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SCIENTIFIC ARTICLE

Hydroponic production of ornamental sunflower with cooling of the nutrient solution and planting density

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Abstract

The temperature of the nutrient solution is one of the main obstacles of hydroponic production in hot climates and can affect the nutrient absorption of plants. Additionally, the hydroponic cultivation of cut flowers is rarely done, and hence, there is a lack of studies on this topic. The objective of this experiment was to determine the ideal temperature of the nutrient solution as well as the influence of the plant density factor for hydroponic cultivation in NFT (Nutrient Film Technique) of the cultivar *Girassol de Jardim Amarelo Alto*, *ISLA*®. The experiment was installed in a greenhouse, with 50% shading. The experiment adopted a completely randomized design in a factorial scheme with plots subdivided in space, with the main plots composed of two densities (15 and 30 plants m^{-2}) and the subplots of four temperatures of the nutrient solution (20, 25, 30 °C and uncontrolled temperature) with three replications each. The variables analyzed were plant height, stem diameter, internal and external diameter of the flower, number of leaves, number of buds and flowers, dry and fresh root mass, dry and fresh shoot mass, and cultivation cycle. The data were submitted to an analysis of variance using the statistical software SISVAR. The density of 15 plants m^{-2} proved to be more efficient, presenting plants of commercialization standard. Cooling the nutrient solution did not improve the production and quality of sunflower flowers.
Keywords: cut flower, *Helianthus annuus* L., hydroponics, ornamental plants.

Resumo

Produção hidropônica de girassol ornamental, com refrigeração da solução nutritiva, e adensamento de plantio.

A temperatura da solução nutritiva é um dos principais empecilhos para a produção hidropônica em climas quentes, podendo afetar a absorção de nutrientes pela planta, além disso, o cultivo hidropônico de flores de corte não é usual, carecendo de trabalhos na área. Objetivou-se com o presente experimento determinar a temperatura ideal da solução nutritiva, assim como a influência do fator adensamento de plantas para cultivo hidropônico, em sistema NFT (Nutrient Film Technique), da cultivar "Girassol de Jardim Amarelo Alto", ISLA®. O experimento foi instalado em casa de vegetação, com sombreamento de 50%. O delineamento experimental adotado foi o inteiramente casualizado em esquema fatorial com parcelas subdivididas no espaço, sendo as parcelas principais compostas por 2 adensamentos (15 e 30 plantas m^{-2}) e as subparcelas por 4 temperaturas da solução nutritiva (20, 25, 30 °C e temperatura não controlada) com 3 repetições. As variáveis analisadas foram: altura de planta; diâmetros da haste, diâmetro interno, e externo da flor; número de folhas, número de botões e flores; massas seca e fresca de raiz, massas seca e fresca da parte aérea e ciclo de cultivo. Os dados foram submetidos ao teste de análise de variância, no software estatístico Sisvar. O adensamento de 15 plantas m^{-2} se mostrou mais eficiente, apresentando plantas com padrão de comercialização. O resfriamento da solução nutritiva não melhorou a produção e qualidade das flores de girassol.
Palavras-chave: flor de corte, *Helianthus annuus* L., hidroponia, plantas ornamentais.

Introduction

In 2019, the ornamental flower production and trade sector generated a total of 210,000 direct jobs and 800,000 indirect jobs, with 8,700 producers working with 350 species and more than 3,000 different varieties of plants (IBRAFLOR, 2021).

The monopolization of cut flowers production in great centers in Brazil is one of the main obstacles to the development of the sector beyond these regions. Production being concentrated in a small number of areas impairs its demand for other regions, and scarcity consequently increases its value in the market (SEBRAE, 2015).

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The ornamental sunflower (*Helianthus annuus*) is a commercialized plant belonging to the Asteraceae family, which is erect and herbaceous, usually without branching, whose height can vary between 1.0 to 3.0 m. It is a product of the genetic improvement of grain sunflower, cultivated over a long period to extract seeds for food purposes (Paiva and Almeida, 2014).

Pest control and correct fertilization are often impaired in soil cultivation, and hydroponic cultivation is an alternative that helps to minimize these barriers. Through this cultivation system, it is possible to produce plants of good phytosanitary quality in a shorter production cycle, in addition to producing material with better quality in the post-harvest (Boldrin et al., 2022).

Furthermore, hydroponic cultivation enables temperature manipulation of the nutrient solution, which could facilitate the utilization of cultures in places with adverse climatic conditions (Al-Rawahy et al., 2019; Sulaiman et al., 2020).

Therefore, the objective of this experiment was to determine the ideal temperature of the nutrient solution, as well as the influence of the plant density factor, for hydroponic cultivation in NFT (Nutrient Film Technique) of the cultivar *Girassol de Jardim Amarelo Alto*, ISLA®.

Material and Methods

The experiment was performed between the months of July and October 2021. The region is characterized by the predominance of a hot and humid climate, of the Tropical type, with a dry winter (Awa, according to the Köppen classification), consisting of two defined seasons: rainy, from November to April, and dry, from May to September (latitude 16°4'36.27" South and longitude 57°39'10.77" West). The average annual temperature is 32.4 °C, reaching temperatures of 40 °C. The annual rainfall is approximately 1,335 mm (Costa et al., 2020).

Cut sunflower seeds, of the *Amarelo de Jardim Alto* variety from the company ISLA, were used. According to the manufacturer, they have an average flowering time of 60 days, with a recommended planting time during the months of August to February (ISLA, 2021).

The implementation of the system was performed in an area with an environment protected by a screen with 50% of shading mesh. The experiment adopted a completely randomized design in a factorial scheme with plots subdivided in space, with the main plots composed of two densities (15 and 30 plants m^{-2}) referred to in the text as A15 and A30 and the subplots of four temperatures of the nutrient solution (20, 25, 30 °C, and uncontrolled temperature) treatments named as T20, T25, T30 and UT with three replications each for a total of 24 experimental plots.

The cultivation system consisted of two horizontal benches containing 12 hydroponic cultivation channels each. The cultivation channels were arranged horizontally, measuring 1.5 m in length and 75 mm in diameter, spaced 25 cm apart, with circular holes measuring 4 cm in diameter spaced 20 cm apart.

The configuration adopted was NFT, so that a water depth of 2 cm was maintained throughout the experiment, adjusted by the rotation of the outlet pipe, which had an eccentric connection.

The nutrient solution circulation system consisted of four independent systems, one for each temperature. Each system had a 0.5 HP pump, which was responsible for sending the solution to six channels, three of each density. The flow in each channel was maintained at approximately 0.5 L min^{-1}, adjusted through registers at the entrance of each repetition, and the return was performed by gravity, maintaining a closed system.

The temperature values of the channels, as well as the temperature and ambient humidity, were monitored by DS18B20 and DHT22 sensors, connected to an Arduino datalogger system, formed by an Uno board and a datalogger shield, with the data stored in a text file in an SD card.

The solutions were cooled indirectly through the circulation of a cooled mixture of water and alcohol in a 5% proportion, pumped through copper coils inside each box of solution. A W1209 electronic thermostat was used to activate the system, connected to a contactor (a type of relay for high-power applications that turns devices on and off), which activated the cooling pump and a solenoid valve that directed the flow into the coil of the boxes. We highlight that the cooling system was in a closed circuit and had no direct contact with the nutrient solutions.

The sunflower seeds were sown in Styrofoam trays with 200 cells, with an individual capacity of 15.58 cm³ of substrate, which was medium grade vermiculite. These were watered with a standard solution for vegetable hydroponics. Germination happened on the third day and the seedlings were transplanted into the channels on the 20th day, when most plants reached the necessary height for transplanting (approximate height of 5 cm).

The seedlings were carefully removed from the cells, and the vermiculite was washed from their roots. They were transplanted into the cultivation channels, where they were tutored with cotton string.

The nutrient solution flow in the system occurred intermittently with the pump 15 minutes on and 15 minutes off, controlled by an analog timer, which activated a contactor and in turn activated the set of pumps. To avoid problems with oxygen availability for the roots, the solution was vortexed by adjusting the inlet flow, and the drops in the return channels were used to make it turbulent and insert air into the channel.

A conductivity meter and a portable pH meter was used to monitor the daily pH and conductivity values of the nutrient solution. The conductivity was maintained between 1,800 and 2,200 µS cm^{-1} and the pH between 5.5 and 6.5 (recommended by the manufacturer of the nutrient solution, for hydroponic cultivation in general). We used the manufacturer's recommendation for 100 L (66 g of Hidrogood Fert Compound + 49.5 g calcium nitrate + 3 g Fe EDDHA) (Table 1).

Table 1. Nutrient concentration in the nutrient solution used in the experiment (mg L^{-1})

N	P	K	Mg	Ca	S	Fe	Mn	B	Cu	Zn	Mo
142.73	59.40	184.80	21.78	128.70	28.38	1.80	0.33	0.40	0.07	0.13	0.46

To maintain an adequate supply of nutrients to all treatments, the nutrient solution was changed weekly. The evaluations were performed individually, according to the opening of the bud of each flower, with the petals at an approximate angle of 180°, considering the following parameters: plant height – PHt (cm), obtained from the length between the base of the plant and the base of the flower bud, measured with a physical tape measure; stem diameter – SmD (mm), obtained by measuring the diameter of the base of the commercial stem, 70 cm from the flower bud, with a caliper; stalk diameter – SkD (mm), obtained by measuring the diameter of the plant base, region of transition to the root, with a caliper; capitulum external diameter – CED (mm), obtained by measuring the external diameter of the inflorescence petals with a caliper; capitulum internal diameter - CID (mm), obtained by measuring the external diameter of fertile flowers with a caliper; fresh shoot mass - FSM (grams), obtained by measuring the fresh mass of the entire aerial part, excluding the root; fresh stem mass - FStM (grams), obtained by measuring the 70 cm commercial stem fresh mass; fresh root mass - FRM (grams), obtained by measuring the root fresh mass; dry shoot mass - DSM (grams), obtained by measuring the dry mass of the entire shoot, excluding the root; dry stem mass - DStM (grams), obtained by measuring the dry mass of a 70 cm commercial stem; dry root mass - DRM (grams), obtained by measuring the root dry mass; and days until flower opening - UFO (days).

All variables were analyzed using laboratory equipment: precision scale to determine fresh and dry mass, physical measuring tape, caliper and ruler to measure the biometry of the plants. The conventional drying method was used to dry the samples, using a forced air circulation stove and demand for 12 to 72 hours, at an average temperature of 65 ºC (Laurett et al., 2021).

Data were subjected to analysis of variance (f test) and, if statistically significant, the Scott Knott test was applied at 5% probability. To perform all the statistical analyses, the computational resources of the AgroEstat platform and the SISVAR software were used.

Results and Discussion

Inflorescences with good appearance were obtained, with good commercial characteristics, mean external diameter of 108.83 mm, mean internal diameter of 59.66 mm, and mean stem diameter of 13.42 mm. All stems were standardized with a height of 70 cm, meeting the commercialization standard, but the mean height of the plants was 119.79 cm.

The mean time until the total opening of the inflorescence was 64 days, slightly higher than the average reported by the manufacturer, which is 60 days (ISLA, 2021), and opening periods varied between 52 and 89 days.

Regarding the temperatures of the nutrient solutions, we found that the sizing of the cooling system was not enough to maintain the exact temperature of the treatments, however there was a difference in mean temperatures, as shown in Table 2.

Table 2. Mean temperatures of nutrient solutions, monitored by the Arduino system. Where: T20 is the average treatment temperature of 20 °C; T25 is the average treatment temperature of 25 °C; T30 is the average treatment temperature of 30 °C; TC is the average temperature of the control box.

Solution box temperatures			
T20 (°C)	T25 (°C)	T30 (°C)	TC (°C)
23.05	26.62	27.54	28.51

The experiment was set up with used or reused equipment, so that the actual thermal load of the environment was not calculated, which may have contributed to the temperature variations. As for the data analysis, for the variable CID there was a statistically significant difference, by the f test ($p \leq 0.05$), for the heat treatments applied. The CID means were compared using the Scott Knott test and the results are shown in Table 3.

Table 3. Table of measures of the internal diameter of the capitulum submitted to different temperatures of nutrient solution.

Temperatures of nutrient solutions	Capitulum internal diameter (CID) (mm)
Uncontrolled temperature (UT)	59.77 AB
20ºC	57.53 B
25ºC	58.40 AB
30ºC	62.92 A
DMS(5%)	5.01

Means followed by the same letters in the column do not differ by Tukey's test at 0.05% significance.

The temperature of 27.54 °C, referring to the T30 treatment, statistically differed from the temperature of 23.05 °C related to the T20 treatment, however the UT and T25 treatments presented a CID statistically equal to the T30. Therefore, energy expenditure to cool the nutrient solution had no effect on flower quality. Root-zone temperature is the important factor which can affect plant growth, yield, uptake of water and nutrient uptake (Al-Rawahy et al. 2019).

Other similar studies with thermal conditioning of nutrient solutions obtained divergent results from our study. Villela Junior et al. (2004), who obtained an increase in the productivity of the strawberry variety "Sweet Charlie" keeping the temperature the cooled nutrient solution at 12 °C. Triyono et al. (2019) found that different temperatures in nutrient solution storage tanks provided different phenotypic characteristics for bok choy, mustard greens, and Chinese broccoli, whereas Rawahy and Mbaga (2019) verified that the thermal conditioning of the nutrient solution promoted better financial return in the production of cucumber in Oman.

Recently, Sun et al. (2016) reported that RZ cooling increased shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, total plant fresh weight, and total plant dry weight in lettuce by 8.9%, 20.5%, 7.8%, 14.3%, 9.7%, and 8.5%, respectively. It is very common to use nutrient solution cooling in hydroponic cultivation systems up to a temperature of 23ºC, but without experimental safety. The results show that in this case, the producer spends electricity unnecessarily, as the lower temperatures do not affect the parameters that improve or increase the value of the commercialized product, but rather increase the variable costs of agricultural production.

Regarding the influence of the density factor, significant differences were observed for the values of CED (mm), CID (mm), SmD (mm), SkD (mm), SM (g), FStM (g), FRM (g), and DStM (g). In all these variables, the least dense planting (15 plants m^{-2}) presented means of more robust and showy physiological characteristics (Table 4 and Figure 1).

Table 4. Summary of analysis of variance (f test) for plant height – (PHt), stem diameter (SmD), stalk diameter (SkD), capitulum external diameter (CED), capitulum internal diameter (CID), fresh shoot mass (FSM), fresh stem mass (FStM), fresh root mass (FRM), dry shoot mass (DSM), dry stem mass (DStM), dry root mass – DRM and days until flower opening (UFO).

	F values											
	PHt	SmD	SkD	CED	CID	FSM	FStM	FRM	DSM	DStM	DRM	UFO
Density (D)	$0,13^{ns}$	15.19^{*}	7.78^{*}	9.42^{*}	14.17^{*}	14.67^{*}	$20,08^{*}$	8.64^{*}	$8,94^{*}$	8.94^{*}	$6,22^{ns}$	0.49^{ns}
Temperature (T)	1.96^{ns}	$0,15^{ns}$	0.16^{ns}	2.25^{ns}	3.97^{*}	1.19^{ns}	$0,26^{ns}$	0.12^{ns}	0.42^{ns}	0.43^{ns}	$0,33^{ns}$	2.01^{ns}
A x T	$0,75^{ns}$	$0,26^{ns}$	0.76^{ns}	1.14^{ns}	3.23^{ns}	0.23^{ns}	$0,91^{ns}$	0.28^{ns}	0.75^{ns}	0.75^{ns}	$0,62^{ns}$	0.71^{ns}

ns: non-significant effect; significance level: *$p < 0.05$.

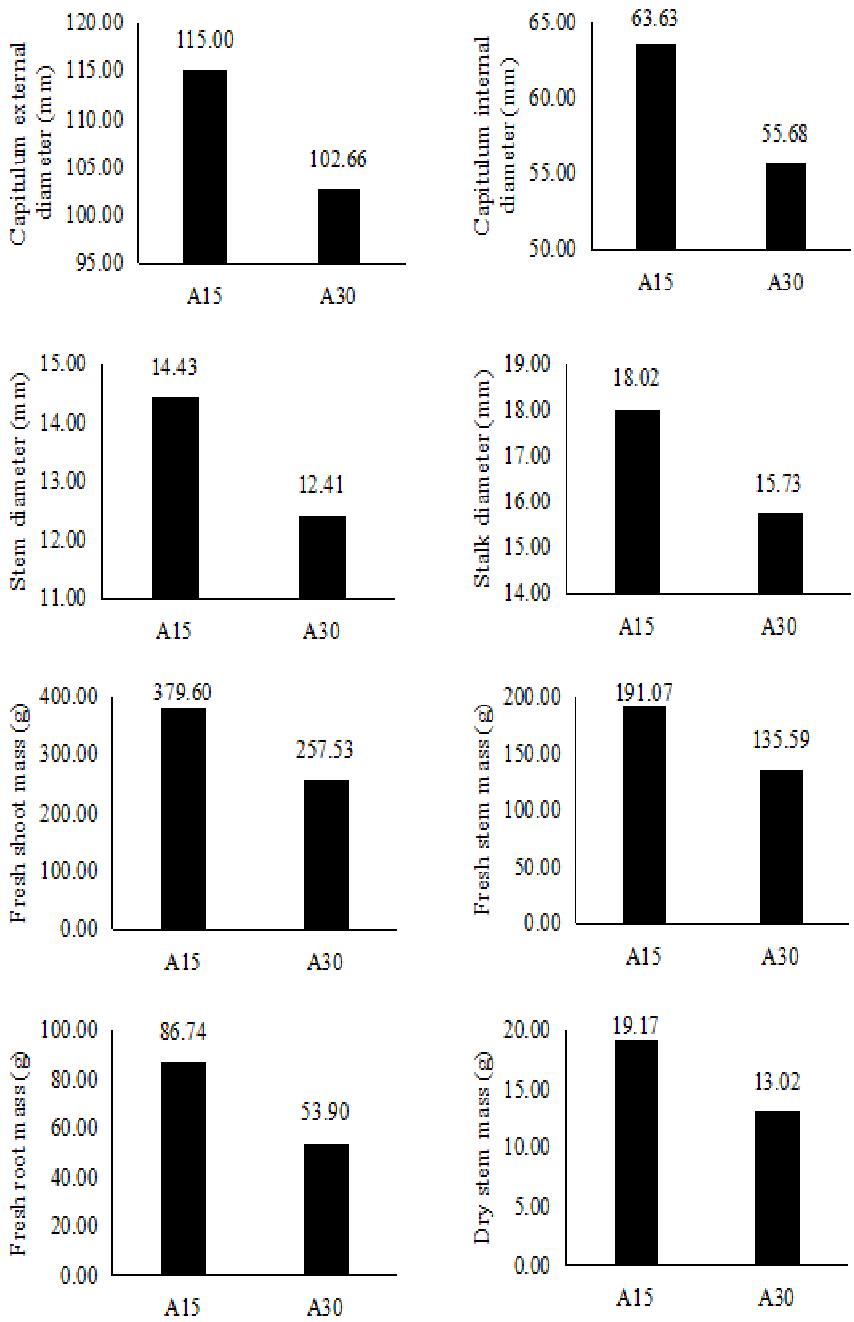

Figure 1. Mean values obtained for the variables in the higher (A30) and lower (A15) densities. Where: a) capitulum external diameter (CED); b) capitulum internal diameter (CID), c) stem diameter (SmD); d) stalk diameter (SkD); e) fresh shoot mass (FSM); f) fresh stem mass (FStM); g) fresh root mass (FRM); h) dry stem mass (DStM).

There are not many studies concerning the optimum plant density in the ornamental sunflower production as in other species. The results of planting spacing are in line with those obtained in the work of Mladenović et al. (2020), who verified that the density promoted differences in the values of CED in ornamental sunflower cultivars, and Júnior et al. (2015), who found that after 35 days of planting, density influenced the mean SkD of sunflower plants grown in a hydroponic system under saline stress and different planting densities. Mladenovic et al. (2020) identified that at the highest density (25 cm × 25 cm) the flower diameter was smaller than at the lowest density (70 cm × 30 cm), this occurred with the stem diameter.

The smaller diameter is suitable for the production of cut sunflowers because those flowers are more suitable and easier to handle in different flower arrangements. Bezerra et al. (2014) found that different spatial arrangements in sunflower plantations promoted phenotypic differences depending on the place of cultivation and according to them such differences may be related to the manifestation of phenotypic plasticity to habitat conditions.

As for the plant's roots, we found that they grew after a certain time of cultivation and competed for space within the cultivation channels, which may be one of the determining factors for the differences found between the densities. This result is similar to that obtained by Landgraf et al. (2017), who observed different patterns of commercial calla lily stems, working with different sizes of hydroponic profiles.

Conclusions

The automated hydroponic system in an NFT configuration, using a standard cultivation solution, is efficient for the production of cut sunflower in the southwest region of Mato Grosso.

A density of 15 plants/m² is the most suitable as it provides plants with good physiological characteristics reaching the commercialization standard.

The temperature of the solution indicated for sunflower cultivation is uncontrolled temperature, as it provides less energy expenditure.

Author Contribution

LAMA: main author of the manuscript, performing the analysis, tabulation of data and discussion of the results. **MKCV**: assistance in the implementation of the experiment, collection, tabulation and interpretation of data and construction of tables and graphs. **PBL**: conception of the work, data analysis and interpretation, drafting and critical revision of the article, final approval of the version to be published

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