Revista ARACÊ
ISSN: 2358-2472

USE OF PLANT EXTRACTS APPLIED VIA SOIL IN THE PRODUCTIVE PERFORMANCE OF ICEBERG LETTUCE

https://doi.org/10.56238/arev7n4-274

Submitted on: 03/26/2025 **Publication date:** 04/26/2025

Isla Vitória de Carvalho Lima[1], Jonathan dos Santos Viana[2], Daniel Carlos Machado[3], Leonidas Leoni Belan[4], Wilson Araújo da Silva[5], Cristiane Matos da Silva[6], André Luiz Pereira da Silva[7] , Anatercia Ferreira Alves[8], Kalyne Pereira Miranda Nascimento[9] and Leanne Teles Pereira[10]

ABSTRACT

Lettuce stands out as a vegetable of great nutritional value, being one of the most consumed by the Brazilian population. There are several obstacles found in the production of this crop, in which the type of soil in which it is cultivated can be highlighted. In view of this scenario, the present study aimed to investigate the effects of plant extracts applied via sandy soil on the productive performance of iceberg lettuce. The study was carried out in a field environment, in the Green Belt, located in Imperatriz, Maranhão. The experiment was designed in randomized blocks, 3 x 4 factorial scheme, in 3 replications. The treatments consisted of a combination of 3 plant extracts and 4 different doses of extracts. The following determinations were made: fresh air, stem and root mass, in addition to the

[1]Undergraduate student in Agronomic Engineering
UEMASUL/Imperatriz Campus
E-mail: virginiabandeira.20200003126@uemasul.edu.br
[2]Dr. in Agronomy (Soil Science)
UEMASUL/Imperatriz Campus
Email: jonathan.viana@uemasul.edu.br
https://orcid.org/0000-0003-4734-9843
[3]Doctorate student in Agronomy (Soil Science)
UNESP/Jaboticabal Campus
E-mail: daniel.c.machado@unesp.br
[4]Dr. in Agronomy (Phytopathology)
UEMASUL/Imperatriz Campus
E-mail: leonidas.belan@uemasul.edu.br
[5]Dr. in Agronomy
UEMASUL/Imperatriz Campus
E-mail: wilson@uemasul.edu.br
[6] Dr. in Environmental Science and Technology
UEMASUL/Imperatriz Campus
Email: cristiane.silva@uemasul.edu.br
[7]Dr. in Agronomy (Soil Science)
UFRA/Castanhal Campus
Email: andreengagronomo@gmail.com
[8] Dr. in Plant Science – Biotechnology and Plant Breeding
UEMASUL/Imperatriz Campus
E-mail: anatercia@yahoo.com.br
[9]Master in Agriculture and Environment
UEMASUL/Imperatriz Campus
Email: kalyneengenheiraag@hotmail.com
[10]Master in Forestry and Environmental Sciences
UEMASUL/CCA
E-mail: leanne.pereira@uemasul.edu.br

Revista ARACÊ
ISSN: 2358-2472

number of leaves, stem diameter and length, and yield. The Mexican sunflower extract stood out, with the doses of 150 g and 225 g 4 $^{L-1}$ of water presenting the best results for aerial fresh mass, number of leaves, stem diameter and weight, in addition to productivity. The vinegar extract showed better performance at the dose of 75 g 4 $^{L-1}$ of water. The castor bean extract had more expressive results at the dose of 75 g 4 $^{L-1}$ of water. It is concluded that the proper management of doses and types of plant extracts can maximize the benefits of these natural products, reducing the dependence on chemical inputs and promoting soil health.

Keywords: *Lactuca sativa* L. Plant extracts. Productivity.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) belongs to the Asteraceae family (Sediyama et al., 2007) originating from wild species, which can still be found in temperate climate regions, in southern Europe and Western Asia, according to Filgueira (2003). Due to its flavor, reduced price for the consumer and nutritional quality, it becomes the main salad consumed by the population (Silva et al., 2013).

Lettuce is pointed out as the most important leafy vegetable in the Brazilian diet, since it is the most consumed vegetable in Brazil and in the world, which ensures an important share of the Brazilian vegetable market for this species, being of great economic and productive importance (Milhomens et al. 2015). The great demand for this vegetable has encouraged the adoption of new cultivation technologies, aiming to increase productivity, reduce production costs and offer the market a better quality product at a more affordable price (Silva et al., 2013).

According to Filgueira (1982), among vegetables, lettuce is one of the richest sources of minerals and cellulose. Lettuce plays a relevant role in the diet and in the promotion of human health, as it is rich in essential vitamins and minerals, it is the most popular among the leaves are consumed. It is recognized for its calming properties, with a high content of vitamins A, B, and C, as well as calcium, phosphorus, potassium, fiber, and other minerals (Shi et al., 2022).

Research in the agricultural sector has been developing increasingly due to the need to provide nutrients to plants, however, taking into account production costs, increased demand in food production and the environmental problems that today's society has been facing (Chiconato et al., 2013).

The search for a safer and more sustainable form of cultivation, the so-called alternative agriculture, brings to discussion the use of less aggressive products with the intention of harmonizing economic growth with social well-being and the preservation of natural resources. These products can be used as fertilizers, antifungals, antimicrobials, resistance inducers, herbicides, nematicides, growth promoters and, mainly, in the control of phytopathogenic organisms Carvalho (2021).

In this sense, the use of plant extracts has proven to be a promising approach, as these extracts contain bioactive compounds that perform essential functions in plants contributing to plant development, including growth regulation, protection against pathogens, and environmental stress. According to Santos et al. (2013), they report that there are several types of plants with insecticidal, fungicide, nematicide and herbicide potential, capable of controlling or avoiding plant and soil contamination through secondary metabolites such as quinones, flavonoids, essential oils, alkaloids, among others.

The effects of plant extracts are due to their phytochemical substances, present in various parts of the plant, such as seeds, leaves and fruits, having properties that have an extensive magnitude in therapeutic treatments against microorganisms and an option for insect control at low cost, without harm to applicators and consumers, coming from renewable sources (Bezerra, 2012). The chemical character of the extract is evidenced by its content in substances of the following groups: alkaloids, saponins, tannins, fatty oils, essential oils, mucilages, antiseptics, flavonoids, organic acid (Carvalho, 2001).

In view of this scenario, the present study aimed to investigate the effects of plant extracts applied via soil on the productive performance of iceberg lettuce. This research aims to contribute to the development of more sustainable and efficient agricultural practices, offering natural alternatives that can improve the productivity and quality of lettuce, as well as promote the conservation of the soil and the agricultural environment as a whole.

METHODOLOGY

CHARACTERIZATION OF THE EXPERIMENTAL AREA

The study was carried out in a field environment, in the Green Belt, located in Imperatriz, Maranhão, Brazil (5º 31' 32' S; 47º 26' 35' W). The climate of the region, according to the Köppen classification, is of the Aw type, tropical with an average annual rainfall of 1,221 mm and an average annual temperature of 27.1 ºC.

The soil of the area where the experiment was conducted is characterized by a predominantly medium to sandy texture, which results in low moisture retention capacity. These characteristics make the soil highly susceptible to erosion. During periods of higher rainfall, points with poor drainage were identified, in which water infiltration is difficult due to the presence of an impermeable layer in the soil profile.

EXPERIMENTAL DESIGN AND TREATMENTS

The experiment was designed in randomized blocks, 3 x 4 factorial scheme, with 12 treatments in 3 replications. The treatments consisted of the combination of 3 plant extracts and 4 different doses of extracts, the first factor being plant extracts of Mexican sunflower

Revista ARACÊ
ISSN: 2358-2472

(*Tithonia diversifolia* L.), vinegar (*Hibiscus sabdariffa* L.) and castor bean (*Ricinus communis* L.) and the second factor, with dose levels of plant extracts: 0; 75 g, 150 g, 225 g of fresh leaves/ 4 L of water.

INSTALLATION AND CONDUCT OF THE EXPERIMENT

The area is historically cultivated with leafy vegetables, quite uniform in relation to soil color and topography, in addition there are no records of soil patches. Soil tillage began with mechanical defragmentation of crop residues, followed by chiseling and leveling of the beds. The seedlings of the lettuce cultivar BRS Leila were obtained from a local producer in the region of Imperatriz – MA, already established with 4 to 5 definitive leaves, ready for transplanting.

The experiment was implemented on 07/15/2024, in an area of 90 m², with 3 beds with dimensions of 1.0 m x 18 m each, totaling 12 plots of 1.5 m2. Each plot was composed of 5 crop rows, adopting spacing of 0.25 m x 0.25 m, with 20 plants per plot. The two crop rows on the sides, as well as 0.25 m at each end of the central rows, were considered as borders, and were not used for the evaluations of the plants in the useful area of the plot.

The soil was turned over for a week and exposed to solar radiation in order to reduce the population of the soil pest. The preparation of the plant extract was carried out with the collection of fresh leaves present on the property. After collection, the material was washed under running water. Subsequently, the leaves were weighed on a scale with a precision of 0.001 g, and after the material was crushed in domestic liquefy, adding the established dosages to a fixed volume of water of 4 L.

The application of the different plant extracts was done by adding the material to the soil without sieving, in order to favor a greater reaction of the final product in the soil. Only after 1 day of the addition of the extract to the soil, the seedlings were transplanted, and after 7 days of transplanting, a mineral fertilization was carried out using the commercial formulation 10 – 10 -10, at the dosage of 47 g $^{\text{plant-1}}$ in a single application.

The crop treatments carried out during crop training consisted of the daily application of 3 mm of water from tripe irrigation, divided twice a day. In addition, manual weeding was carried out weekly, in order to reduce the competition of spontaneous herbs for water and nutrients present in the cultivation area of the main crop, lettuce. During the development of the crop in the field, the presence of pathogens and pests was not noticed, and the use of pesticides was not necessary.

Revista ARACÊ
ISSN: 2358-2472

VARIABLES ANALYZED

In the period of 32 days after transplanting the seedlings, plants were harvested from the experimental area in order to evaluate the agronomic characteristics of the crop. For this, 5 plants were collected from the useful areas of each plot and later evaluated according to the established parameters.

The following determinations were made: fresh mass of the aerial part, stem and root, in addition to the number of leaves, diameter and length of the stem and productivity. The determination of fresh aerial, stem and root mass were carried out by weighing on a semi-analytical scale, at the Weighing Laboratory of UEMASUL/CCA, and this measurement was expressed in g $^{plant-1}$. The number of leaves was measured by counting total leaves per plant. The diameter and length of the stem were determined using a digital caliper, values expressed in mm. And the yield, expressed in kg $^{ha-1}$, was estimated based on the fresh mass of the lettuce plant and extrapolated to hectare.

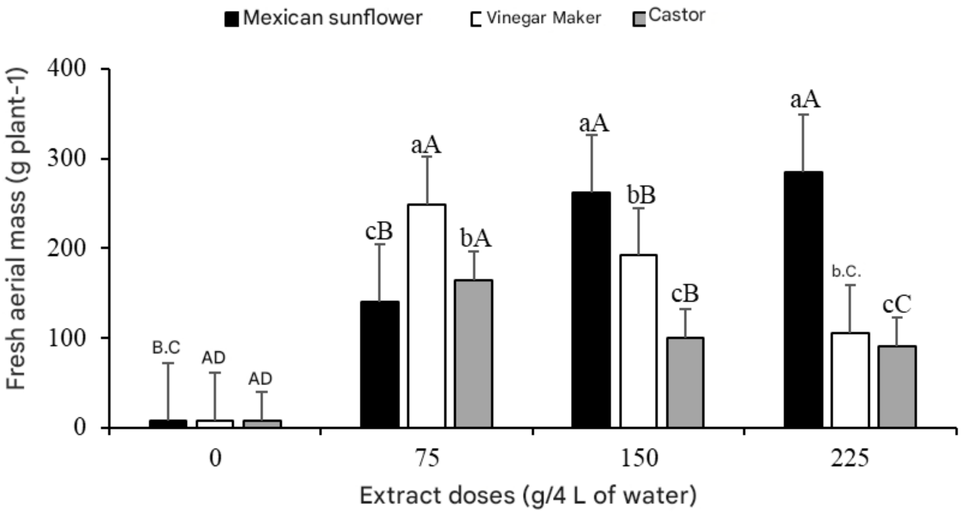
STATISTICAL ANALYSIS

The data obtained were tested for normality of errors (Royston, 1995) and homogeneity of variance (Gastwirth et al., 2009), and were submitted to analysis of variance by the F test ($p<0.05$), and the means were compared by Tukey's test ($p<0.05$), using the Agroestat software, version 1.0.

RESULTS

Figure 1 illustrates the behavior of the lettuce crop as a function of the application of different plant extracts in the crop soil. The results of the study indicated significant differences in the interaction of the factors studied (p-value < 0.01). Specifically for Mexican sunflower extract (*Tithonia diversifolia*), the dosages of 150 and 225 g 4 $^{L-1}$ of water were the most expressive, providing fresh air masses of 262.2 g and 284.9 g $^{plant-1}$, respectively.

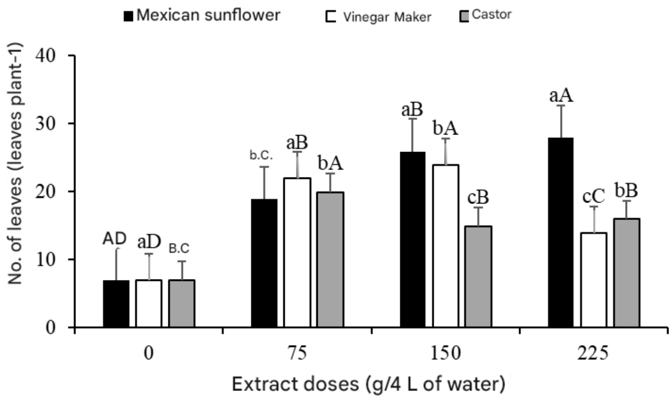
Figure 1. Fresh aerial mass of lettuce submitted to the application of extracts of Mexican Sunflower (*Tithonia diversifolia* L.), Vinaigrette (*Hibiscus sabdariffa* L.) and Castor bean (*Ricinus communis* L.) via soil. Capital letters indicate the comparison of extracts between doses; The lowercase letters indicate the comparison of the extracts within the dose. **significant ($p < 0.01$).



Source: Lima *et al*. (2025)

Figure 2 presents the results related to the amount of leaves developed in lettuce plants submitted to the application of plant extracts in the soil. The experiment revealed significant differences for the interaction of the factors studied (p-value < 0.01).

Figure 2. Number of lettuce leaves submitted to application of extracts of Mexican Sunflower (*Tithonia diversifolia* L.), Vinaigrette (*Hibiscus sabdariffa* L.) and Castor bean (*Ricinus communis* L.) via soil. Capital letters indicate the comparison of the extracts between the doses; The lowercase letters indicate the comparison of the extracts within the dose. **significant ($p < 0.01$).

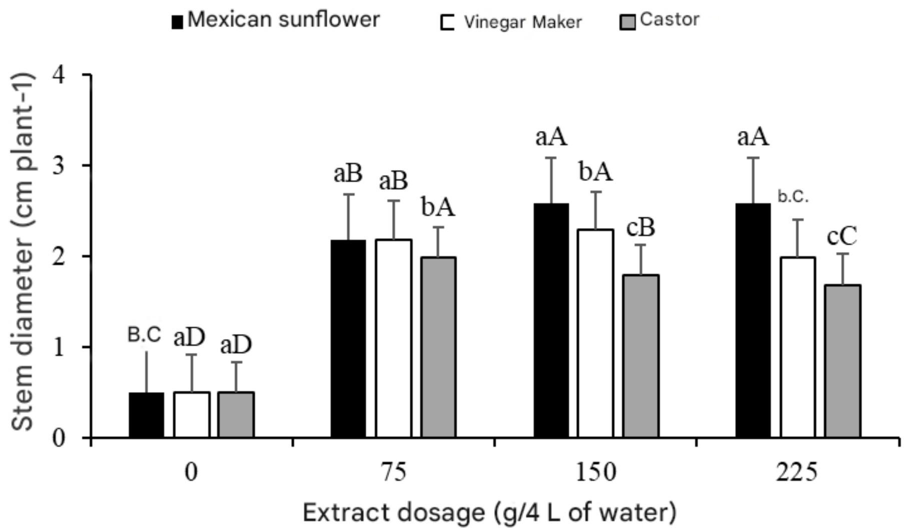


Source: Lima *et al*. (2025)

Figure 3 shows the stem diameter of lettuce plants submitted to the application of plant extracts in the soil. There was a significant interaction for the interaction of the factors, p-value <0.01.

Revista ARACÊ
ISSN: 2358-2472

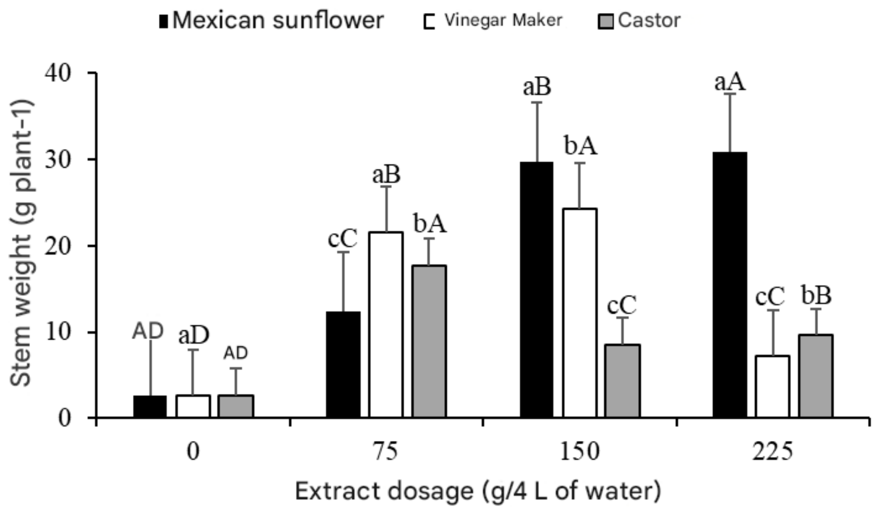
Figure 3. Diameter of the stem of lettuce submitted to the application of extracts of Mexican Sunflower (*Tithonia diversifolia* L.), Vinaigrette (*Hibiscus sabdariffa* L.) and Castor bean (*Ricinus communis* L.) via soil. Capital letters indicate the comparison of the extracts between the doses; The lowercase letters indicate the comparison of the extracts within the dose. **significant (p < 0.01).



Source: Lima *et al*. (2025)

Figure 4 shows the stem weight of lettuce plants submitted to the application of plant extracts in the soil. A significant difference was observed in relation to plant factors, doses and species, with a p-value < 0.01.

Figure 4. Weight of the lettuce stem submitted to the application of extracts of Mexican Sunflower (*Tithonia diversifolia* L.), Vinaigrette (*Hibiscus sabdariffa* L.) and Castor bean (*Ricinus communis* L.) via soil. Capital letters indicate the comparison of the extracts between the doses; The lowercase letters indicate the comparison of the extracts within the dose. **significant (p < 0.01).



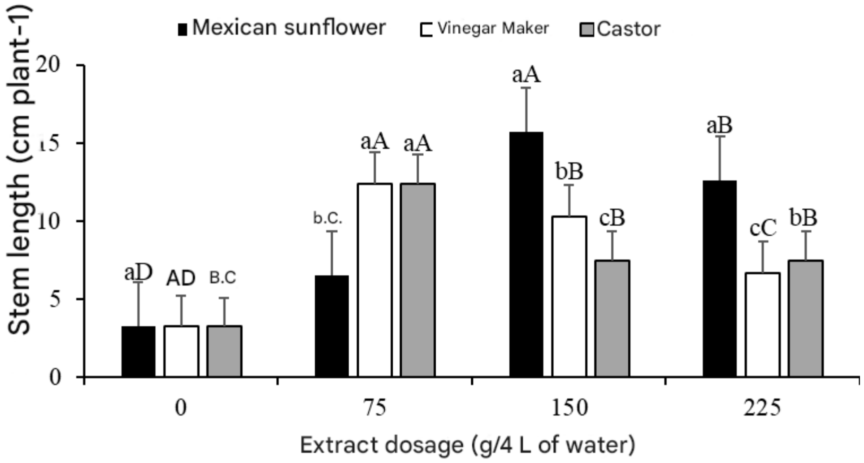
Source: Lima *et al*. (2025)

Revista ARACÊ
ISSN: 2358-2472

Figure 5 shows the stem length of lettuce plants submitted to the application of plant extracts in the soil. A significant difference was observed in relation to plant factors, doses and species, with a p-value < 0.01.

According to Figure 5, the Mexican sunflower extract (*Tithonia diversifolia*) showed a significant difference in relation to the doses and the other treatments. The highest mean stem length was observed at the dose of 150 g 4 $^{L-1}$ of water, with 15.69 cm, while the lowest mean occurred at the dose of 75 g 4 $^{L-1}$ of water, with 6.56 cm, when compared to the control group (control).

Figure 5. Length of the lettuce stem submitted to the application of extracts of Mexican Sunflower (*Tithonia diversifolia* L.), Vinaigrette (*Hibiscus sabdariffa* L.) and Castor bean (*Ricinus communis* L.) via soil. Capital letters indicate the comparison of extracts between doses; The lowercase letters indicate the comparison of the extracts within the dose. **significant (p < 0.01).

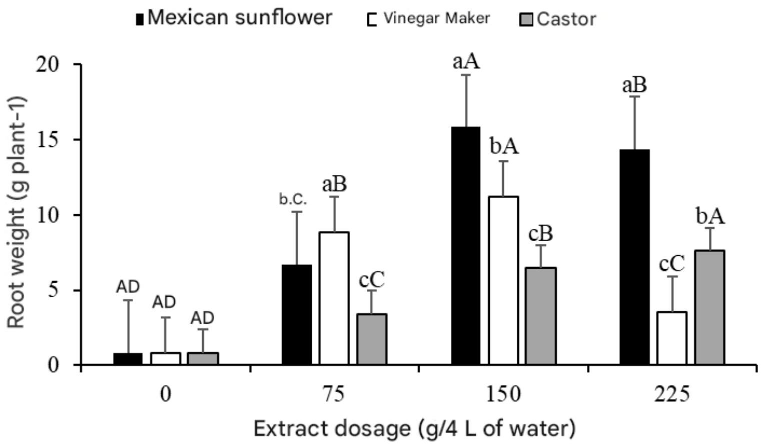


Source: Lima *et al*. (2025)

Figure 6 refers to the root weight of lettuce plants submitted to the application of plant extracts via soil. A significant difference was observed between both the doses and the treatments studied (p < 0.01).

Revista ARACÊ
ISSN: 2358-2472

Figure 6. Root weight of lettuce submitted to application of extracts of Mexican Sunflower (*Tithonia diversifolia* L.), Vinaigrette (*Hibiscus sabdariffa* L.) and Castor bean (*Ricinus communis* L.) via soil. Capital letters indicate the comparison of the extracts between the doses; The lowercase letters indicate the comparison of the extracts within the dose. **significant (p < 0.01).

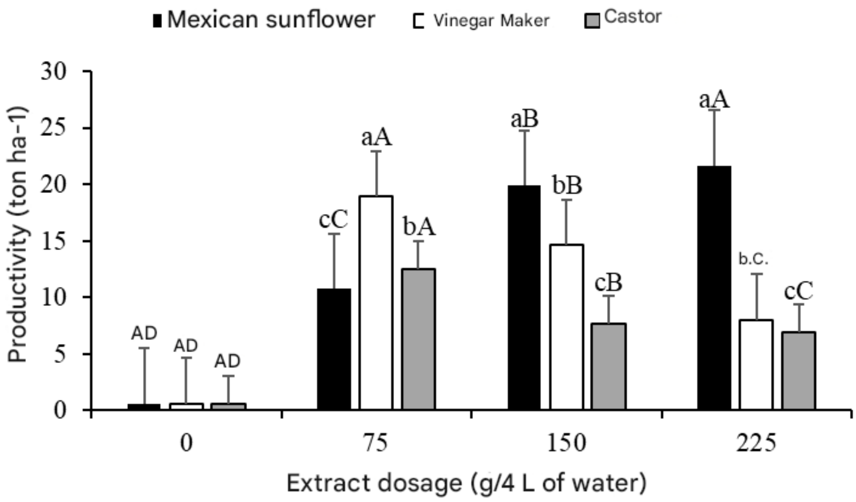


Source: Lima *et al*. (2025)

The Mexican sunflower extract (*Tithonia diversifolia*) showed the highest root weight compared to the other treatments, with an average of 15.83 g at the dose of 150 g 4 $^{L-1}$ of water and 14.39 g at the dose of 225 g 4 $^{L-1}$ of water.

Figure 7 shows the yield of lettuce submitted to application of plant extracts via soil. Regarding productivity, it is notorious that there was a significant difference for the variables studied (p<0.01).

Figure 7. Yield of lettuce submitted to the application of extracts of Mexican Sunflower (*Tithonia diversifolia* L.), Vinaigrette (*Hibiscus sabdariffa* L.) and Castor bean (*Ricinus communis* L.) via soil. Capital letters indicate the comparison of the extracts between the doses; The lowercase letters indicate the comparison of the extracts within the dose. **significant (p < 0.01).



Source: Lima *et al*. (2025)

Revista ARACÊ
ISSN: 2358-2472

The highest yield was observed in the treatment with sunflower extract, followed by vinegar extract and, finally, castor bean extract (Figure 7). Sunflower extract provided the highest yield, with 21.69 ton ha-1 at the dose of 225 g 4 $^{L-1}$ of water, due to the availability of sufficient nutrients for lettuce development.

DISCUSSION

With the increase in the doses of Mexican sunflower extract, there was a progressive increase in the aerial fresh mass of lettuce plants (Figure 1). This behavior can be attributed to the high concentration of nitrogen present in the composition of the Mexican sunflower, an essential nutrient for leaf development. Previous studies have highlighted the ability of *T. diversifolia to* accumulate high amounts of nitrogen and other minerals in its leaves (Ruiz et al., 2009; García, 2017), which reinforces its effectiveness as a biofertilizer in agricultural cultivation.

Research indicates that this species has significant concentrations of nutrients, especially nitrogen (N) and phosphorus (P), as well as a high carbon/nitrogen (C/N) ratio (Almeida et al., 2009). These characteristics make the plant an excellent option for fertilization, being used as a plant extract to promote plant development, thus allowing the increase of the fresh mass of the aerial part. Therefore, the combination of essential nutrients, bioactive compounds, biostimulant effect and improvement of soil conditions favors the increase of the aerial fresh mass of lettuce. This is because *Tithonia diversifolia* acts as a fast-release organic fertilizer and growth promoter, maximizing the plant's physiological and biochemical processes.

In relation to the vinegar extract (*Hibiscus sabdariffa*), a different behavior is observed from that observed with the Mexican sunflower extract (Figure 1). At the dose of 75 g 4 $^{L-1}$ of water, the performance was superior, resulting in an aerial fresh mass of 249.13 g. However, at the doses of 150 g 4 $^{L-1}$ of water and 225 g 4 $^{L-1}$ of water, there was a sharp decline in performance, with values reduced to 192.63 g and 106.27 g of aerial fresh mass, respectively.

This decline in the weight of the fresh air mass of lettuce can be attributed to the increase in the concentration of vinegar extracts, which contain allelopathic compounds. These compounds are known to induce chemical, oxidative, and osmotic stress, interfering with plant metabolism and creating harsh soil conditions. Although they contribute to increased nutrient availability and growth efficiency at moderate concentrations, excessive doses become toxic, harming plant development.

Studies by Hoffmann et al*.* (2007) corroborate these findings, demonstrating that extracts from species such as oleander (*Nerium oleander*) and me-nobody-can (*Dieffenbachia seguine*) cause reductions in the fresh and dry biomass of lettuce and picão-preto (*Bidens pilosa) seedlings*. These reductions were proportional to the increase in the concentration of the extracts, evidencing the toxic effects of high doses.

A similar behavior was observed in the treatment with castor bean extract (*Ricinus communis*), whose best performance occurred at the dose of 75 g 4 $^{L-1}$ of water, resulting in 165.05 g of fresh air mass. With the increase in doses, there was a progressive reduction in the aerial fresh mass of lettuce plants submitted to this treatment (Figure 1).

This decline is attributed to the possible allelopathic effect of castor bean extract on lettuce plants. At higher concentrations, the compounds present in the extract may have negatively impacted the development of both the shoot and the root system of the plants. This effect occurs due to interference with plant metabolism, potentially caused by secondary compounds that limit growth and physiological efficiency.

According to Dela Pena et al. (2013), the aqueous extract of daisy can be used as an alternative to organic foliar fertilizer, being effective to increase the productivity of leafy vegetables in the Philippines. In addition, studies indicated that the biomass of *T. diversifolia* had positive effects on the development of the aerial parts and roots of the bean plant. This benefit is associated with the application of mulch, which contributed to the significant addition of phosphorus (P) and potassium (K) to the soil, promoting greater absorption of these nutrients by plants (Mustonen et al., 2014).

For the vinegar extract (*Hibiscus sabdariffa*), the best response was observed at the dose of 150 g 4 $^{L-1}$ of water, with an average of 23.98 leaves per plant. On the other hand, the lowest amount of leaves was recorded at the dose of 225 g 4 $^{L-1}$ of water, with an average of 13.98 leaves.

Regarding the variable number of leaves, the treatment with Mexican sunflower (*Tithonia diversifolia*) stood out. As the doses were increased, the plants submitted to this treatment showed superior responses, reaching an average of 27.96 leaves at a dose of 225 g 4 $^{L-1}$ of water.

Regarding castor bean extract (*Ricinus communis*), lettuce plants submitted to a dose of 75 g 4 $^{L-1}$ of water exhibited the highest average number of leaves, with 19.96

Revista ARACÊ
ISSN: 2358-2472

leaves per plant. However, there was a gradual reduction in the number of leaves as the doses were increased.

The decrease in the number of leaves in both treatments is explained by the presence of chemical compounds in high doses, with allelopathic properties in plant extracts, such as flavonoids. These compounds are known to interfere with plant growth and development, directly impacting the process of cell division (Hess, 1987).

It was observed that lettuce plants treated with sunflower extract (*Tithonia diversifolia*) had the largest stem diameters at doses of 150 and 225 g 4 $^{L-1}$ of water, with no significant differences between these doses, with an average value of 2.59 cm. When comparing these results with those obtained for the other extracts at each dose, a significant difference was found between the treatments. Sunflower extract stood out as the most effective, followed by vinegar extract (*Hibiscus sabdariffa*), while castor bean extract (*Ricinus communis*) had the lowest mean stem diameter values.

Plants treated with Mexican sunflower extract (*Tithonia diversifolia*) showed an increasing response as doses of the extract increased. The lowest stem weight was observed at the dose of 75 g 4 $^{L-1}$ of water, with 12.37 g, while the highest weight was recorded at the dose of 255 g 4 $^{L-1}$ of water, with 30.8 g $^{plant-1}$.

The results obtained in this study are consistent with those of Oyerinde et al. (2009), who investigated the allelopathic effects of *T. diversifolia* on germination, growth and chlorophyll content of maize. Its results indicated that the aqueous extract of fresh shoots of *T. diversifolia* significantly promoted the increase of fresh weight, dry weight of the leaf area, and root weight, in addition to stimulating the growth of corn seedlings.

The plants treated with the vinegar extract (*Hibiscus sabdariffa*) showed the highest stem weights at the doses of 75 and 150 g 4 $^{L-1}$ of water, with averages of 21.61 g and 24.13 g, respectively. On the other hand, the lowest stem weight values were observed in plants submitted to the dose of 225 g 4 $^{L-1}$ of water, with 7.17 g $^{plant-1}$.

On the other hand, castor bean extract (*Ricinus communis*) resulted in the lowest stem weight values when compared to the other extracts. The plants treated with the dose of 75 g 4 $^{L-1}$ of water showed the highest stem weight, with an average of 17.69 g, while the doses of 150 and 225 g 4 $^{L-1}$ of water showed the lowest values.

Similar results were found by Borges et al. (2007), who observed the decrease in the growth of the shoot and roots of lettuce plants as the concentration of dry castor bean leaf extract increased. Additional research indicated that the application of dried castor bean

Revista ARACÊ
ISSN: 2358-2472

leaf extract reduced both germination and development of lettuce plants Borges et al. (2011).

In a research carried out by Ajayi et al. (2017) with cowpea (*Vigna unguiculata* L.), it was observed that the extracts of *Tithonia diversifolia* promoted the development of plants throughout the cycle, from germination to the maturity phase, also caused the reduction of the density of spontaneous plants such as *Bidens pilosa* and *Brachiaria brizantha*. Ilori et al. (2007) also observed that *T. diversifolia* may favor the development of growth intervals in more mature plants, after the initial phase of establishment of *Oryza sativa seedlings*.

The castor bean extract (*Ricinus communis*) showed better performance at the dose of 75 g 4 $^{L-1}$ of water, with an average stem length of 12.39 cm. In the doses of 150 and 225 g 4 $^{L-1}$ of water, no significant difference was observed between the doses, and both presented lower values compared to the dose of 75 g 4 $^{L-1}$ of water. Similar results were found by Silva et al. (2011), who studied the extract of dried castor bean leaves. The authors reported that the extract caused significant interference with seedling development, especially by inhibiting root growth, and that this influence was more pronounced at the higher concentrations of the extract.

The application of Mexican sunflower extract favored a better absorption of nutrients by the root system, resulting in more vigorous roots. The bioactive compounds present in the extract stimulated root growth, promoting root expansion and, consequently, increasing weight and root mass.

The vinegar extract (*Hibiscus sabdariffa*) had the highest average root weight at the dose of 150 g 4 $^{L-1}$ of water, with 11.21 g, and the lowest weight at the dose of g 4 $^{L-1}$ of water, with 3.54 g. Between the doses of 150 and 225 g 4 $^{L-1}$ of water, A marked decrease in root weight was observed. This behavior can be explained by the fact that roots are generally more sensitive to substances present in extracts, compared to other seedling structures (Chon et al., 2000). This occurs due to the direct and prolonged contact of the roots with the allelochemicals present in the extract, while the other structures of the seedlings are in less continuous contact. In addition, this response may be a reflection of the distinct physiology between different parts of the plant (Aquila et al., 2000).

Lettuces submitted to castor bean extract (*Ricinus communis*) showed an increase in root weight as the doses were increased, reaching a weight of 7.59 g at a dose of 225 g 4 $^{L-1}$ of water (Figure 6). Castor bean extract contains bioactive compounds, such as alkaloids, terpenes, and ricinin, which have allelopathic or biostimulant properties. These compounds

Revista ARACÊ
ISSN: 2358-2472

can act selectively, affecting certain plants or specific parts, but without significantly interfering with root development. Even with the increase in the doses of castor bean extract, it was observed that the roots developed more vigorously at the higher dose of the extract, indicating a positive response to these compounds.

In Ghana, green manure with *T. diversifolia* is widely recommended for vegetables (Partey et al., 2011), and in Cameroon, the combination of T*. diversifolia* biomass with NPK increased cassava production by 45% compared to treatment without inputs (Bilong et al., 2017). Studies in Kenya have also shown that the biomass of *T. diversifolia* can result in maize yield similar to that of fertilization with N, P and NPK, suggesting its use as an alternative source of fertilizer (Achieng et al., 2010).

According to Dayoolagbende et al. (2019), the combination of nitrogen fertilizer (urea) with *Tithonia diversifolia* mulch significantly increased the levels of nitrogen, organic matter, total porosity, moisture content, cation exchange capacity, and soil infiltration rate. These effects resulted in an increase in corn yield and an improvement in the physicochemical properties of the soil.

The vinegar extract showed the highest productivity at the dose of 75 g 4 $^{L-1}$ of water, with 18.96 ton $^{ha-1}$, while the castor bean extract also obtained the highest productivity at the dose of 75 g 4 $^{L-1}$ of water, with 12.56 ton $^{ha-1}$. However, lettuces treated with vinegar and castor bean extracts showed lower development compared to those treated with Mexican sunflower extract. Doses higher than 75 g 4 $^{L-1}$ caused allelopathic effects, reducing yield due to the difficulty of the plants to develop with the increase in the concentrations of the compounds. According to Rodrigues et al. (1999), these effects can be attributed to allelopathic compounds, which inhibit germination and growth by interfering with cell division, membrane permeability, and enzyme activation, impairing final productivity.

CONCLUSION

It is concluded that the application of plant extracts via soil proved to be an effective strategy to enhance the productive performance of iceberg lettuce, promoting a better development compared to the control treatment.

The Mexican sunflower extract (*Tithonia diversifolia*) stood out, with the doses of 150 g and 225 g 4 $^{L-1}$ of water presenting the best results for the aerial fresh mass, number of

Revista ARACÊ
ISSN: 2358-2472

leaves, diameter and weight of the stem, in addition to the yield, which reached 21.69 ton $^{ha-1}$ at the dose of 225 g 4 $^{L-1}$.

The vinegar extract (*Hibiscus sabdariffa*) showed better performance at the dose of 75 g 4 $^{L-1}$ of water, providing better growth and yield of lettuce, the increase in the concentrations of the stratum doses resulted in harmful allelopathic effects, reducing the productive efficiency. Similarly, castor bean extract (*Ricinus communis*) had more expressive results at the dose of 75 g 4 $^{L-1}$ of water, achieving better lettuce responses to the evaluated indexes, reaching a yield of 12.56 ton $^{ha-1}$.

This study shows that the proper management of doses and types of plant extracts can maximize the benefits of these natural products, reducing dependence on chemical inputs and promoting soil health.

ACKNOWLEDGMENTS

We thank the State University of the Tocantina Region of Maranhão (UEMASUL) of the Center for Agrarian Sciences - CCA for the infrastructure that made it possible to carry out the evaluations of the experiment. We also express our deep gratitude to Mr. Jesusmar, for the partnership established in the implementation and conduct of the experiment, located on his property in the Green Belt of Imperatriz – MA.

Revista ARACÊ
ISSN: 2358-2472

REFERENCES

1. Achieng, J. O., Ouma, G., Odhiambo, G., & Muyekho, F. (2010). Effect of Tithonia diversifolia (Hemsley) and inorganic fertilizers on maize yield on Alfisols and Ultisols of Western Kenya. Agriculture and Biology Journal of North America, 1(5), 740–747.

2. Ajayi, O. A., Akinola, M. O., Rasheed, O., & Awodoyin, R. O. (2017). Allelopathic potentials of aqueous extracts of Tithonia diversifolia (Hemsley) A. Gray in biological control of weeds in cowpea cropping system. International植物 Journal of Agriculture and Economic Development, 5(1), 11–28.

3. Aquila, M. E. A. (2000). Efeito alelopático de Ilex paraguariensis A. St.-Hil. na germinação e crescimento inicial de Lactuca sativa L. Iheringia Série Botânica, 53(23), 51–66.

4. Almeida, A. P., Xavier, A. S., Arruda, L. A. M., Barros, A. P. O., Alves, A. O., & Lopes, V. (2009). Influência do tipo de estaca na propagação de Tithonia diversifolia (Hemsley) Gray. Environmental Research, 3, 39–46.

5. Bezerra, N. A. (2012). Avaliação da atividade antimicrobiana de Eugenia uniflora L. [Undergraduate thesis, Universidade Estadual da Paraíba]. Campina Grande, Brazil.

6. Bilong, E. G., et al. (2017). Effets des biomasses vertes de Tithonia diversifolia et des engrais minéraux sur la croissance, le développement et le rendement du manioc (Manihot esculenta Crantz) en zone forestière du Cameroun. International Journal of Biological and Chemical Sciences, 11(4), 1716–1726. https://doi.org/10.4314/ijbcs.v11i4.25

7. Borges, C. S., Cuchiara, C. C., Silva, S. D. A., & Bobrowski, V. L. (2011). Efeitos citotóxicos e alelopáticos de extratos aquosos de Ricinus communis utilizando diferentes bioindicadores. Tecnologia & Ciência Agropecuária, 5(3), 15–20.

8. Borges, C. S., Cuchiara, C. C., Maculan, K., Sopezku, M. de S., & Bobrowski, V. L. (2007). Alelopatia do extrato de folhas secas de mamona (Ricinus communis L.). Revista Brasileira de Biociências, 5(Suppl. 2), 747–749.

9. Carvalho, J. V. (2001). Fitoterápicos do Cerrado [Undergraduate thesis, Centro Universitário de Brasília]. Brasília, Brazil.

10. Carvalho, R. S. (2021). Extratos vegetais na agricultura e no tratamento de sementes [Master's dissertation, Universidade Federal de São Carlos]. Araras, Brazil.

11. Chiconato, D. A., Simoni, F., Galbiatti, J. A., Franco, C. F., & Caramelo, A. D. (2013). Resposta da alface à aplicação de biofertilizante sob dois níveis de irrigação. Bioscience Journal, 29(2), 392–399.

12. Chon, S. U., Coutts, J. H., & Nelson, C. J. (2000). Effects of light, growth media, and seedling orientation on bioassays of alfalfa autotoxicity. Agronomy Journal, 92(4), 715–720. https://doi.org/10.2134/agronj2000.924715x

Revista ARACÊ
ISSN: 2358-2472

13. Dayo-Olagbende, G. O., Ewulo, B. S., & Akingbola, O. O. (2019). Combined effects of Tithonia mulch and urea fertilizer on soil physico-chemical properties and maize performance. Journal of Sustainable Technology, 10(1), 86–93.

14. Dela Peña, C., Bartolome, D., & Banwa, T. (2013). The potential of Tithonia diversifolia (Wild Sunflower) as organic foliar fertilizer. European Scientific Journal, 4, 465–468.

15. Filgueira, F. A. R. (1982). Manual de olericultura (2nd ed.). São Paulo, Brazil: Agronômica Ceres.

16. Filgueira, F. A. R. (2002). Novo manual de olericultura: Agrotecnologia moderna na produção e comercialização de hortaliças (2nd ed.). Viçosa, Brazil: UFV.

17. García, I. R. (2017). Potencialidades de Tithonia diversifolia (Hemsl.) Gray en la alimentación animal. Livestock Research for Rural Development, 29(4).

18. Hess, F. D. (1987). Herbicide effects on the cell cycle of meristematic plant cells. Reviews of Weed Science, 3, 183–203.

19. Hoffmann, C. E. F., Neves, L. A. S. das, Bastos, C. F., & Wallau, G. L. da. (2007). Atividade alelopática de Nerium oleander L. e Dieffenbachia picta Schott em sementes de Lactuca sativa L. e Bidens pilosa L. Revista de Ciências Agroveterinárias, 6(1), 11–21.

20. Ilori, O. J., Otusanya, O. O., & Adelusi, A. A. (2007). Phytotoxic effects of Tithonia diversifolia on germination and growth of Oryza sativa. Research Journal of Botany, 2(1), 23–32.

21. Milhomens, K. K. B., Nascimento, I. R. do, Tavares, R. de C., Ferreira, T. A., & Souza, M. E. (2015). Avaliação de características agronômicas de cultivares de alface sob diferentes doses de nitrogênio. Revista Verde de Agroecologia e Desenvolvimento Sustentável, 10(1), 143–148. https://doi.org/10.18378/rvads.v10i1.3502

22. Mustonen, P. S., Oelbermann, M., & Kass, D. C. L. (2014). Response of the common bean (Phaseolus vulgaris L.) to Tithonia diversifolia (Hamsl.) Gray biomass retention or removal in a slash and mulch agroforestry system. Agroforestry Systems, 88(1), 1–10. https://doi.org/10.1007/s10457-013-9651-6

23. Oyerinde, R. O., Otusanya, O. O., & Akpor, O. B. (2009). Allelopathic effect of Tithonia diversifolia on germination, growth and chlorophyll content of maize (Zea mays L.). Scientific Research and Essay, 4(12), 1553–1558.

24. Partey, S. T., et al. (2011). Decomposition and nutrient release patterns of the leaf biomass of the wild sunflower (Tithonia diversifolia): A comparative study with four leguminous agroforestry species. Agroforestry Systems, 81(2), 123–134. https://doi.org/10.1007/s10457-010-9360-3

Revista ARACÊ
ISSN: 2358-2472

25. Rodrigues, F. C. M. P., & Lopes, B. M. (1999). Potencial alelopático de Mimosa caesalpiniifolia Benth sobre sementes de Tabebuia alba (Cham.) Sandw. Série Técnica Floresta e Ambiente, 8(1), 130–136.

26. Ruíz, T. E., Febles, G., Díaz, H., & Achang, G. (2009). Effect of the section and the planting method of the stem on the establishment of Tithonia diversifolia. Cuban Journal of Agricultural Science, 43(1), 89–91.

27. Santos, P. L., Prando, M. B., Morando, R., Pereira, G. V. N., & Kronka, A. Z. (2013). Utilização de extratos vegetais em proteção de plantas. Enciclopédia Biosfera, 9(17), 2562–2576.

28. Sediyama, M. A. N., Ribeiro, J. M. O., & Pedrosa, M. W. (2007). Alface (Lactuca sativa L.). In T. J. de P. Júnior & M. Venzon (Eds.), 101 Culturas: Manual de Tecnologias Agrícolas (pp. 1–800). Belo Horizonte, Brazil: EPAMIG.

29. Shi, M., Gu, J., Wu, H., Rauf, A., Emran, T. B., Khan, Z., Mitra, S., Aljohani, A. S. M., Alhumaydhi, F. A., & Al-Awthan, Y. S. (2022). Phytochemicals, nutrition, metabolism, bioavailability, and health benefits in lettuce—A comprehensive review. Antioxidants, 11(6), 1158. https://doi.org/10.3390/antiox11061158

30. Silva, L. B., Nodari, I. D. E., Júnior, S. S., Dias, L. D. E., & Neves, J. F. (2013). Produção de alface sob diferentes sistemas de cultivo. Enciclopédia Biosfera, 9(16), 1742.

31. Silva, R. R., Silva, M. J. S., Diniz, N. B., & Coelho, M. J. A. (2011). Efeito alelopático de extrato seco de mamona (Ricinus communis L.) no desenvolvimento inicial de feijão (Vigna unguiculata (L.) Walp.). Cadernos de Agroecologia, 6(2).