"Hydroponic hop crop (*Humulus lupulus* L.) under greenhouse conditions in Mexico City".

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***Abstract*—** *H. lupulus is a dioecious plant member of the Cannabaceae family whose female flowers are used in the brewing industry. The value of female plants lies in the lupulin glands that contain resins and essential oils required for the flavor and aroma of beer. Hop crop growths between 35 ° and 55 ° latitude north and south, however, it has been possible to cultivate where conditions does not resemble those observed in the mentioned latitudes. Even more, hop has been hydroponic cultivated in traditional crop areas. Hydroponics provides controlled conditions, isolation and all needed nutrients in an aqueous solution. The aim of this work was to establish a hydroponic hop culture in greenhouse conditions, using a modified Hoagland nutrient solution. An average daily growth rate of 1.17 cm was obtained by rhizome plants and of 1.38 cm for those from freshly germinated seedlings, and an average overall height of 218 cm, an adequate growth when compared to the background of this crop. The data obtained show that hydroponics hop crops can be settle in areas with different conditions from those of the traditional cultivation zone.*

***Keywords*— Brewing industry, hop, hydroponics, rhizome, seedling.**

I. INTRODUCTION

H. lupulus is a dioecious plant member of the Cannabaceae family whose female flowers are used in the brewing industry. The cultivated hop, a short day, climbing, herbaceous plant produces new shoots in early spring and senesces to the perennial rootstock in autumn [1]. The value of female plants lies in the lupulin glands that contain resins and essential oils required for the flavor and aroma of beer [2, 3].

Hops are native to the regions of North America, Europe and Asia. It has been used in brewing for hundreds of years, the oldest crop known to date 500 years ago in central Europe [4]. Currently, the main producers are: Germany, the United States and China [5]. One of the most important places for hops cultivation is Hallertau, Germany, which has a Dfb climate (hemiboreal without dry season, mild summer and cold winter), according to the Köppen classification [6], these climatic conditions favor the growth of hops and for that reason, the main producers are areas with similar conditions. Due to the high demand of these flowers, it is now possible to find traditional hop crops in places with different conditions in countries such as Argentina, Chile and Mexico; while hydroponic crops, in addition to the first ones, that were carried out in Armenia, are also commercially developed in Colorado, United States [7, 8, 9, 10, 11, 12, 13].

Like any plant, hops need nutrients from the soil to develop, nitrogen, phosphorus, potassium, calcium, magnesium and sulfur that requires in large quantities (more than 1000 mg/kg of dry matter); and iron, manganese, zinc, boron, molybdenum, nickel, copper and chlorine, which the plant needs in small quantities (less than 100 mg/kg of dry matter) [14, 15, 16]. For the hops plant, the most critical macronutrients are potassium and nitrogen. Regarding micronutrients, hops are negatively impacted considerably by deficiencies of boron and zinc [17]. In the hydroponic culture established in Armenia, the nutrient solution of Davtyan was used: 311 ppm of nitrogen, 65 ppm of phosphorus, 350 ppm of potassium, 150 ppm of calcium and 30 ppm of magnesium as main nutrients [12, 18]. This technique could allow to establish crops in other places where there is a growing demand of high quality and inexpensive hops but the conditions are not favorable, as it is Mexico City [8, 19, 20, 21, 22, 23]. So, the aim of this work was to establish hydroponic hop culture in greenhouse conditions, using a modified Hoagland nutrient solution.

II. MATERIAL AND METHOD

Hop seedlings of the Cascade variety were kept in soil for three months and then each placed in a 1 liter glass with substrate (50% vermiculite and 50% agrolite) [24] and modified Hoagland nutrient solution "A" (Table 1). After 27 days, the plants were moved to larger containers (8L). Hop rhizomes of the same variety were also placed with the same treatment. After 107 days in "A" solution, both the seedlings and the rhizome plants were watered with the modified Hoagland nutrient solution "B" (Table 1). During the entire growth time (plant from seedlings 207 days and plant from rhizome 183 days), 2

measurements were taken a week from the length of the stem. A Student's t test was applied comparing the final size and the daily growth rate between rhizome plants and seedlings plants [25].

TABLE 1
NUTRIENT SOLUTION USED IN THIS WORK [28, 29, 30]

Element	Concentration		
	Hoagland	Hoagland modified "A"	Hoagland modified "B"
Nitrogen (NO_3 -N)	210 ppm	182.45 ppm	148.44
Phosphorus (P)	31 ppm	31 ppm	66.36
Potassium (K)	235 ppm	235 ppm	173.14
Sulfur (SO_4 - S)	64 ppm	71 ppm	71 ppm
Calcium (Ca)	200 ppm	283 ppm	283 ppm
Magnesium (Mg)	48 ppm	125 ppm	125 ppm
Iron (Fe)	1-5 ppm	12 ppm	12 ppm
Chlorine (Cl)	95 ppm	176 ppm	176 ppm
Manganese (Mn)	0.5 ppm	7 ppm	7 ppm
Boron (B)	0.5 ppm	2 ppm	2 ppm
Zinc (Zn)	0.05 ppm	7 ppm	7 ppm
Copper (Cu)	0.02 ppm	2 ppm	2 ppm
Molybdenum (Mo)	0.01 ppm	2 ppm	2 ppm

The last 90 days the plants were subjected to the photoperiod of Hallertau, Germany, beginning with 16 light hours and decreasing weekly 15 minutes the first four weeks, 20 the second four and 30 the last four weeks [26].

III. RESULTS AND DISCUSSION

The daily growth rate of the plants from the rhizome was 1.17 cm; In the case of plants from seed, the daily growth rate was 1.38 cm (figures 1, 2, 3). The Student t test with a confidence interval of 95% showed that there is no statistically significant difference between the two samples, in the same way the final average height reached by each group was 2.18 m and 3.048 m respectively for which there was no statistically significant difference.

FIG. 1. PLANTS FROM RHIZOME AND SEEDLINGS AT THE END OF THE EXPERIMENT.

Hops plants grew considerably under hydroponic conditions, reaching an overall average height of 2.54 m, but taller than two of varieties used by Pearson and collaborators [27], who reported average heights of 6.09 m, 4.89 m, 2.29 m and 2.21 m for the Chinook, Columbus, Amalia and Neo1 varieties respectively. There are commercially productive hop crops of Amalia and Neo1 varieties in the southeastern part of USA, even with these sizes.

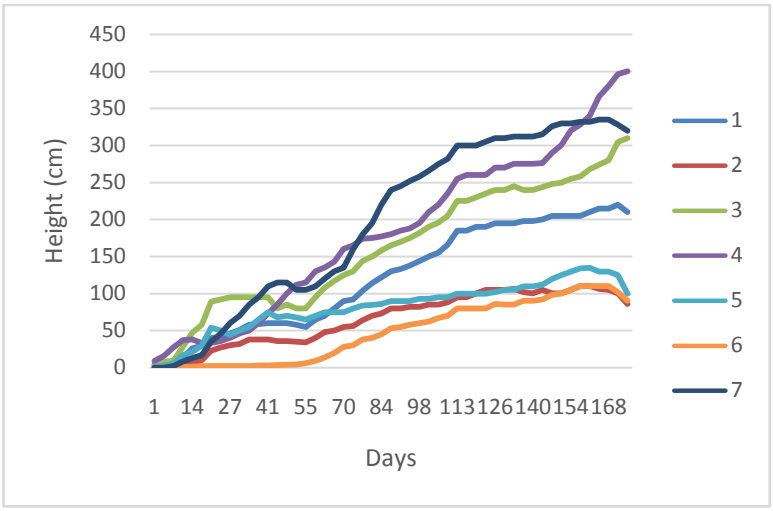

FIG. 2. GROWTH OF *H. LUPULUS* PLANTS FROM RHIZOMES.

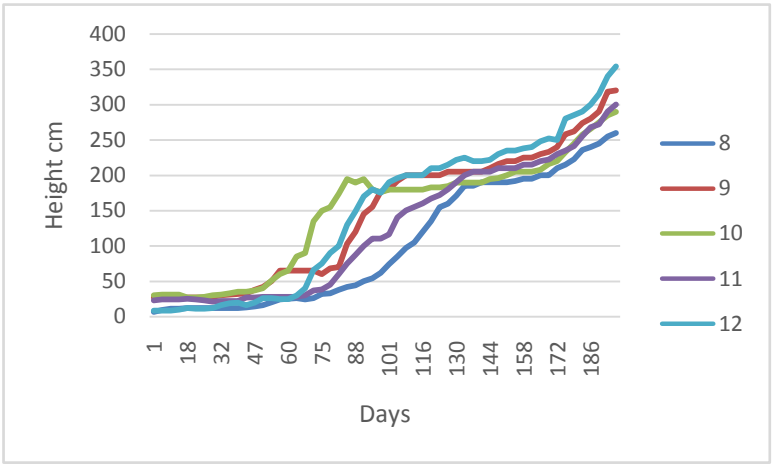

FIG. 3. GROWTH OF *H. LUPULUS* PLANTS FROM SEEDLINGS.

In contrast, hop plants grown in hydroponic culture [12], reached an average height of 4.3 m, however it is important to consider that Armenia is located in the latitudes corresponding to the traditional growing area.

IV. CONCLUSION

The results of this work support the establishment of hydroponic hop crops in places where conditions are not favorable, such as Mexico City, where there is a growing demand for high quality hops at a reasonable price.

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