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# Hydroponic production of the medicinal plants Arnica (*Arnica montana* L) and Toronjil *(Agastache mexicana*) under greenhouse conditions

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***Abstract*— *For the treatment of chronic-degenerative diseases, the use of medicinal plants is an attractive alternative compared to traditional pharmaceutical drugs, the supply of this type of plants occurs in most cases by collection in the wild. Hence, the information available on hydroponic production for these plant inputs is scarce and little is known about their development under optimal and ideal conditions, different from their wild condition. The objective of the research was to evaluate the growth of Arnica (Arnica montana L) and Toronjil (Agastache mexicana) produced hydroponically under greenhouse conditions, for which two crops were managed, one with treatment and the other without it as a control, the first with hydroponics (inorganic substrate with nutrient solution) and the second, with organic substrate without adding nutrients. The experimental design was completely randomized with five repetition cycles per treatment. It was statistically proven that hydroponic production positively affected plant growth. In both cases, Arnica and Lemon Balm increased their growth and mass compared to the control by 36.5% and 38.4% respectively, the variables of dry and fresh weight followed a similar trend, being favored by the hydroponic culture with respect to the control; On the other hand, the yield of dry extract from a 20.0% tincture for both species were very similar in percentage terms, being slightly higher for plants produced hydroponically.*

***Keywords*— Arnica, medicinal plants, Toronjil, Biodiversity.**

## I. INTRODUCTION

In Mexico, the set of knowledge related to the curative properties of medicinal plants that are effective in the treatment of many conditions is called herbal medicine, because its action is given by the set of its components, which is why it is considered more comprehensive than the specific action of an allopathic medicine, **(1,2)** this alternative is called herbal remedy.

In this sense, medicinal plants are all those that contain in some of their parts, active principles, which if administered in an adequate dose can produce curative effects in the human body such as pain control. In Latin America, the use of plants or part of them for healing purposes since pre-Hispanic cultures has been used as antecedents. (3)

The medicinal plants have secondary metabolites (MS) that are produced as a means of defense against attack by insects, microorganisms, and adaptation to adverse environments (temperature, humidity, light intensity, drought, etc.), which essentially gives them their medicinal properties ; however, they will not be the object of study in this work. (4.5)

It is estimated that 80.0% of the world population depends on traditional herbal remedies and that there are at least 35,000 plant species with potential for medicinal-therapeutic use, being used mainly for their antibacterial, anthelmintic, antidiabetic, analgesic, antioxidant, analgesic, anti-inflammatory and antipyretics. (6,7)

México is a country that is home to a great plant biodiversity, which is why there is an enormous variety of phytotherapeutic treatments, not only for physical or organic disorders, but their efficiency has also been demonstrated in the field of psychology using plant resources in the depressive disorder forming part of the knowledge of traditional Mexican medicine, which is supported by an approximate number of 4,500 species, which makes Mexico the second place worldwide in the number of registered medicinal plants. (8,9)

According to the Ministry of Health [1]*, the 90.0% of the Mexican population has opted for one of the 4,500 medicinal plants available in the country, at least once in their lives, for this reason botany has been the most accessible and effective medicine for indigenous peoples and communities. The National Commission for the Knowledge and Use of Biodiversity [2]* (CONABIO) highlights the registry of the Mexican Institute of Social Security [3]* (IMSS) of 3,000 species of plants with medicinal attributes, of the 4,000 that are estimated to exist in the country, and that represent 15.0% of the total Mexican flora. It specifies that only 5.0% of the total number of these plants has been pharmacologically analyzed. Of this universe, 250 are commercialized on a daily basis, 85.0% are extracted from the wild without sustainable management plans, and 80.0% of the Mexican population has made use of them. (10)

The most common form of use of medicinal plants are decoctions or infusions, followed by juice, micro doses, tinctures and capsules. In this regard, it is known that there are plants whose products are for external use and others for internal use. (11)

The plants used for this work were *Arnica montana* L. known in Mexico only as Arnica and *Agastache mexicana* known in the region as Toronjil.

*Arnica montana* L. is a therapeutic plant traditionally widely used to treat various ailments, its extracts have been reported to have antibacterial, antitumor, antioxidant, anti-inflammatory, antifungal and immunomodulatory activity. (12)

In Mexico it is commonly used to treat inflammatory conditions, as an antimicrobial and antioxidant, it has been considered effective for the treatment of bruises, sprains, rheumatic problems, wounds, bruises, pain and angina. (13)

The Toronjil (*Agastache Mexicana*), is a native perennial vascular plant, it is identified for its medicinal properties against anxiety, promoter of sleep, aid in wound healing, antispasmodic agent and against stomach pain, as well as to treat diseases of the heart, despite its spectrum for pain relief, pharmacological studies of its bioactive components have hardly been investigated. (14,15)

Obtaining this type of medicinal plants is through collection in their wild state, however; its production can be carried out successfully through different techniques; in the open air, in backyard or urban gardens, under greenhouse conditions and even through more controlled and ideal techniques such as hydroponics, which ensures its safety and the best conservation of its medicinal properties.

Hydroponics is a production system in which plant roots are introduced into a mixture of essential nutrients dissolved in water, thus creating a nutrient solution (NS) with which soil of organic origin is replaced, which can also be contained in another inert and sterile material of mineral origin, or in the solution itself, in which the root of each plant is kept in suspension, this being a very suitable option to produce medicinal plants due to the benefits that we describe later, another The advantage of this system is that it can be scaled, adapted to any space, climatic condition and financial budget. (16,17)

Another advantage of hydroponics as a production system implemented under greenhouse conditions is that it increases efficiency in the use of water, by creating a

[1]* Ministry of Health, agency of the Mexican State in charge of coordinating, organizing and monitoring all public and private social health services in the country.
[2]* CONABIO, inter-ministerial commission of the Mexican State in which scientific academies, civil society and the government participate to promote, coordinate, support and carry out activities aimed at knowledge of biological diversity, as well as its conservation and sustainable use for the benefit of society.
[3]* IMSS. State decentralized body dedicated to providing health and social security services to the population that has affiliation to the institute (called beneficiaries), conducts research and medical practice.

microclimate that improves plant photosynthesis, reducing excessive evapotranspiration, thus increasing yields. [16]

Few studies are currently reported in the literature that relate hydroponics to 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. [18,19]

For this reason, the purpose of this research was to evaluate the growth of medicinal plant species Arnica (*Arnica montana* L) and Toronjil (*Agastache mexicana*) produced by hydroponics under greenhouse conditions.

## II. MATERIALS AND METHODS

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

The temperature in the greenhouse was recorded with a digital thermo-hygrometer of the CONTROL COMPANY® brand, model cc4154, with which the variables temperature and relative humidity (RH) were collected daily with an accuracy of + 0.1 °C and + 1 % RH. The average temperature during the experiment inside the greenhouse was 22.5°C, with the maximum temperature being 39°C and the minimum being 4.5°C.

The plants used were Arnica (*Arnica montana* L) and Toronjil (*Agastache mexicana*), which were produced by cuttings of wild mother plants, obtained in EDOMÉX itself. Once the plants developed an adequate root volume and formed new shoots from the axillary buds, they were transplanted into the final place of growth, about three weeks after cutting the original cuttings.

The plants were divided into two cultures for their development: one hydroponic (ideal conditions) in inorganic substrate with nutrient solution, and the control (for comparison) by means of conventional production in organic substrate without nutrient solution, carried out in 32cm long black polyethylene bags. with an approximate volume of 7 liters, with a mixture of red tezontle mineral substrate (igneous rock of volcanic origin) and black earth as organic substrate.

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 was maintained between 5.5-6.5 and the electrical conductivity between 1.5 and 3 millisiemens, this in order to that the 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 conventional treatment, the nutritional contribution was given by means of 300g of HORTAFLOR® brand vermicompost every 20 days and irrigation every third day with an initial volume of 200 ml, which was modified throughout the growth until reaching a volume final 350ml.

Preventive applications were made every 15 days in a foliar manner with Tecto® 60 with a concentration of 1g/L-1 and Imidacloprid 0.5ml/L-1 to avoid fungal and aphid problems, both applications were made during the afternoon to minimize the product evaporation.

The drying of the plants was carried out in the laboratory by means of a dehydrator with 12 stainless steel trays of the BUTCHI® brand, model B-300 Base.

To analyze the yield between both cultivation treatments, the following variables were evaluated: height of the plant measured from the base of the stem to the apex; fresh and dry weight (without the root), in addition to the amount of dry extract obtained from 500ml of a 20.0% tincture. Weight measurements were made once the harvest was done between the third and fourth month after transplanting the cuttings.

The design is experimental at random, having been constituted by a treatment (hydroponics) and a control (conventional), 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, an analysis of variance and comparison of means was carried out by means of the Tukey test ($P \leq 0.05$), for continuous variables, with the statistical program Minitab® version 18.

## III. RESULTS AND DISCUSSION

**Plant height**

According to the data obtained, it was observed that the Arnica and Lemon balm plants were favored by hydroponic production (inorganic substrate with nutrient solution) compared to the control, conventional production (organic substrate without nutrient solution) showing significant differences as observed in table 1. In both cases the growth was higher in Arnica its height increased by 36.5%, for Melissa its increase was 38.4%, in both cases it is compared to the control as observed in figure 1.

*Cuadro 1. Árnica (Arnica montana L) and Toronjil (Agastache mexicana) height, grown under greenhouse conditions.*

| Treatment | Plant height (cm) Árnica | Toronjil |
|---|---|---|
| Hydroponics (inorganic substrate with nutrient solution) | 106.8 a[z] | 99.4 a |
| Control (organic substrate without nutrient solution) | 78.2 b | 71.8 b |
| ANOVA=p≤ | <.0001* | <.0001* |
| DMS | 5.146 | 5.457 |
| CV | 3.814 | 4.371 |

[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= least significant difference.

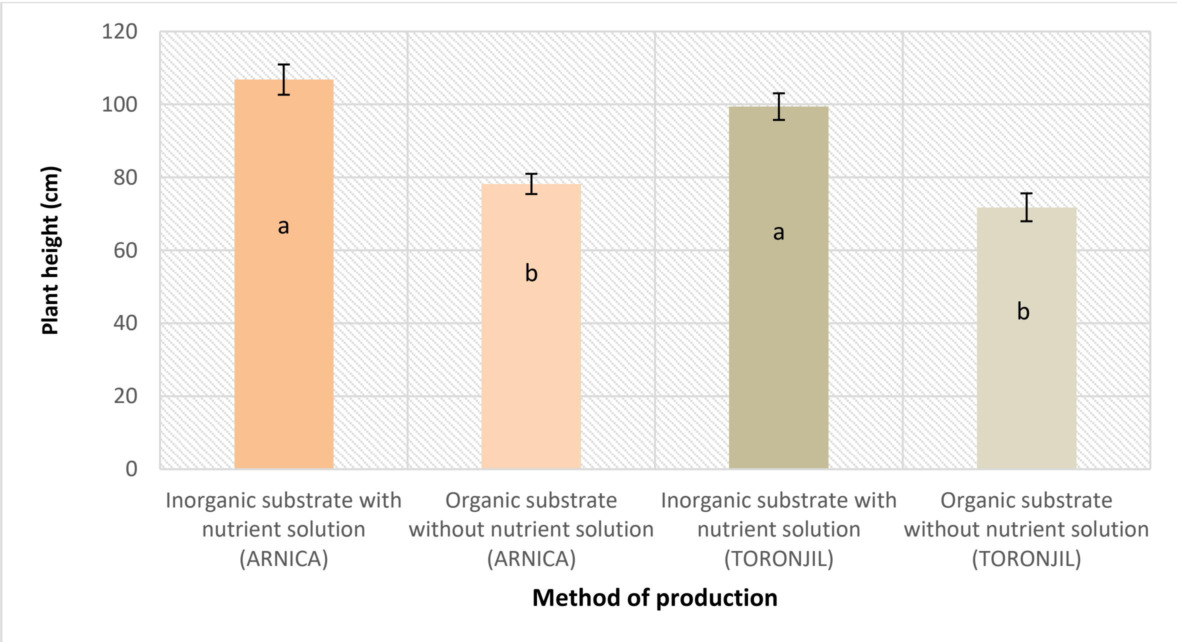


*Fig.1. Plant height of Arnica (Arnica montana L) and Toronjil (Agastache mexicana), produced under greenhouse conditions. Treatments with the same letter are statistically the same for each species (Tukey, p<0.05). The bars include the standard deviation of the mean.*

Studies that address the production of medicinal plants from a hydroponic method are scarce or almost non-existent, however, in the literature it is reported that Wormwood (*Artemisa absinthium* L.) cultivated using a 50.0% Steiner nutrient solution increased the height at least 25.0% with respect to the control that were not treated with hydroponic profile. [(18a)]

In this same order, relevant information can be found for non-medicinal plants, but for edible plants, such is the case of tomato and purslane, where the application of nutrient solution brought about an increase in the height of the plant, between a 3.0 and 4.0% for the first case and 27.0% for the second, in both cases it is with respect to the control without nutritive solution. [(20,21)]

The continuous and balanced supply of nitrogen and phosphorus provided by the nutrient solution are essential for plant growth, since both are structural elements for the plant. Where nitrogen is part of amino acids, proteins, coenzymes, nucleic acids and chlorophyll, and also; promote rapid cell division and elongation that favors plant height, while phosphorus constitutes enzymes, nucleic acids, phospholipids, glucose, ATP and is a very important growth factor, favoring root development at the beginning of the vegetative cycle that later It will help to obtain a greater height of the plant. [22]

**Plant fresh weight**

According to what is presented in table 2, it is observed that the fresh weight of Arnica and Toronjil present significant differences between the hydroponic production (inorganic substrate with nutrient solution) and the control (organic substrate without nutrient solution); resulting in the hydroponic method who promotes a greater formation of biomass (fresh weight). On the one hand, in Arnica the increase corresponded to 81.0% with respect to the control, while for purple lemon balm this increase was almost double 93.6% as recorded in figure 2.

*Cuadro 2. Fresh weight of Arnica (Arnica montana L) and Toronjil (Agastache mexicana), grown under greenhouse conditions.*

| Treatment | Plant fresh weight (g) | |
|---|---|---|
| | Árnica | Toronjil |
| Hydroponics (inorganic substrate with nutrient solution) | 454.39 a$^z$ | 64.99 a |
| Control (organic substrate without nutrient solution) | 251.01 b | 33.56 b |
| ANOVA=p≤ | <.0001* | <.0001* |
| DMS | 20.54 | 3.301 |
| CV | 3.99 | 4.60 |

$^z$ 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= minimum significant difference.

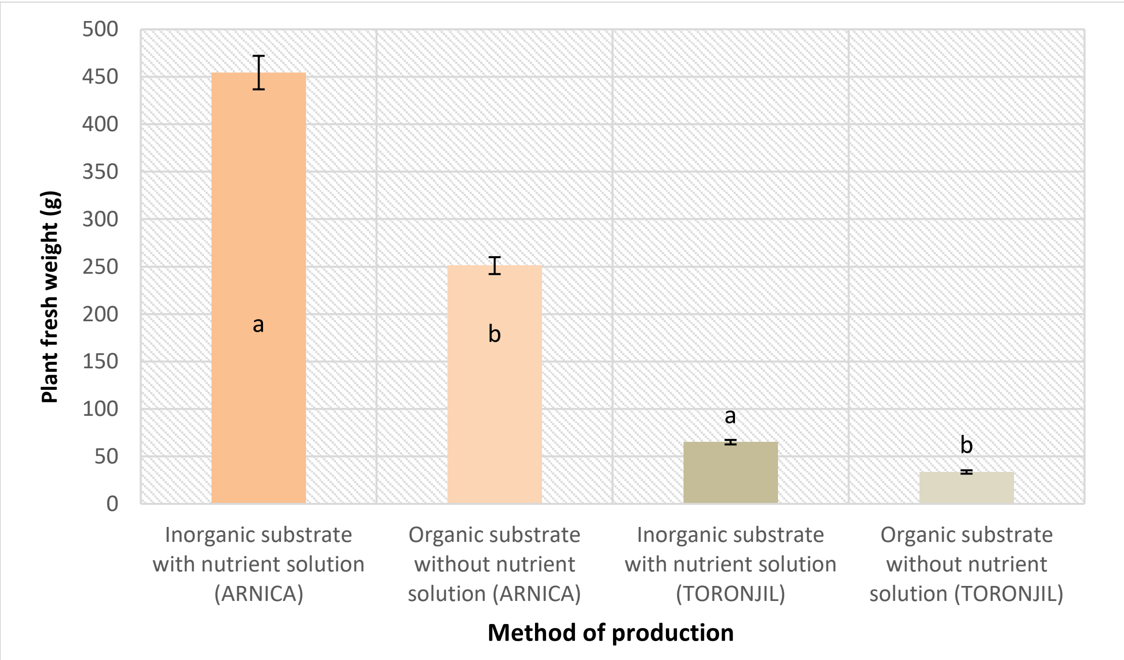


*Fig.2. Fresh weight of the Arnica plant (Arnica montana L) and Toronjil (Agastache mexicana), produced under greenhouse conditions. Treatments with the same letter are statistically the same for each species (Tukey, p<0.05). The bars include the standard deviation of the mean.*

As previously mentioned, no studies are reported in the literature that specifically relate medicinal plants and the use of nutritive solutions; however, what was stated in the previous paragraph partially coincides with what has been reported in the cultivation of thyme, where it has been mentioned that when cultivated under a greenhouse in a hydroponic system, 18.45 kg m–2 of biomass (fresh weight) can be obtained per year. , while in the open field only 3.79

kg m–2 per year are obtained, offering this cultivation system an increase in fresh weight yield of 386.8 %. [23]

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. [24]

**Plant dry weight**

In the same way as the previous cases, this variable was also favored by the hydroponic production in both observed species, showing significant differences between the hydroponic method and the control as shown in table 3. In Arnica the increase was 56.0% while that for the toronjil this difference was more evident, around 70.3 % with respect to the control in both species as can be seen in Figure 3.

Additionally, it is important to mention that the plants with an organic substrate without nutrient solution (control), presented a greater loss of water, unlike those that were produced by a hydroponic method.

*Cuadro 3. Dry weight of Arnica (Arnica montana L) and Toronjil (Agastache mexicana), grown under greenhouse conditions.*

| Treatment | Plant dry weight (g) | |
|---|---|---|
| | Árnica | Toronjil |
| Hydroponics (inorganic substrate with nutrient solution) | 113.6 a[z] | 14.29 a |
| Control (organic substrate without nutrient solution) | 72.79 b | 8.39 b |
| ANOVA=p≤ | <.0001* | <.0001* |
| DMS | 5.20 | 3.26 |
| CV | 3.83 | 4.80 |

[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= minimum significant difference.

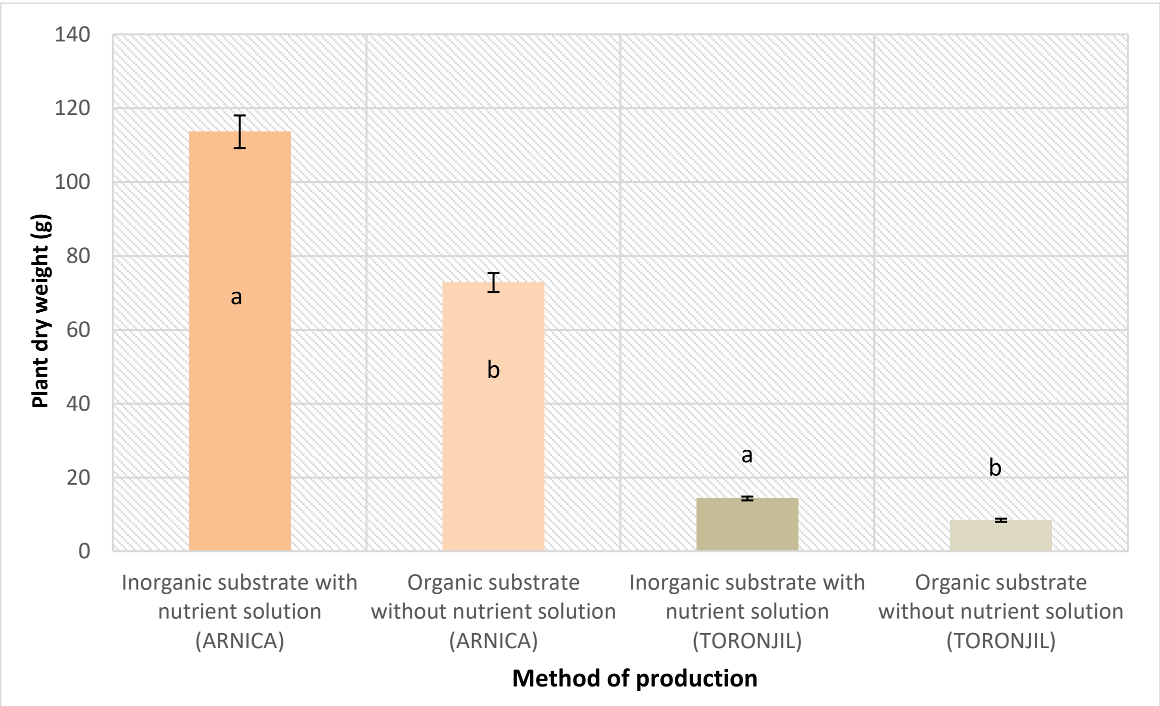


*Fig.3. Dry weight of the Arnica plant (Arnica montana L) and Toronjil (Agastache mexicana), produced under greenhouse conditions. Treatments with the same letter are statistically the same for each species (Tukey, p<0.05). The bars include the standard deviation of the mean.*

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. [25]

A higher percentage yield of dry extract was obtained for every 100g of plant drug obtained from the hydroponics treatment, as can be seen in figures 4 and 5 of Arnica and Toronjil respectively, although the difference that can be observed between hydroponic and the witness is minimal.

**Dry extract**

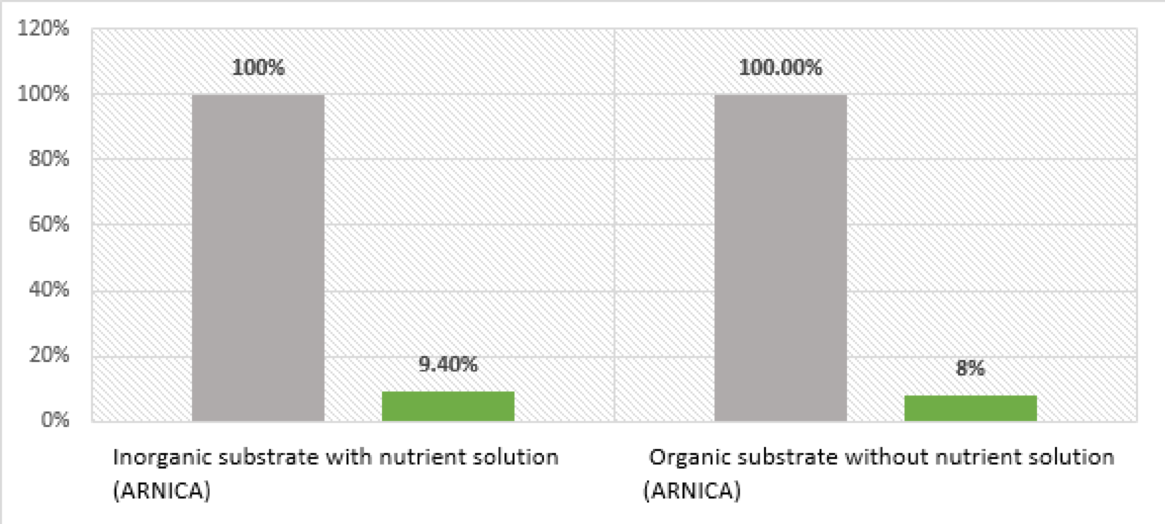


*Fig.4. Dry extract yield obtained from 100 g of Árnica plant drug (Arnica montana L) produced under greenhouse conditions.*

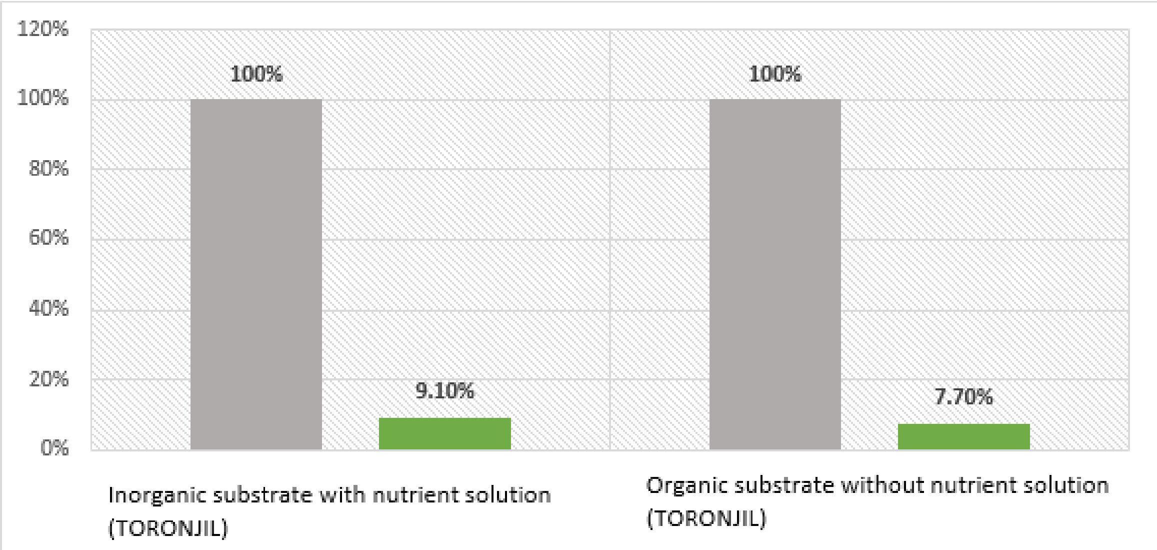


*Fig.5. Dry extract yield obtained from 100 g of Toronjil plant drug (Agastache mexicana) produced under greenhouse conditions.*

## IV. CONCLUSIONS

Based on the results obtained from the Arnica plant (*Arnica montana* L) and Toronjil (*Agastache mexicana*) they showed favorable growth through a hydroponic technique (inorganic substrate with nutrient solution) when compared with the conventional medium, control (organic substrate without nutrient solution) since, for the variables of height, fresh and dry weight there were significant differences.

The difference was stronger in the cultivation of Toronjil (*Agastache mexicana*) since the growth in height, fresh and dry weight was higher compared to the Arnica plant (*Arnica montana* L).

In the case of the dry extract in both species, the similar percentage yield from a 20.0% tincture, being slightly higher when they were treated by hydroponics, however; it could not be determined if there were significant differences since repetitions were not applied to this procedure, which will be important to verify at another time.

As described above; More extensive and in-depth research is needed on this type of hydroponic production and its effects on the agronomic and physical-chemical characteristics of medicinal plants, since the existing information is almost null and the results show that the hydroponic production of medicinal plants by less for these species and variables is an alternative that is worth considering to be used in the treatment of conditions for which they are traditionally used and it is necessary to compare the yields with other plants used in different traditional medicines to extend their benefits to other people.

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