilizer via foliar and biofertilizer via soil increased the intensity of the a* parameter significantly, which represents the green color, and the green color of the leaves is an indicator of lettuce quality. In addition, the organomineral and bokashi fertilization significantly promoted the water and ash content, respectively, of the plant compared to the other fertilizations. Color is an important quality parameter essential in the purchase decision of this vegetable.

The lettuce cultivated as control and fertilized with organic, organomineral, mineral, biofertilizer via leaf and biofertilizer via soil showed the highest values of a*, which tends towards green color (-a*), then for fertilization with bokashi, which presented the lowest value, indicating a trend towards the red color (+a*). According to Ozgen & Sekerci (2011), changes in the color of the lettuce leaf depend on maturation, with the outer leaves being more mature than the inner ones. The former does not only have higher pigment content, but also present a more abundant synthesis of secondary metabolites, which results from their more direct exposure to the environment. Although there were some color differences between the fertilizers, it is important to emphasize that numerical values differing by less than three units are not noticeable to the human eye.

Lettuces produced with different fertilizers had statistically different physicochemical characteristics as a function of the applied fertilizer. The lettuce that received the organomineral fertilization had a higher water content in the composition compared to other plants (Table 1). Mineral fertilization associated with organic compost provides a constant supply of various nutrients and improves the physical, chemical and biological properties of the soil, since they act as conditioners and increase the availability of nutrients, aeration and the capacity to retain water and aggregates soil, actions that promote plant growth and development (Elrahman *et al*., 2022). Wang *et al*. (2021), investigating the physical and mechanical properties for automatic harvesting, obtained a water content of 95.73% for hydroponic lettuce. This variation in water content is probably due to the length of time the lettuce plants remain in the final stage, since the longer this period, the greater the accumulation of dry mass and the lower the water content (Ohse *et al*., 2009).

A higher amount of ash was observed in plants whose fertilization was applied with Bokashi (Table 1). Bokashi fertilizer has the important function of stimulating the increase of microorganisms that live in the soil and these microorganisms decompose organic matter making nutrients available to plants (Silva *et al*., 2018).

Fertilization with biofertilizer via soil showed a more pronounced variation in titratable acidity than the other fertilizations. The inclusion of biofertilizer via foliar led to a significant increase in the pH of the leaves in relation to the other fertilizations (Table 1). Lettuce ascorbic acid and total polyphenols increased when they received mineral and organic compost fertilization, respectively.

The application of different fertilizers resulted in statistically significant changes of pH and acidity of lettuce (Table 1). The lettuce fertilized with bokashi, mineral and biofertilizer via leaf, presented an average value higher than the others evaluated, which are within the ideal 5 and 7 range for plant tissues. The pH stability is possibly due to the decreased concentration of organic acids in the vacuoles. Meanwhile, lettuces submitted to treatment with organomineral fertilization presented high content of acidity compared to the other treatments.

Plants with higher content of ascorbic acid were observed when submitted to treatment with mineral fertilizer, different from what was observed when fertilization occurred with biofertilizer via leaves. When the biofertilizer was applied via soil, a significantly increase in ascorbic acid content was observed. The incorporation of biofertilizer into the soil is an alternative that brings benefits for the development of plants, however, each cultivar can respond differently, depending on its need. The producer must take care when performing total replacement of mineral fertilizers by organic ones, since minerals offer readily available nutrients to plants, while organic ones are of gradual release, which may or may not be beneficial (Chiconato *et al*., 2013). Under the conditions of this experiment, lettuce plants responded well to the replacement of mineral fertilizers by organic ones.

About the total extractable polyphenols, there was a significant difference between the fertilization in cultivation of the lettuce (Table 1). The nutrients available in the control treatments and the organic compost to the lettuce provided a higher content of total extractable polyphenols compared to other nutrient sources. Leafy vegetables respond very well to organic fertilization. Therefore, it is possible to infer that the mineralization of organic matter occurred in a timely manner for the supply of nutrients to the plants, considering that the area has been maintained for the organic system for five years (Oliveira *et al*., 2010).

Phenolic compounds refer to an important group of secondary plant metabolites, serving as a defense for plants, as well as modulating plant growth and development (Erb & Kliebenstein, 2020). These compounds, in addition to affecting the sensory and nutritional properties of foods, have greater antioxidant activity than vitamins C and E, with beneficial effects on consumer’s health (Kim *et al*., 2016).

In lettuce, the subgroups of phenolic compounds reported are phenolic acids and flavonoids. The highest concentrations of phenolic compounds are found in the lettuces treated with organic compound and in the lettuces of the control treatment. According to Riga *et al*. (2019), the ‘Batavia’ lettuces grown in the open field accumulated higher amounts of phenolic compounds such as chlorogenic acid, chicory acid, caffeic acid, quercetin-3-O-glycoside and luteolin-7-O-glycoside. Different from what was reported in this study, where levels of phenolic compounds between 43.76 and 57.55 mg GAE/100 g were observed. The content of total extractable polyphenols different from those found in the literature may have occurred due to the compounds being influenced by genetic and edaphoclimatic factors.

The peroxidase activity of lettuces cultivated under different fertilizer sources was not altered (Table 1). The enzyme oxidizing phenols catalyzed by peroxidase enzymes is known to be the main factor influencing browning (Zhang *et al*., 2022). This response plays an important role, forming the first line of defense against oxidative stress (Piñero *et al*., 2022). So, the applied treatments did not cause oxidative stress in lettuce.

Vegetable mineral composition

It can be observed (Table 2) that the treatments exert significant effect on the foliar contents of the nutrients. There was a significant effect of fertilization with biofertilizer via soil on the absorption of P, Mg, S, Cu and Zn in lettuce leaves. The inclusion of the organomineral significantly increased Mn (45.37 mg/kg) and Ca (17.84 g/kg), as well as the plants that were fertilized with organic, mineral and biofertilizer compost via the soil accumulated higher content of Fe (1020.32 mg/kg), N (40.13 g/kg) and K (35.84 g/kg), respectively, considered within the ideal range.

Table 2. Mineral composition of lettuces as a function of different fertilizations. Bananeiras, UFPB, 2017.

Variables	Treatments						
	1	2	3	4	5	6	7
N (g/kg)	30.16g	33.49c	34.11b	32.66d	40.13a	32.02e	31.63f
P (g/kg)	3.88f	4.13e	4.57b	4.53bc	4.27d	4.75a	4.45c
K (g/kg)	28.51f	26.76g	33.98d	35.77b	33.37e	35.53c	35.84a
Ca (g/kg)	14.87e	13.87f	16.44d	17.84a	16.82c	17.17b	16.87c
Mg (g/kg)	5.27e	5.18f	5.92b	5.46d	5.91b	6.36a	5.66c
S (g/kg)	3.47b	4.17ab	4.22ab	4.45ab	4.04ab	5.74a	4.14ab
Cu (mg/kg)	8.72d	7.75g	9.92b	8.03f	8.25e	10.35a	9.62c
Mn (mg/kg)	31.39d	37.32b	28.93f	45.37a	30.24e	32.45c	32.79c
Zn (mg/kg)	134.01f	131.08g	140.86e	149.00c	147.02d	159.34a	154.92b
Fe (mg/kg)	744.02ab	341.29b	1020.32a	516.86ab	816.98ab	756.05ab	699.53ab

*Treatments: 1) Control, 2) Bokashi, 3) Organic compost, 4) Organomineral, 5) Mineral, 6) Biofertilizer via leaf and 7) Biofertilizer via soil. **Means followed by the same letter in the line do not differ statistically from each other by Tukey test (p>0.05).

The mineral composition of the leaves was significantly influenced by the type of fertilizer applied for the production of lettuce in this study. Mineral fertilization significantly increased the nitrogen content in plants, followed by fertilization with organic compost. This result is related to the increase in yield (Figure 2). The same relationship between nitrogen content and yield of lettuce was reported by Sofo *et al*. (2016) in the study of different agronomic and fertilization systems under the polyphenolic profile, antioxidant capacity and mineral composition of lettuce.

Minerals play a crucial role in versatile biological processes during the growth and development phases of plants, where up to 17 essential minerals participate, which are transferred to human nutrition (Waterland *et al*., 2017). A number of dietary macrominerals such as P, K, Ca and Mg are crucial components of the human diet due to their multifaceted nutraceutical properties such as lowering blood pressure and hypertension, promoting bone health and reducing osteoporosis (Kim *et al*., 2016).

Fertilization with biofertilizer via leaf stood out with high levels of P, Mg, S, Cu and Zn compared to other types of fertilizers. However, in Table 2, it is observed that fertilization with organic compost resulted in lettuce with satisfactory mineral composition, except for the Mg and Zn contents, which was one of the lowest contents compared to the treatments applied to lettuce.

Fertilization had no influence on the chlorophyll a, b and total index, as well as on the color parameters. About the physical characteristics, the mineral and organomineral fertilization had a higher yield by the fertilization, reaching a better productive performance of the lettuces.

The application of organic, organomineral, mineral and biofertilizer compost via soil effectively improved the nutritional quality of lettuce in terms of physicochemical characteristics.

The content of P, Mg, S, Cu and Zn increased as a result of fertilization with biofertilizer via leaf, while Mn and Ca increased considerably with fertilization of organomineral.

The results show that the proper use of nutrients provides quality production. Therefore, organomineral and biofertilizer fertilization via soil is recommended for lettuce production under cultivation conditions, in terms of lettuce productivity and quality.

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