Revista ARACÊ
ISSN: 2358-2472

POTENTIAL OF MEXICAN SUNFLOWER PLANT EXTRACT AS A SUSTAINABLE ALTERNATIVE IN CURLY LETTUCE PRODUCTION

https://doi.org/10.56238/arev7n2-048

Submitted on: 01/05/2025 **Publication date:** 02/05/2025

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ABSTRACT
Lettuce is one of the most cultivated and consumed vegetables nationally, recognized for its short growing cycle, high nutritional value, and significant economic relevance. However, the production of this crop often resorts to the use of chemical inputs, which can result in adverse environmental impacts and increased production costs. Thus, the objective of this present study was to evaluate the productive behavior of curly lettuce submitted to increasing doses of Mexican sunflower plant extract. The experiment was carried out in the Green Belt of Imperatriz, adopting a randomized block design, with treatments, which consisted of increasing doses of Mexican sunflower extract, as follows: 0 g; 50 g; 100 g; 150 g; 200 g and 250 g 4 L-1 in 4 replications. Significant effects of increasing the doses of Mexican sunflower extracts were observed on the characteristics head diameter, plant height and aerial fresh mass. The dose of 50 and 100 g 4 L-1 was more expressive in these behaviors. It is concluded that the moderate application of plant extract based on Mexican sunflower leaves and stalks reduced the dependence on chemical fertilizers, standing out as a sustainable and economically viable alternative for agriculture.

Keywords: Lactuca Sativa L. Green Manure. Tithonia diversifolia L. Sustainable Agriculture. Biofertilizer.

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ISSN: 2358-2472

INTRODUCTION

The search for sustainable and efficient agricultural practices has driven the use of green manure in several crops (FAO, 2019). In this context, the Mexican sunflower (*Tithonia diversifolia* L.) stands out as a promising alternative due to its high nutrient content and soil enrichment capacity.

Tithonia diversifolia L. is a plant widely recognized for its potential as a green manure, due to its rapid growth, high biomass production, and significant content of essential nutrients to the soil, such as nitrogen, phosphorus, and potassium. Originally from Central America, this plant has been exploited in sustainable agricultural systems as a natural alternative to improve soil fertility and reduce the use of chemical fertilizers.

This species has an excellent capacity for regrowth, even when subjected to cuts close to the ground. In the first 60 days after regrowth, its growth is relatively slow, with a rate of 1.0 cm.day-1. However, between 60 and 100 days, this rate increases to 2.5 cm.day-1, reaching 3.5 cm.day-1 after 100 days (Silva et al., 2018). Regarding productivity, the species can produce between 30 and 70 ton.ha-1 of green mass and 3.9 to 9.0 ton.ha-1 of dry mass, with these variations depending on several factors (Reis et al., 2015).

The accumulation of dry and green mass in vegetables is related to the advancement through the different phenological stages, a process that occurs due to cell multiplication and expansion. Gualberto et al. (2011) reported yields of 3.5; 7.6 and 16.0 ton ha-1 of dry mass in the pre-flowering, flowering and post-flowering stages, respectively, and these stages corresponded to 103, 137 and 544 days of regrowth. Calsavara et al. (2015) observed yields of 8.1 and 5.6 ton ha-1 of dry mass at the rubberizing and pre-flowering stages, respectively. Silva et al. (2018) found yields ranging from 14 to 28 ton/ha of dry mass for 100 and 145 days of regrowth, respectively.

In addition, Padovan, Siqueira and Guimarães (2021) highlight that the use of green manures, such as the Mexican sunflower, has been shown to be effective in improving soil fertility, increasing the efficiency of nutrient use and promoting sustainable agricultural practices, especially in vegetable crops.

The use of Mexican sunflower in agriculture is particularly important in regions where soil quality is low or where the cost of chemical inputs represents an economic challenge for producers. Rodrigues and Gama-Rodrigues (2018) highlight that the Mexican sunflower is a viable alternative for green manure due to its high biomass production and high content of essential nutrients, contributing significantly to the improvement of soil

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quality in sustainable agricultural systems. Its ability to quickly decompose and release nutrients favors crop development, in addition to promoting ecological benefits, such as reducing erosion and increasing organic matter in the soil.

Teixeira and Silva (2020) point out that the use of Mexican sunflower as green manure is a promising practice for agricultural systems, promoting not only the increase in soil fertility, but also the reduction of costs with chemical fertilizers, making production more accessible and environmentally sustainable.

Understanding the effects of different dosages of this fertilization on curly lettuce (*Lactuca sativa* L.) can provide valuable data to maximize productivity and minimize costs, benefiting producers and promoting more ecological practices.

In this context, the objective of this study was to evaluate the effects of green manure dosages with Mexican sunflower (*Tithonia diversifolia*) on the development and yield of curly lettuce (*Lactuca sativa L.)* cultivated in Imperatriz - MA.

METHODOLOGY

CHARACTERIZATION OF THE EXPERIMENTAL AREA

The study was carried out in a field environment at Hortícola Sr. Massao - Cinturão Verde, located in Imperatriz, Maranhão, Brazil (5º 31' 32' S; 47º 26' 35' W). The climate of the region, according to Koppen's 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 experimental area has a texture ranging from medium to sandy, a condition that limits its water retention capacity and contributes to low levels of organic matter. These properties increase the vulnerability of the soil to water erosion.

EXPERIMENTAL DESIGN AND TREATMENTS

The experiment was designed in randomized blocks, with 6 treatments in 4 replications. The treatments consisted of 5 dosages of the plant extract of the Mexican sunflower (*Tithonia diversifolia* L.), as follows: T0: Control (No application of sunflower extract); T1: 50 g. 4 $^{L-1}$; T2: 100 g. 4 $^{L-1}$; T3: 150 g. 4 $^{L-1}$; T4: 200 g. 4 $^{L-1}$ and T5: 250 g. 4 $^{L-1}$.

INSTALLATION AND CONDUCT OF THE EXPERIMENT

The experimental area has a history of growing leafy vegetables, characterized by uniformity in terms of soil color and topography, without the presence of evident spots or

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irregularities in the soil. The seedlings of the lettuce cultivar BRS Leila were obtained directly from the producer responsible for the experimental area, presenting 4 to 5 definitive leaves, corresponding to the ideal phenological stage for transplanting.

The experiment was implemented on 11/15/2024, in an area of 58.5 m², with 4 beds with dimensions of 1.0 m x 9 m each, totaling 6 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.

Manual weeding was carried out, and cleaning of the area with the use of hoes and rakes. The soil was turned over for one week and exposed to solar radiation in order to reduce the population of the soil pest, nematode. The preparation of the plant extract was carried out with the collection of fresh Mexican sunflower leaves present near the location of the experiment. 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 dosages of Mexican sunflower extract was carried out directly on the soil, without the sieving process, with the objective of maximizing the interaction of the material with the soil and enhancing the reactions of the product in the edaphic environment. 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 56 g $^{\text{plant-1}}$ in a single application.

The cultural treatments carried out during the lettuce crop were applied 4 mm of water daily by means of a "tripe" irrigation system, divided into two applications throughout the day. During the lettuce cycle in the field, no incidences of pests or pathogens were observed, which dispensed with the need to use pesticides.

VARIABLES ANALYZED

In the period of 34 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.

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The following determinations were made: head diameter, aerial fresh mass, stem and root, in addition to the number of leaves, plant height, stem diameter, root length and productivity. The diameter of the head was performed "*in loco*", by means of measurement using a graduated ruler. 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 height of plants determined by the use of a graduated ruler, values expressed in cm. The diameter of the stem was determined using a digital caliper, values expressed in mm. Root length, through the use of a graduated ruler. 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 polynomial regression analysis performed for doses of Mexican sunflower extracts when significant, using the Agroestat software, version 1.0.

RESULTS

By 2nd degree polynomial regression, an increase of 17.96% and 11.66% was observed for curly lettuce head diameter at the dose of 50 g.4 L^{-1}, compared to the extreme doses, of 0 and 250 g.4 L^{-1}, respectively.

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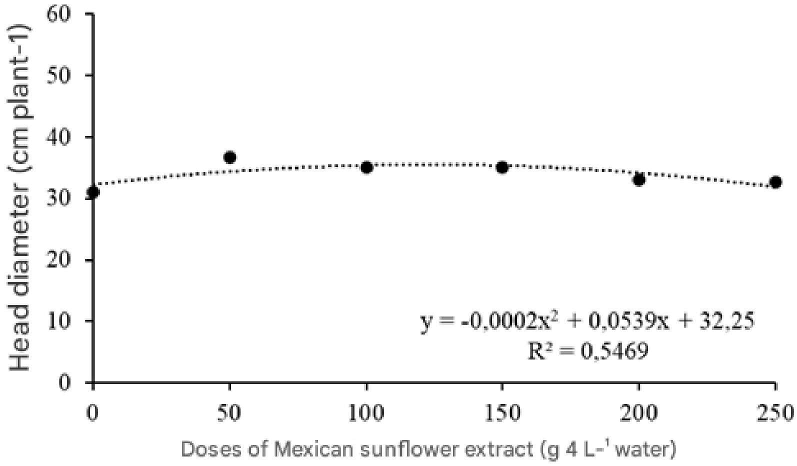
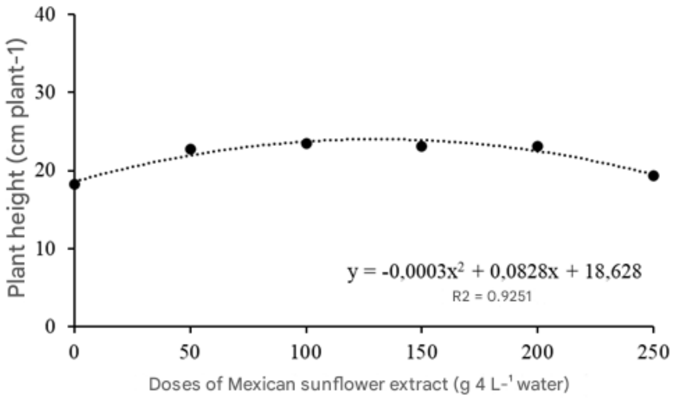
Figure 1. Head diameter of lettuce under the effect of the application of increasing doses of Mexican sunflower extract. **significant (p < 0.01).



Source: Santos et al. (2024).

The use of different doses of Mexican sunflower plant extract on the soil influenced the increase in height of curly lettuce plants, when applied at a dose of 50 g.4 L^{-1}, reaching an average value of 22.82 cm plant-1, a value 24.90% higher than the control treatment, 0 g.4 L^{-1} (Figure 2).

Figure 2. Height of lettuce plant under the effect of the application of increasing doses of Mexican sunflower extract. **significant (p < 0.01).



Source: Santos et al. (2024).

The effects of doses of Mexican sunflower extracts on the root length variable are shown in Figure 3. The regression model showed a good fit, explaining 97% of the occurrences for the increasing doses of extract. The maximum root length was obtained at a dose of 50 g.4 L^{-1}, providing an increase of 11.89% in relation to the constrole treatment,

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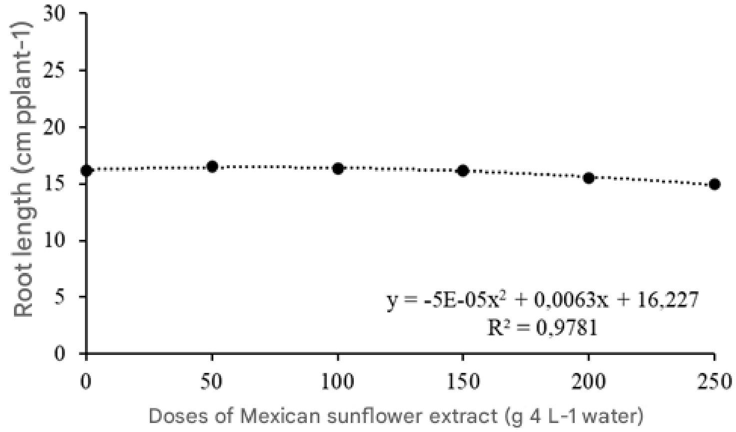
0 g.4 L⁻¹, This increase indicates a greater availability of nutrients provided by the plant extract in the subsurface, which culminated in cell division, in addition to favoring a larger area of contact with the soil solution (Figueira, 2013).

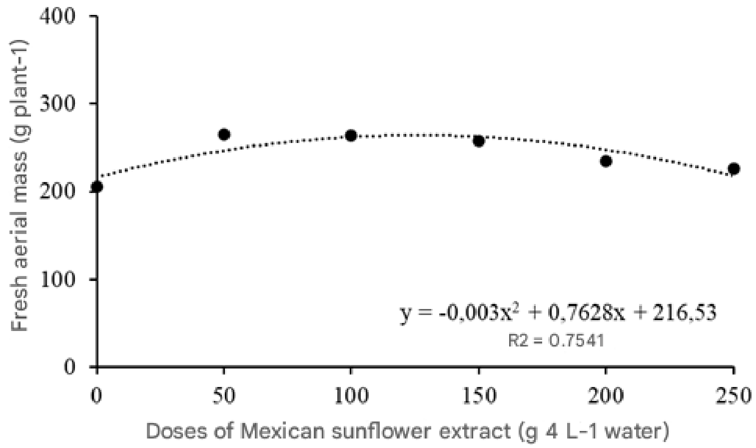
Figure 3. Length of lettuce root under the effect of the application of increasing doses of Mexican sunflower extract. **significant ($p < 0.01$).



Source: Santos et al. (2024).

For the aerial fresh mass, it was observed that the dose of 50 g.4 L⁻¹ resulted in the highest gain, with an average value of 327.8 g per plant, representing a percentage increase of 15.83% compared to the control treatment (0 g.L⁻¹), which obtained 283 g per plant (Figure 4).

Figure 4. Fresh aerial pasta of lettuce under the effect of the application of increasing doses of Mexican sunflower extract. **significant ($p < 0.01$).



Source: Santos et al. (2024).

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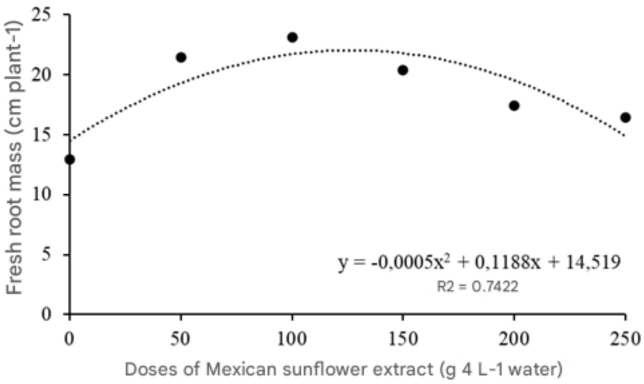
The aqueous extract of Mexican sunflower leaves had a significant impact on the fresh root mass of curly lettuce (Figure 5). The treatment with a dose of 50 g.L⁻¹ stood out, reaching a mean mass of 20.35 g, which corresponds to an increase of 37.55% in relation to the control treatment, which presented an average of 14.8 g.

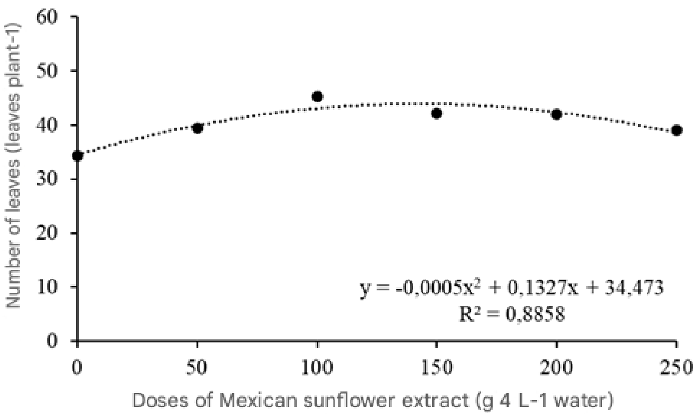
Figure 5. Fresh lettuce root pasta under the effect of the application of increasing doses of Mexican sunflower extract. **significant ($p < 0.01$).



Source: Santos et al. (2024).

Figure 6 shows the number of curly lettuce leaves as a function of the doses of Mexican sunflower plant extract. The treatment with 100 g.L⁻¹ stood out, providing an average number of 45.25 leaves per plant, representing an increase of 23.35% compared to the control treatment, which presented an average of 34.25 leaves per plant. These results suggest that the use of plant extract increases the photosynthetic capacity of plants, promoting greater leaf development and, consequently, improved physiological performance.

Figure 6. Number of lettuce leaves under the effect of the application of increasing doses of Mexican sunflower extract. **significant ($p < 0.01$).



Source: Santos et al. (2024).

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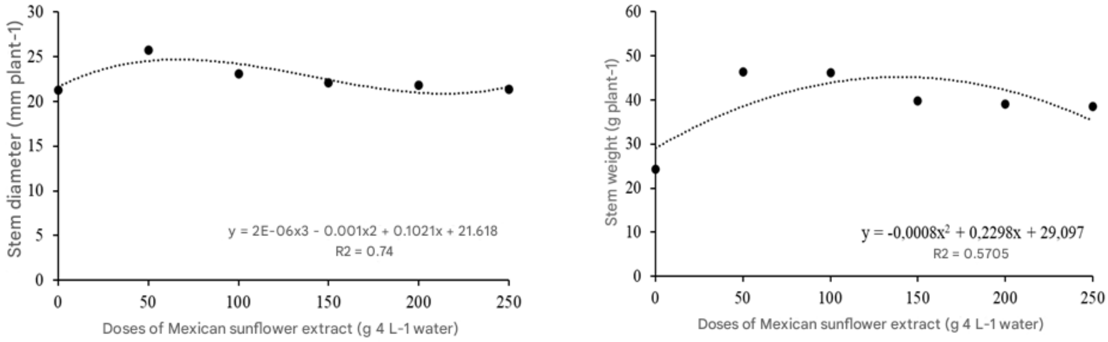
Figure 7 shows the diameter and average weight of the curly lettuce stem submitted to doses of Mexican sunflower plant extract. The largest diameter and weight were observed at the dose of 50 g.4 L⁻¹, with values of 25.76 mm and 46.31 g plant-1, respectively.

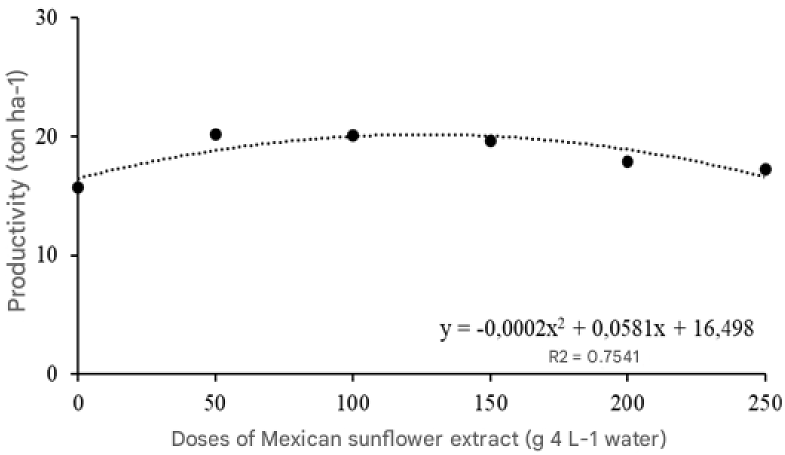
Figure 7. Diameter and weight of lettuce stem under the effect of the application of increasing doses of Mexican sunflower extract. **significant ($p < 0.01$).



Source: Santos et al. (2024).

Figure 8 shows the yield of lettuce submitted to the application of Mexican sunflower extract via soil. The results show a statistically significant difference in the variable evaluated ($p < 0.01$).

Figure 8. Lettuce yield under the effect of the application of increasing doses of Mexican sunflower extract. **significant ($p < 0.01$).



Source: Santos et al. (2024).

DISCUSSION

The optimized response to the variable stem diameter observed for the dose of 50 g.4 L⁻¹ can be attributed to the ability of leaves and stems to provide essential

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macronutrients, such as N, K and Ca. This stability after the application of 50 g.4 L^{-1} may be associated with the saturation of the nutrient absorption capacity of the plants or the nutritional balance of the soil (Jiménez et al., 2001).

Similar results were observed by Akinde et al. (2017), who highlight the beneficial effects of moderate doses of green manure on vegetable diameter, corroborating the findings of this study. On the other hand, the low R^2 suggests that external factors, such as edaphoclimatic conditions or other experimental variables, may have influenced the development of plant diameter (Teixeira et al., 2015). Adjustments to the frequency of application or concentration can improve the efficiency of the extract.

Plant height was positively influenced by moderate doses of Mexican sunflower extract, reaching an average of 23.5 cm per plant at a dose of 100 g.4 L-1 (Figure 2). This behavior can be attributed to the balanced release of nutrients by the extract, promoting efficient vegetative growth (Padovan et al., 2018). However, higher doses may have caused nutritional imbalance or phytotoxic effect, resulting in reduced height.

The high R^2 shows that the doses of Mexican sunflower had a direct impact on the height of the lettuce, which reinforces the efficiency of green manure when used at adequate levels (Rodrigues and Gama-Rodrigues, 2020). Additional studies may explore fractional applications to avoid the negative effects of higher doses.

The results indicate that the length of the lettuce root did not present great variations as a function of the applied doses of Mexican sunflower extract (Figure 3). This behavior is elucidated by the absence of a direct influence of the extract on the stimulation of root growth, or by the fact that the soil already provides adequate conditions for the development of roots, meeting the physiological needs of the plant (Gachengo et al., 1999).

Studies, such as the one by Rodrigues et al. (2019), indicate that, in soils with good structural conditions, the impact of organic fertilizers on the root system tends to be less expressive. On the other hand, it is relevant to consider that the bioactive compounds present in Mexican sunflower extract may be more directly associated with the development of the aerial part of the plant, rather than root growth, as observed in similar research (Teixeira et al., 2015).

The trend observed in Figure 4 suggests that moderate doses of Mexican sunflower extract are more beneficial for the gain of fresh aerial mass of lettuce. The reduction in

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fresh mass after the dose of 150 g.4 L-1 water may be associated with the allelopathic effect, common in high concentrations of plant extracts, which can inhibit growth.

This result highlights the role of the plant extract in promoting root growth, possibly due to the presence of bioactive compounds and nutrients that favor root development (Rodrigues et al., 2020).

Studies, such as that of Miranda et al. (2015), highlight that phenolic compounds present in the Mexican sunflower, when in high concentrations, can negatively interfere with root development, acting as growth regulators or promoting toxic effects on root tissues.

The increase in the number of leaves up to a dose of 100 g.4 L^{-1} reinforces the potential of Mexican sunflower extract as a growth promoter, possibly due to the presence of plant nutrients and hormones. However, the reduction at higher doses, above 101 g.4 L-1, can be attributed to soil saturation with secondary compounds. According to Rodrigues et al. (2020), excessive doses of plant extracts can cause physiological imbalances, directly impacting leaf production.

The behavior of the stem diameter evidenced for a dose of 50 g.4 L^{-1}, is evidenced by the supply of readily absorbable nutrients in the soil solution, which have a direct impact on the greater resistance of the lettuce plant, as well as on the accumulation of phytoassimilates. The increase in stem weight up to the dose of 50 and 100 g.4 L^{-1} of water is associated with the plant's root system in absorbing the essential nutrients provided by the application of Mexican sunflower extract, which promotes the strengthening of plant structure and translocation of crude sap to organs that are developing.

The highest yield was observed at the doses of 50 g and 100 g.4 L^{-1}, with values of 20.18 and 20.11 ton.ha^{-1}, respectively. This result is mainly corroborated by the behavior of the variables in the aforementioned dosages, in which better performances were observed for head diameter, plant height, root length and fresh mass, aerial fresh mass, number of leaves, diameter and stem weight at the doses of 50 g and 100 g.4 L^{-1}, which directly culminated in the increase in yield of the curly lettuce crop.

In addition, the application of these dosages in sandy soil favored soil aggregation through the mineralization of organic matter, increasing the cation exchange capacity and, consequently, the root absorption of nutrients. This resulted in an increase in final productivity.

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CONCLUSION

This study showed that Mexican sunflower plant extract is a viable and sustainable alternative to improve the growth and development of curly lettuce in sandy soils. The doses of 50 and 100 g.4 L-1 stood out, promoting significant increases in the variables studied in relation to the control treatment.

The use of plant extracts as biofertilizers can reduce dependence on chemical inputs, increasing agricultural sustainability. In addition, the positive effects at intermediate doses suggest greater efficiency in the absorption of essential nutrients, even in soils with low retention capacity.

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. Massao Takaoka for the partnership established in the implementation and conduct of the experiment on his property, located in the Green Belt of Imperatriz – MA.

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