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Quality and Yield of basil (*Ocimum basilicum* L.) essential oil under hydroponic cultivation

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ABSTRACT

Objective: to assess the production of basil (*Ocimum basilicum* L.) grown in a greenhouse under open hydroponic system, using tezontle (volcanic gravel) as substrate.

Methodology: three planting densities were evaluated: D1, D2 and D3 (14, 28 and 71 plants m^{-2}, respectively) and two concentrations of Steiner nutrient solution (S1: 100%, and S2: 50%).

Results: the highest values for fresh and dry weight of the aerial part, were the treatments S1 D1, S1 D2 and S2 D1. With S1 D1 the largest leaf area was obtained. Dry matter obtained was 14.03 mg g−1 of essential oil.

Findings: the use of hydroponics with an increase in sowing density can generate up to 70.21 t ha^{-1}.

Keywords: aromatic plant, sowing density, essential oil.

INTRODUCTION

Basil (*Ocimum basilicum* L.) is an aromatic plant native to South Asia of the Lamiaceae family, characterized by containing essential oils in all the aerial parts of the plant that give the species a particular smell and flavor. Those are product of its chemical components, which include estragol, eugenol, linalool, linalyl acetate, camphor, and o-cymene (Muñoz, 2002; Sam *et al*., 2002). Although in the past the chemical composition and properties of its oil were unknown, since ancient times it has been appreciated in traditional medicine. Nowadays, with the advancement in the knowledge and action of its components, basil essential oil has an immense value for perfumery, cosmetic, pharmaceutical and food industries (Muñoz, 2002; Kalita and Khan, 2013). In addition, antioxidant properties, insecticidal, nematicidal, fungicidal and microbicidal activities are attributed to it (Wannisorn *et al*., 2005; Bozin *et al*., 2006; Kelen and Tepe, 2007; Politeo *et al*., 2007; Abdullah *et al*., 2008).

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This species is cultivated in many countries, but the European Union and the United States are the largest importers and exporters where basil is marketed as fresh, dry, frozen, as essential oil, or in any other available form. Cost depends on the origin and cultivation type (Guerrero and Ruiz, 2012). In Mexico, basil cultivation covers 363 ha, mainly in Baja California Sur, Morelos, Nayarit and Baja California; the main producer is Baja California Sur, 273 ha (SIAP, 2015). *O. basilicum* cultivation is developed mainly in the field, without defined programs of irrigation, nutrition and planting densities. However, in order to increase yields and extending the growing season, the producers venture into greenhouse cultivation; even tough adequate nutrition has not been established to increase performance of the essential oil from the species. Considering the species potential is great, it seems possible that protected cultivation, complemented with the use of a balanced nutrient solution, in open hydroponic production system, can be an intensive production alternative, which facilitates supply throughout the year. Based on the above, the yield of basil (*Ocimum basilicum*) cultivated in hydroponics was evaluated at different planting densities and concentrations of nutrient solution.

MATERIALS AND METHODS

Basil seeds from Hortaflor™ were sown in 200-cavities germinating trays filled with a commercial organic substrate (Peat Moss™). Two daily irrigations with running water were applied until the appearance of the first true leaves; and from that stage on, it was watered once a day with a 50% Steiner nutrient solution until the moment of transplantation, which was carried out when the seedlings had 4 or 5 true leaves, at 45 d after sowing (in Spanish, dds).

The transplant was carried out in tezontle (inert volcanic gravel), granulometrics (3 to 5 mm in diameter) disinfected with 5% sodium hypochlorite, placed in beds 2.10 m long × 0.60 m wide × 0.20 m high, divided with Styrofoam plates in three equal parts. Each of these parts constituted a sowing unit (0.42 m^2), where basil seedlings were placed according to the studied planting densities D1, D2 or D3 (14, 28 and 71 plants m^{-2}, respectively). In general, 14 plants m^{-2} is the sowing density used by growers in conventional field cultivation. The Steiner universal nutrient solution (Steiner, 1984) was used at 100 and 50% (S1 and S2, respectively); the pH of the solutions was kept at 5.5. Watering was applied by dripping, 5 min four times a day, a daily flow of 1.33 L of nutrient solution, for each sowing density (0.42 m^2). The experimental design was completely randomized with four replicates, and a 3×2 factorial arrangement. The experimental unit consisted of three plants per density.

The harvest was carried out at the beginning of flowering (60 days after transplantation). Plants were cut from the base of the stem. The height of the main stem was measured in millimeters. Aerial parts were immediately weighed on a digital scale (ACCULAB VI-3 mg, USA). Total leaf area was determined with a LI-COR™-MODLI-3100 leaf area integrator. The leaves and stems of each harvested plant were placed in brown paper bags to be dried in an LC-Oven LAB-Line oven for 4 to 5 days, at a maximum temperature of 25 °C until constant weight was obtained.

The oil extraction was carried out by steam distillation of 35 g of dry matter, obtained by drying in the shade of three plants for each planting density. The chemical composition of basil oil was obtained by analyzing the samples in a gas chromatograph (HP 6890) coupled to a mass spectrometer (HP-5973). The components of the oil were identified by comparing their mass spectrum with the spectrometer database. The analysis was done following the methodology of Aligiannis *et al.* (2001) using linalool as a standard. With the data obtained, analysis of variance and Tukey means comparison test were performed, analyzing the data with the SAS statistical software, version 6.1 (SAS, 1994).

RESULTS AND DISCUSSION

In the final height of the plants, little significant difference was observed among treatments. However, the treatments S1 D1, S1 D2, and S1 D3 showed the highest values and S2 D3 registered the lowest plant growth (Figure 1). Although the highest value obtained was 30.17 cm, at S1 D3, great heterogeneity of sizes was also observed in this density, attributed to the competition for nutrients and light. Similar observations were made by Velásquez (2019), who reported that a high planting density caused a decrease in yield, due to competition and proliferation of pathogens. Considering size variation under S1 D3, the treatments S1 D1 and S1 D2 were considered as the best, if the objective of the producer was to obtain taller plants.

The obtained results suggest that by providing a 100% nutrient solution, basil reaches its optimum growth,

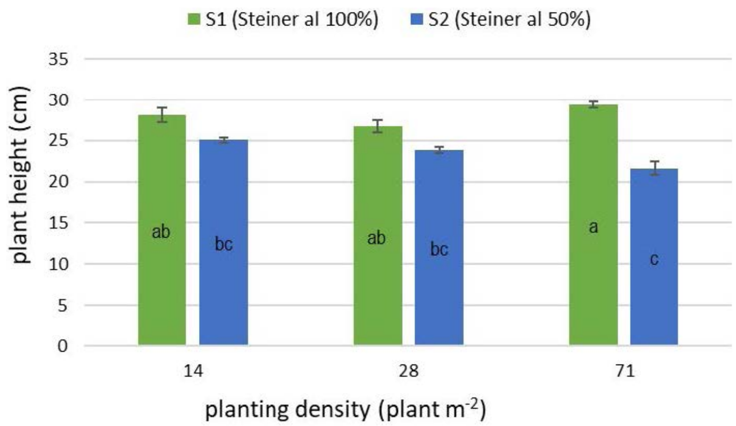

Figure 1. Basil (*Ocimum basilicum* L.) plant height, cultivated with two nutrient solutions (S1: 100% and S2: 50%) and three planting densities (D1: 14, D2: 28 and D3: 71 plants m^{-2}) ± standard error. Means with different letters show significance (Tukey α=0.05).

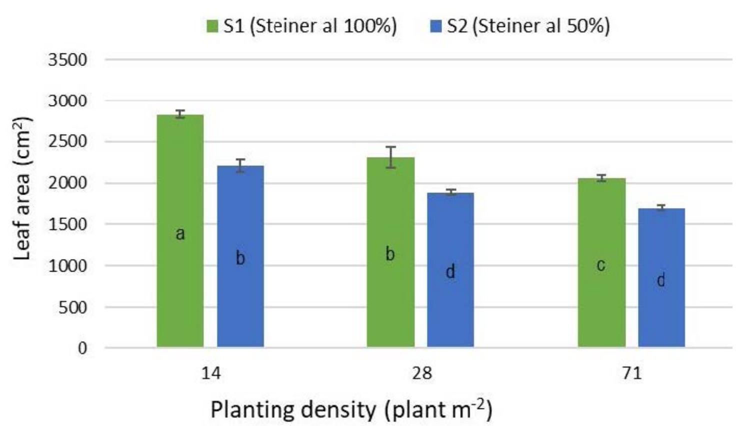

Figure 2. Total leaf area of basil plants (*Ocimum basilicum* L.), grown with two nutrient solutions and three planting densities, (plants m^{-2}) ± standard error. Means with different letters show significance (Tukey α=0.05).

obtaining those 13 nutrients which are necessary for its different physiological functions. Such a circumstance agrees with Santos *et al*. (2005), who conclude that nutrient availability affects basil height growth. Their results showed a positive response in height by providing 100% of nutrients and an inverse effect by reducing nutrients to 50%.

An increase in fresh and dry weight of the aerial part could be observed, with the treatments S1 D1, S1 D2 and S2 D1, while S1 D3, S2 D2 and S2 D3 showed lower values (Table 1). Although these results show that any of the three aforementioned treatments can be used, it is considered that with S1 D2 higher yields of fresh and dry weight per unit area can be obtained; since it is the one with the largest number of plants compared to S1 D1 and S2 D1. Open field crops in Mexico reach a yield of 8.89 t ha^{-1} of fresh weight (SIAP; 2015), while with the use of this system with S1 D2, up to 70.21 t ha^{-1} can be obtained, increasing production by 600 %.

Regarding leaf area, the statistical difference of S1 D1 (2828.44 cm^2) was clear, over the rest of the treatments (Figure 2) S1 D2 was statistically lower (2308.89 cm^2). However, if the 100% increase in plants per unit area is considered, then the recommended treatment for this variable is S1 D2, as S1 D3 treatment was the one that presented the lowest value, possibly due to the competition for light and nutrients.

It has been shown by Sifola and Barbieri (2006), that basil is a species that responds positively to the increase of nitrogen and phosphorous fertilizers, causing an increase in the foliar area, which generates an increase in fresh- and dry weight of the plant. This also causes an accumulation of secondary metabolites; a circumstance that was observed in this research when the tallest plants of S1 D1 and S1 D2 were the ones that also presented the highest values of fresh and dry weight. The yield of essential oils obtained ranged between 10.47 and 14.03 mg g^{-1} of dry matter. However, the comparison of means did not show significant differences among the evaluated treatments (Figure 3). With S1 D2, the percentage obtained was the one with the lowest value, but even so, it was 1.047%, higher than the 0.13% obtained by Teixeira *et al*. (2002). Furthermore, although statistical

Table 1. Means comparison of fresh- and dry weight of the aerial part of basil (*Ocimum basilicum* L.) plants cultivated with two nutrient solutions and three planting densities.

Nutrient solution Steiner	Planting density (plant m^{-2})	Fresh weight aerial part (g)	Standard error	Dry weight aerial part (g)	Standard error
100%	14	354.5a	±16.05	39.0a	±1.76
	28	250.7ab	±22.80	27.5ab	±2.51
	71	194.2b	±30.41	23.3bc	±3.65
50%	14	280.3ab	±19.40	33.6ab	±2.33
	28	205.3b	±26.43	24.6bc	±3.17
	71	172.3b	±38.54	18.9c	±4.24

* Means with different letters show significance (Tukey α=0.05); SE=Standard error. Each value is the mean of 3 replicates ± standard error.

differences were not evident among treatments, the choice S2 D2 allowed obtaining the highest yield of essential oil (14.03 mg g^{-1} DM).

From the sample analyzed in the gas chromatograph, a total of six components were obtained, the most abundant observed was linalool (Table 2). No differences were observed among treatments, in terms of essential oil components. Despite the fact that the concentration and composition of the essential oil from basil has been reported as irregular due to the chemotypes of the species, several authors agree that the majority component of this species is linalool (Smith *et al.*, 1997; Sánchez *et al.*, 2000; Teixeira *et al.*, 2002; Fernández *et al.*, 2004), a circumstance that was observed in our research. In the present study, it was demonstrated without any doubt that greenhouse cultivation with a hydroponic system, at the planting density D2, allows the production of basil with high yields and commercial quality, both for the fresh market and for the essential oils industry.

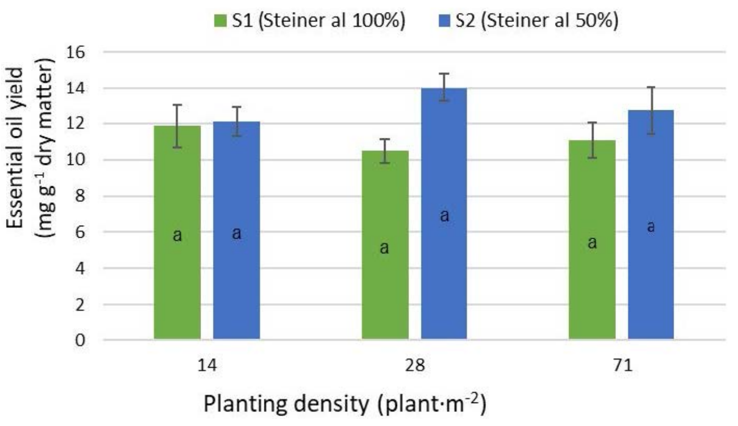

Figure 3. Yield of the essential oil from basil (*Ocimum basilicum* L.) grown with two nutrient solutions and three planting densities. Values are means ± standard error. Means with different letters show significance (Tukey α=0.05).

CONCLUSIONS

The planting density D2 (28 plants per m^2) is suggested. When the cultivation is required for leaf production, the use of the 100% nutrient solution (SI) is recommended, whilst, for the production of essential oil, we suggest the 50% nutrient solution (S2).

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Table 2. Major compounds in the essential oil of basil (*Ocimum basilicum* L.), grown with two nutrient solutions and three planting densities.

Compound	Retention time (min)	Area (%)
Linalol	12.889	32.633
Terpin-4-ol	15.768	0.850
Borneol	19.685	1.148
Cyclohexane-1-ethenyl-1-methyl-2,4-bis(1-methyleth)	23.246	1.377
Methyl eugenol	23.660	1.527
1,6-cyclodecadiene, 1-methyl-5-methylene-8-(1-methyl)	26.044	0.630

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