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Hydroponic production of the medicinal plants *Artemisia ludoviciana* and *Tradescantia zebrina* under greenhouse conditions

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***Keywords*— Hydroponic production, medicinal plants, nutritive solution.**

***Abstract*— *The use of medicinal plants for the treatment of chronic-degenerative diseases is an attractive alternative to traditional pharmaceutical drugs, the supply of this type of plants is given in most cases by harvesting in the wild. Hence, the information available on hydroponic production for these plant inputs is still scarce. Therefore, the objective was to evaluate the growth of estafiate (Artemisia ludoviciana) and chicken grass (Tradescantia zebrina) produced hydroponically under greenhouse conditions. For which a treatment and a control were managed, the first by means of hydroponics (inorganic substrate and nutritive solution) and the second was the control by means of conventional production (organic substrate without nutritive solution). The experimental design was completely randomized with five replications per treatment. It was statistically demonstrated that hydroponic production positively affected plant growth. In estafiate the height increased by 31.4%, while for the chicken grass this increase was 28% with respect to the control, the variables of dry and fresh weight followed a similar trend, being favored by the hydroponic treatment with respect to the control.*

I. INTRODUCTION

In Mexico, herbalism is defined as the set of knowledge related to the healing properties of medicinal plants that can to a certain extent replace conventional drugs (Aguilar, B.G.C., Martínez, P.C.C., Star, M.J.V., & Cárdenas, B.M, 2011; Gallegos Zurita, M., 2016).

Being medicinal plants, all those that contain in some of their parts, active ingredients, which if administered in an adequate dose can produce healing effects in the human body such as pain control. In Latin America, there is a history of the use of plants or part of them for healing purposes since pre-Hispanic cultures (Calderón Pérez L., Llauradó E., Companys J., et al., 2021).

In this sense, medicinal plants have secondary metabolites (MS) that are produced as a means of defense against attack by insects, microorganisms and to adapt to adverse environments (temperature, humidity, light intensity, drought, etc.), which essentially gives them its medicinal properties; however, they will not be the object of study in this work (Vélez Terranova M., Gaona R., Sánchez H., 2014; Wang Y.S., Shen C.Y., Jiang J.G., 2019).

The most common form of use of medicinal plants are decoctions or infusions, followed by juice, microdoses, tinctures and capsules. In this regard, it is known that there are plants whose products are for external use and others for internal use. The biological forms of plants used vary from bush, grass, tree, vine (epiphytic plant with long stems), while the parts of the plant used (vegetable drug) range from the leaf, flower, bulb, fruit, bark, stem, seed, root, or the entire plant, however, extensive studies are required to identify, authenticate and characterize the bioactive compounds present in these plants that can generate added value in the pharmaceutical industries by providing a cost-effective way of treatment with minimal side effects (Akram M., Riaz M., Noreen S., et al., 2020).

It is estimated that 80% of the world population depends on traditional herbal remedies and that at least 35,000 plant species have potential for medicinal use, being used mainly for their antibacterial, anthelmintic, antidiabetic, analgesic, antioxidant, analgesic, anti-inflammatory and antipyretic effects (Annan K., Houghton P.J., 2008; Moharram F.A., Nagy M.M., El Dib R.A., El - Tantawy M.M., El Hossary G.G., El -Hosari D.G., 2021).

Mexico is a country that hosts a great plant biodiversity, for which there is an enormous variety of Phytotherapeutic treatments, not only for physical or organic disorders, but its efficiency has also been demonstrated in the field of psychology using plant resources in depressive disorder. forming part of the knowledge of traditional Mexican medicine, which is supported by an approximate number of 4500 species, which makes Mexico rank second worldwide in the number of registered medicinal plants (García de Alba García J.E., Ramírez B.C., Robles A.G., et al., 2012; Zhang Y., Long Y., Yu S., et al., 2021).

The plants used for this work were ***Artemisia ludoviciana***, known in Mexico as estafiate, and ***Tradescantia zebrina,*** commonly called chicken grass in the region.

The estafiate (*Artemisia ludovician*) it is a plant of warm, semi-dry and temperate climates, it can be found from Canada to Guatemala; It is one of the most popular herbal remedies in contemporary Mexico. The crude oil and drug (aerial parts) are widely marketed throughout the country for the treatment of gastrointestinal disorders, pain and diabetes (Anaya Eugenio, G.D., Rivero Cruz, I., Bye, R., Linares, E. & Mata, R., 2016; Ezeta Miranda, A., Vera Montenegro, Y., Avila Acevedo, J.G., Alvarez Mercado, J.M., & Francisco Márquez, G., 2016).

Chicken grass (*Tradescantia zebrina*) is native to Mexico. It is distributed especially in the tropical regions of the Mexican southwest. Its main use is as fresh water or as an infusion or tea. Medicinal properties are attributed to these drinks to treat diuretic diseases, dysentery, dysuria or urinary tract infections and stomach pain. It has also been reported to have antioxidant, antimicrobial and anti-inflammatory activity in methanolic extracts (Olivo Vidal, Z. E., Ruiz Ruiz j., Vega Salazar M., Ochoa Díaz H., Irecta Nájera C., Sanchez Chino X., 2020).

Obtaining this type of medicinal plants is done in the vast majority of cases by wild collection, however; The production of this type of plants can be carried out in different ways; in the open air, in urban gardens, under greenhouse conditions and even with hydroponic techniques, always ensuring the safety of the plant and the conservation of its medicinal properties given by the adequate concentration of secondary metabolites.

In this sense one of these production methods; Hydroponics is defined as a production system in which the roots of plants are irrigated with a mixture of essential nutritional elements dissolved in water (Nutrient Solution; SN) and in which instead of soil (substrate of organic origin) an inert and sterile material is used as substrate (substrate of mineral origin), or even the same solution, which is an interesting option to produce medicinal plants in a general way, which allows better management of water consumption parameters, safety and supply of nutrients (Salazar Moreno R., Rojano A.A., López C.L., 2018).

Hydroponics is developed in most cases under greenhouse conditions since this is a production system that can increase water use efficiency, creating a microclimate to improve plant photosynthesis, reducing excessive evapotranspiration, and increasing yields (Salazar Moreno R., Rojano A.A., López C.L., 2018).

Currently there are few studies that relate hydroponics with the production of medicinal plants, this may be due to the fact that to a large extent the development of these plants is mediated by competition and allelopathic relationships that they develop with other species, being especially true when these plants are found in the wild (Guerrero Lagunes, L.A., Ruiz-Posadas, L.D.M., Rodríguez-Mendoza, M.D.L.N., Soto Hernández, M., & Castillo Morales, A., 2011).

For this reason, the objective of this work was to evaluate the growth of estafiate (*Artemisia ludoviciana*) and chicken grass (*Tradescantia zebrina*) produced hydroponically under greenhouse conditions.

II. MATERIALS AND METHODS

The experiment was carried out between August and October 2022 in two greenhouses with roof ventilation located at the Ecatepec Valley State University (UNEVE) located at coordinates 19°30' north latitude and 99°2' west longitude at an altitude of 2,250 m.

The average temperature in the greenhouse was 22.5 °C from August to October 2022, and a maximum temperature of 38 °C and a minimum temperature of 6.5 °C were obtained. This variable was monitored inside the greenhouse, with a digital thermo-hygrometer of the CONTROL COMPANY® model cc4154 to record daily temperature and relative humidity (RH) with an accuracy of + 0.1 °C and + 1 % RH.

The production of the medicinal plants was carried out by cuttings (a branch was cut from the mother plant which was put in water so that the buds or nodes of these developed roots, the use of additional rooters was not necessary) that were obtained of local varieties of the State of Mexico.

The plants used were estafiate (*Artemisia ludoviciana*) and chicken grass (*Tradescantia zebrina*).

Once the plants developed an adequate root volume and formed new shoots from the axillary buds, the plants were transplanted to the definitive growth site, approximately 3 weeks after the cuttings were cut.

A treatment and a control were managed, the first through hydroponics (inorganic substrate with nutrient solution) and the control through conventional production (organic substrate without nutrient solution).

Black polyethylene bags 32 cm long with an approximate volume of 7 L were used using an inorganic substrate (red tezontle) and an organic substrate (black earth), respectively.

The nutrition for the treatment by means of hydroponics was given from a nutrient solution for vegetables of the HYDRO ENVIRONMENT ® brand, taking care that the pH oscillates between 5.5 and 6.5 and the electrical conductivity between 1.5 and 3 millisiemens , this in order that nutrients can be adequately absorbed by the plant.

The initial volume of nutrient solution applied was 200 ml per plant every third day, but it was modified throughout the cycle until reaching a volume of 350 ml per plant.

For the second treatment, the nutritional contribution was given by means of 300 g of vermicompost of the HORTAFLOR ® brand every 20 days and an irrigation every third day with an initial volume of 200 ml, which was modified throughout the growth until reaching a final volume of 350ml.

applications were made preventive every 15 days in a foliar way with Tecto 60 with a concentration of 1 g L^{-1} and Imidacloprid 0.5 ml L^{-1} to avoid problems caused by fungi and aphids, both applications were made during the afternoon to avoid evaporation of the product.

The drying of medicinal plants was done by forming small bunches which were covered with paper bags to avoid direct exposure to the sun, these bags had some perforated holes to let the air circulate and prevent the formation of fungi due to humidity; these clusters were hung upside down to speed up the drying process.

The plants lost all their water content approximately 15 days after harvest where they could be stored safely.

The variables evaluated were plant height, measured from the base of the stem to the apex; the fresh weight of the plant (weighed without the root) and the dry weight of the plant, once the plants were harvested; which was carried out between the third and fourth month after the transplantation of the cuttings.

The experimental design was completely randomized, consisting of a treatment and a control, where the experimental unit consisted of a bag with a plant, with five repetitions, giving a total of 10 experimental units for each species.

With the data obtained, analysis of variance and comparison of means were performed using the Tukey test ($P \leq 0.05$), for continuous variables; the statistical program Minitab® version 18 was used.

III. RESULTS AND DISCUSSION

Plant height: The production of medicinal plants by means of hydroponics (inorganic substrate with nutrient solution) promoted the height of the plants for species studied with respect to the control (organic substrate without nutrient solution) as shown in table 1. In estafiate the height increased around 31.4 %, while for the chicken grass this increase was 28% with respect to the control, as can be seen in figure 1.

In this sense, there is very little information on previous studies of the effects of nutrient solutions on the growth of medicinal plants, however, for the species *Artemisa absinthium* L. it was observed that the application of Steiner's nutrient solution at 50% increased the height at least 25% with respect to the control that were not treated with a hydroponic profile (Luz, J.M.Q., Oliveira, R.C., Aguilar, A.S., & Santos, T.N., 2018).

Table 1. Estafiate height (Artemisia ludoviciana) and chicken grass (Tradescantia zebrina), grown under greenhouse conditions.

Treatment	Plant height (cm) Estafiate	chicken grass
Hydroponics (inorganic substrate with nutrient solution)	66.2 to [z]	49 to
Control (organic substrate without nutrient solution)	50.4 to	38.2b
ANOVA=p≤	0.0026*	0.0138*
AMD	8.47	7.93
CV	9.96	12.48

[z] Means with the same letter in each column are equal according to Tukey's multiple comparison test with p≤ 0.05. ANOVA= analysis of variance; * statistically different. CV= coefficient of variation. MSD= minimal significant difference.

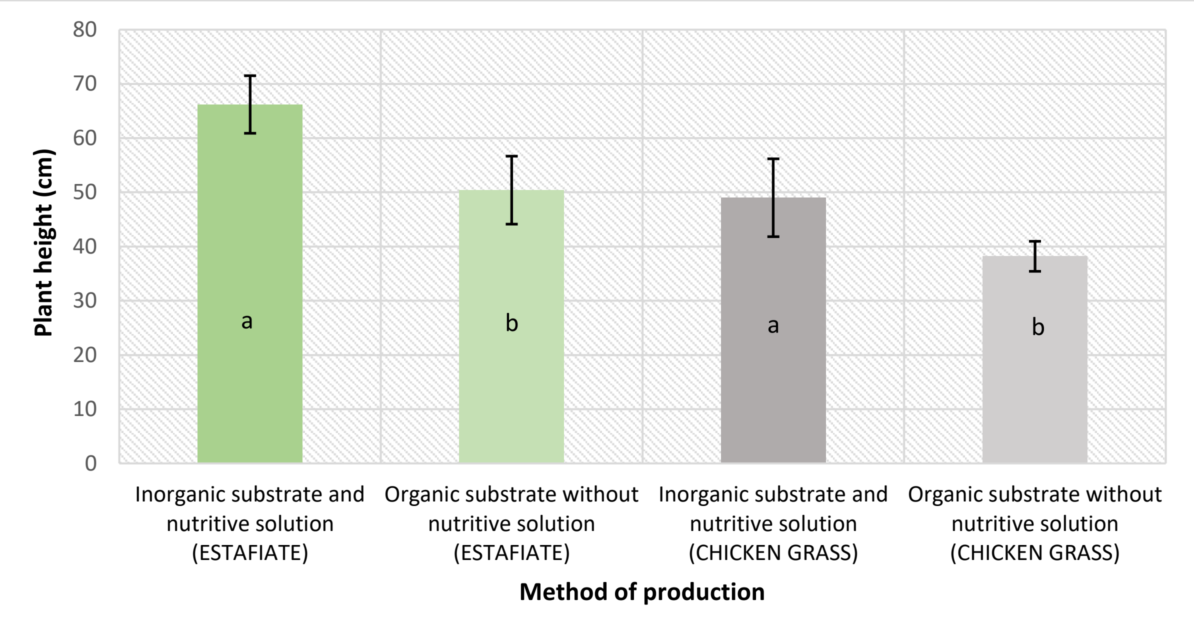

Fig.1. Estafiate plant height (Artemisia ludoviciana) and chicken grass (Tradescantia zebrina), produced under greenhouse conditions. Treatments with the same letter are statistically the same for each species (Tukey, p<0.05). The bars include the standard deviation of the mean.

On the other hand, it has been reported that in non-medicinal plants such as tomato, the nutrient solution increased the height of the plant between 3 and 4% and in purslane by 27%, for which the additions of SN notably favored the height of the plant. plant in these cases (Luna Fletes, J.A, Cruz C. E., Can-C. Á., 2021; Montoya García, C.O., Volke H.A., Santillán Á. N., López E., and Trinidad S.A., 2019).

In a similar way, positive effects were observed from the SN of the HYDRO ENVIRONMENT ® brand with respect to the control, to which it was not added.

The continuous and balanced supply of nitrogen and phosphorus provided by the nutrient solution are essential for plant growth, since both are structural elements. Like nitrogen, phosphorus is a very important growth factor and, in addition, root development is favored by a correct supply of this nutrient at the beginning of the vegetative cycle (Luquet, M., Galatro , A., Buet , A., 2020).

Fresh weight of the plant: According to what is presented in table 2 and following the trend of the previous variable, production by hydroponics (inorganic substrate with nutrient solution) promoted the fresh weight of the plant for the two managed species, showing differences significant compared to the control. On the one hand, in estafiate the increase corresponded to more than double (164 %) with respect to the control, while for chicken grass this difference was around 96 % as observed in figure 2.

Table 2. Fresh weight of estafiate (Artemisia ludoviciana) and chicken grass (Tradescantia zebrina), grown under greenhouse conditions.

	Plant fresh weight (g)	
Treatment	Estafiate	chicken grass
Hydroponics (inorganic substrate with nutrient solution)	284.5 to [z]	418.6 to
Control (organic substrate without nutrient solution)	107.63b	213.74b
ANOVA=p≤	<.0001*	<.0001*
AMD	9.47	65.16

[z] Means with the same letter in each column are equal according to Tukey's multiple comparison test with p≤ 0.05. ANOVA= analysis of variance; * statistically different. CV= coefficient of variation. MSD= minimal significant difference.

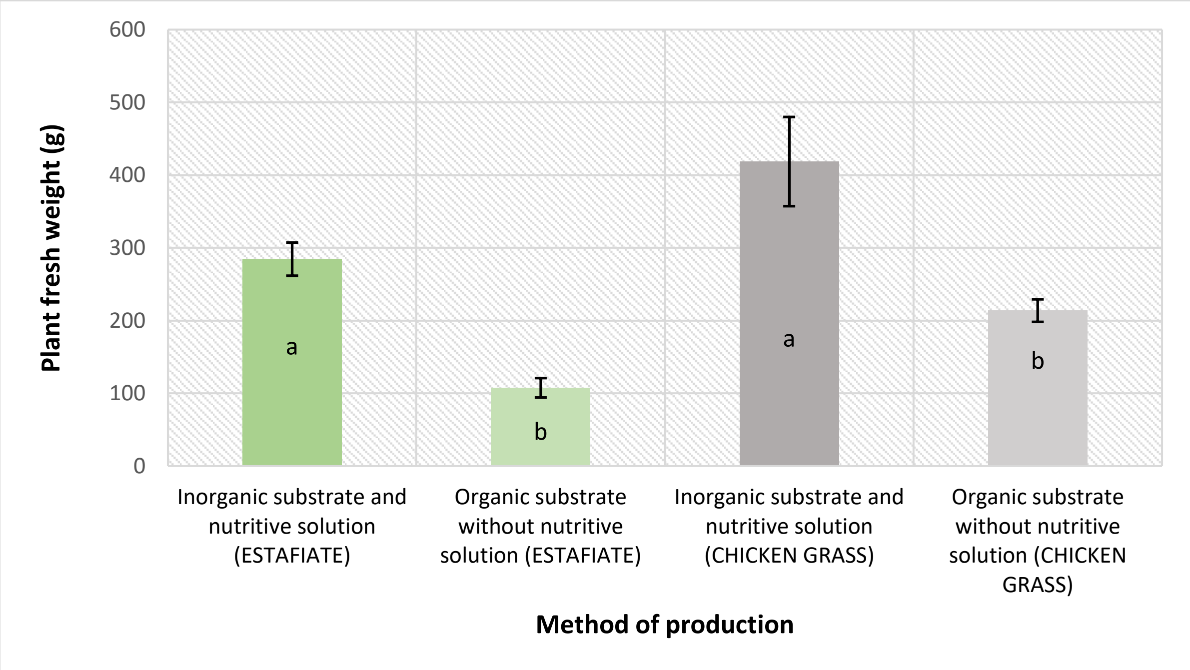

Fig.2. Fresh weight of the estafiate plant (Artemisia ludoviciana) and chicken grass (Tradescantia zebrina), produced under greenhouse conditions. Treatments with the same letter are statistically the same for each species (Tukey, p<0.05). The bars include the standard deviation of the mean.

As mentioned above, there are no studies that concretely relate medicinal plants and the use of nutritional solutions; however, in thyme it has been mentioned that, when cultivated under a greenhouse in a hydroponic system, 18.45 kg m - 2 of fresh thyme can be obtained per year, while in the open field only 3.79 kg m – 2 per year, offering this cultivation system an increase in fresh weight yield of 386.8% (Guerrero Lagunes, L.A., Ruiz Posadas, L.D.M., Rodríguez Mendoza, M.D.L.N., Soto Hernández, M., & Castillo Morales, A., 2011).

It has also been pointed out that, in non-medicinal plants such as tomato seedlings developed from nutrient solutions, the fresh weight increased up to 55% compared to the control (Magdaleno Villar, J.J., Peña L.A., Castro B.R., Castillo G.A.M., Galvis S.A., 2006).

Plant dry weight: this variable was also favored by hydroponic production in both species observed, showing significant differences between the treatment and the control as shown in Table 3. Estafiate increased a little more than triple in a percentage of 206 %, while the chicken grass increased in a ratio of 95 % with respect to the control in both species, as can be seen in graph 3.

Table 3. Dry weight of estafiate (Artemisia ludoviciana) and chicken grass (Tradescantia zebrina), grown under greenhouse conditions.

	Plant dry weight (g)	
Treatment	Estafiate	Chicken grass
Hydroponics (inorganic substrate with nutrient solution)	107.35 to [z]	137.03 to
Control (organic substrate without nutrient solution)	35.88b	70.03b
ANOVA=p≤	<.0001*	<.0001*
AMD	10.09	21.28
CV	9.66	14.08

[z] Means with the same letter in each column are equal according to Tukey's multiple comparison test with p≤ 0.05. ANOVA= analysis of variance; * statistically different. CV= coefficient of variation. MSD= minimal significant difference.

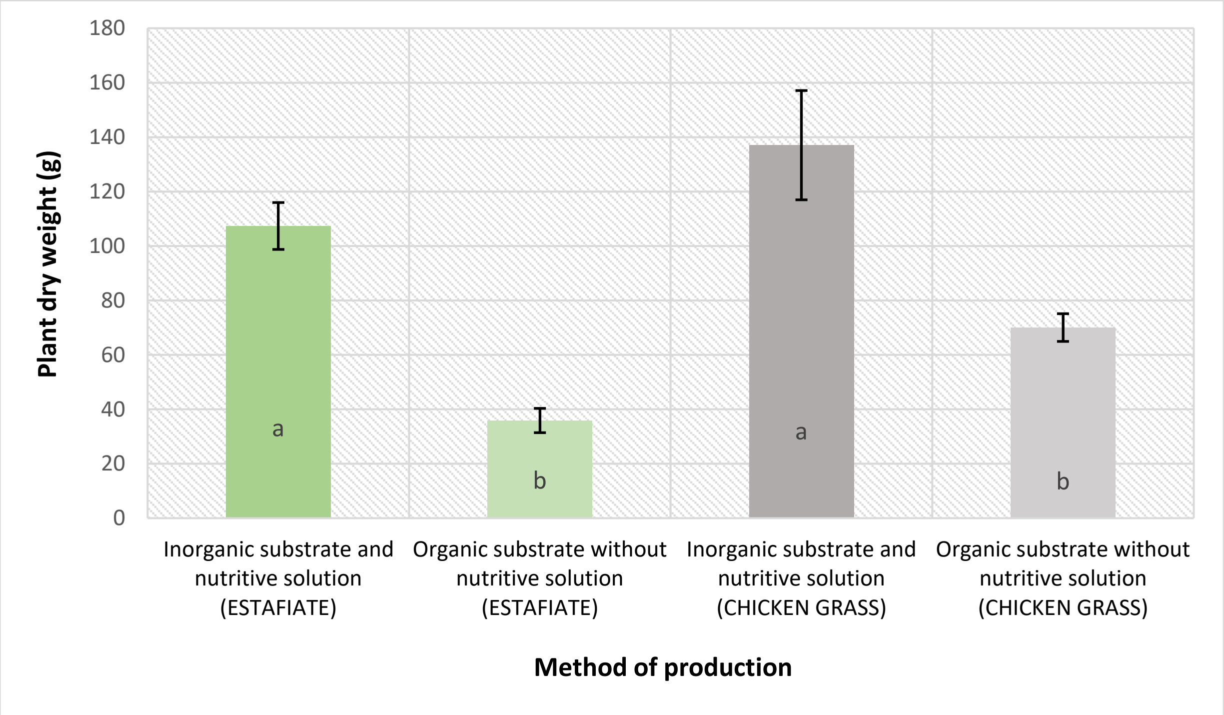

Fig.3. Dry weight of the estafiate plant (Artemisia ludoviciana) and chicken grass (Tradescantia zebrina), produced under greenhouse conditions. Treatments with the same letter are statistically the same for each species (Tukey, p<0.05). The bars include the standard deviation of the mean.

The results obtained are similar to those reported by Cruz-Crespo et al. (2017), who found that the Steiner nutrient solution at 100% concentration generated the highest dry weight in coriander plants (Cruz Crespo, E., Can-Chulim, A., Loera-Rosales, J., Aguilar Benítez, G., Pineda-Pineda, J. and Bugarín Montoya, R., 2017).

IV. CONCLUSIONS

Based on the results obtained from the estafiate plant (*Artemisia ludoviciana*) and chicken grass *(Tradescantia zebrina*) showed a favorable growth by means of a hydroponic technique (inorganic substrate with nutrient solution) when compared with the control (organic substrate without nutrient solution) since, for the variables of height, weight fresh and dry there were significant differences.

The difference was more consistent in the estafiate plant (*Artemisia ludoviciana*) since growth in height, fresh and dry weight was higher compared to chicken grass (*Tradescantia zebrina*)

The deeper and continuous investigation of this type of production and its effects on the physical-chemical characteristics of medicinal plants are necessary since the existing information is almost null and the results show that the hydroponic production of medicinal plants at least for these species is an alternative worth considering.

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