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Germination and growth control in ornamental sunflower grown under photoconverter screen using different doses of gibberellic acid

Germinação e controle do crescimento de girassol ornamental cultivado em tela fotoconversora utilizando diferentes doses de ácido giberélico

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Highlights

A 500 mg L^{-1} dose of GA_3 induces the uniform germination of dwarf sunflower seeds.
Dwarf sunflower grown under photoconverter screens exhibit inproved flower quality.
Dwarf sunflower grown under photoconverter screens exhibit an improved growth rate.

Abstract

Helianthus annuus L., commonly known as the dwarf sunflower, has become popular in the ornamental flower market in Brazil, increasing its demand in floriculture retail. It is one of the most commercialized flowers. In addition to its unique characteristics, such as its inflorescence and vibrant petal color, it is a hardy plant that adapts to the different environments. However, excessive sunlight can harm its floral composition, affecting its appearance and marketability. Various management strategies have been adopted to achieve adequate productivity and meet market demands. These strategies include applying gibberellic acid to increase seed germination, and using photoconverter screens to minimize sunlight-induced damage to petals by altering light spectrum and intensity and converting direct radiation into diffuse radiation without impairing plant development and photosynthesis. Two consecutive experiments were conducted in this study. The first aimed to determine the optimal gibberellic acid dose by observing

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the germination speed index, and quantifying normal and abnormal seedlings. Four different doses (0, 100, 250, and 500 mg L^{-1} of gibberellic acid) were tested with four replicates. The second experiment aimed to verify the ideal color of photoconverter screen by comparing three treatments, including the control (without using photoconverter screens), a red photoconverter screen, and a silver photoconverter screen. Ten replicates were used, assessing agronomic traits essential for the commercial value of plants, such as plant height, stem diameter and length, root length, and relative growth rate of the plant. The experiments were conducted in the municipality of Dracena, São Paulo, Brazil. The first experiment was performed in a completely randomized design, while the second in a randomized block design, in a greenhouse with automatic irrigation. The results indicated that for dwarf sunflower seeds, the optimal dose of gibberellic acid was 500 mg L^{-1}, which achieved 100% germination after seven days and significantly differed from the lower doses for normal plants and plant length. This optimal dose was used in seed treatment for the second experiment. The results revealed that the use of both red and silver photoconverter screens improved the development of plants, increasing their height, stem diameter, and stem length, fundamental traits required for their commercialization, while improving the development and relative growth rate.
Key words: Dwarf sunflower. *Helianthus annuus* L. Potted Flowers. Vegetable regulator.

Resumo

Helianthus annuus L., comumente conhecido como girassol anão, vem se popularizando no mercado de flores ornamentais no Brasil, aumentando sua demanda no varejo de floricultura. É uma das flores mais comercializadas. Além de suas características únicas, como sua inflorescência e a cor vibrante das pétalas, é uma planta rústica que se adapta aos diferentes ambientes. No entanto, o excesso de luz solar pode prejudicar sua composição floral, afetando sua aparência e comercialização. Várias estratégias de manejo têm sido adotadas para atingir a produtividade adequada e atender às demandas do mercado. Essas estratégias incluem a aplicação de ácido giberélico para aumentar a germinação das sementes e o uso de telas fotoconversoras para minimizar os danos induzidos pela luz solar às pétalas, alterando o espectro e a intensidade da luz e convertendo a radiação direta em difusa sem prejudicar o desenvolvimento da planta e a fotossíntese. Dois experimentos consecutivos foram conduzidos neste estudo. O primeiro teve como objetivo determinar a dose ótima de ácido giberélico observando o índice de velocidade de germinação e quantificando mudas normais e anormais. Quatro doses diferentes (0, 100, 250 e 500 mg L^{-1} de ácido giberélico) foram testadas com quatro repetições. O segundo experimento teve como objetivo verificar a cor ideal da tela fotoconversora comparando três tratamentos, incluindo o controle (sem uso de telas), tela vermelha e tela prateada. Foram utilizadas dez repetições, avaliando características agronômicas essenciais para o valor comercial de plantas, como altura da planta, diâmetro e comprimento do caule, comprimento da raiz e taxa de crescimento relativo da planta. Os experimentos foram conduzidos no município de Dracena, São Paulo, Brasil. O primeiro experimento foi realizado em delineamento inteiramente casualizado, enquanto o segundo em blocos casualizados, em casa de vegetação com irrigação automática. Os resultados indicaram que, para sementes de girassol anão, a dose ótima de ácido giberélico foi de 500 mg L^{-1}, que atingiu 100% de germinação após sete dias e diferiu significativamente das menores doses para plantas normais e comprimento da planta. Esta dose ótima foi utilizada no tratamento de sementes para o segundo experimento. Os resultados revelaram que o uso de telas fotoconversoras vermelha e prateada melhorou o desenvolvimento de plantas, aumentando sua

altura, diâmetro do caule e comprimento do caule, características fundamentais para comercialização, ao mesmo tempo em que melhorou o desenvolvimento e a taxa de crescimento.
Palavras-chave: Flores em vasos. Girassol anão. *Helianthus annuus* L. Regulador vegetal.

Introduction

Floriculture in Brazil is growing due to the high demand for ornamental plants and the large-scale production of flowers by specialized centers. This expansion has increased the consumer market, making floriculture one of the fastest-expanding branches of agribusiness today (Moreira & Bento, 2018). According to data from the Instituto Brasileiro de Floricultura [IBRAFLOR] (2024), floriculture currently presents a gross domestic productivity of approximately R$ 18 billion. Helianthus annuus L., popularly known as the dwarf sunflower, is a species that assumes a prominent role, both for the production of potted flowers and cut flowers (Moura et al., 2022), which can be attributed to the emergence of new cultivars (Nascimento et al., 2019).

The capitulum-like inflorescence and heliotropism the act of following light beams provide this plant unique characteristics (Ecker, 2013). The sunflower plant can adapt to the environment, and its sowing season is wide, making it an alternative source of income for small producers, contributing to income generation in the field (Curti, 2010; Curti et al., 2012). The commercial value of the flower depends on both its aesthetic qualities, such as floral structure, capitulum length and diameter, and petal color, and its vase life (Siqueira et al., 2024), considering the aspects of shelf life and marketing.

Various techniques are used to break the dormancy of seeds to improve seed germination and produce healthy seedlings, including the use of gibberellin, a plant hormone implicated in dormancy breaking (Louzado et al., 2021), which yields superior results than those obtained with other methods (Saturnino et al., 2019). Pre-soaking seeds in gibberellin stimulates their germination and improves the germination speed index (GSI) (Aragão et al., 2006); therefore, when this technique is applied to high-quality seeds with high germination capacity, vigorous seedlings can be obtained (Castan et al., 2017).

Proper management ensures the optimal visual quality of sunflowers, enhancing their attractiveness in the market (Siqueira et al., 2024), and with the utilization of different management practices, the added value of commercialized plants can be increased. For example, photoconverter screens can stimulate morphophysiological reactions, offering alternatives to plant regulators, promoting the physical protection of the plant, reducing direct sunlight exposure, and improving microclimatic conditions (Pereira et al., 2020). The color of the photoconverter screen directly impacts the plant, with red being responsible for increasing the transmission of photosynthetically active radiation (Gama et al., 2017) and silver-colored screens being linked to increased stomatal density (Fogaça et al., 2007).

In this study, we aimed to determine the optimal dose of gibberellic acid (GA3) for treating ornamental sunflower seeds to obtain seedlings, and subsequently to verify the performance of plants grown under different photoconverter screens, aiming to achieve plants with better agronomic characteristics for commercialization. Our findings provide valuable insights for improving seed germination performance and obtaining desired agronomic attributes required for the commercialization of sunflower varieties.

Materials and Methods

This study included the development of two experiments, both performed at the *Faculdade de Ciências Agrárias e Tecnológicas of Universidade Estadual Paulista* (UNESP) on the Dracena Campus, São Paulo. In the first experiment, different doses of GA_3 were evaluated for the germination of dwarf sunflower seeds in the Fruit and Floriculture laboratory. The seedlings obtained from this experiment were used in the second experiment, which was conducted in a greenhouse.

The first experiment was conducted in a completely randomized design, using four doses of GA_3 (SIGMA®, concentration ≥ 90% GA_3 - $C_{19}H_{22}O_6$): 0 (control), 100, 250, and 500 mg L^{-1} of distilled water. Each treatment had four replicates. Seeds were immersed in these solutions for 4 h and then placed in Germitest paper, representing each experimental unit. The Germitest columns with seeds were then transferred to a biochemical oxygen demand incubator set at a constant temperature of 25 °C until the start of counts.

The germinated seedlings were classified as normal or abnormal on the fourth and seventh days after the treatments were set up. Seedling lengths were measured using a graduated ruler, from the tip of the largest root to the insertion of the cotyledons. The germination percentage was calculated from the count of seeds that produced epicotyls. On the seventh day, the normal and abnormal plants were counted and classified based on their development.

GSI was calculated using the formula described by Maguire (1962), which is as follows:

$$GSI = \frac{G1}{N1} + \frac{G2}{N2} + \cdots + \frac{Gn}{Nn}, \quad (1)$$

where *G* is the number of normal seedlings, and *N* is the number of days after setup.

On the seventh day, the seedlings were removed from the Germitest paper and weighed using a precision scale to obtain their fresh mass, and subsequently placed in an incubator at 65 °C for 48 h to determine their dry mass.

After the destructive analyses, the remaining seedlings were manually transplanted into plastic pots with a capacity of 1,050 mL, at a depth of 4 cm, filled with homogenized substrate of sandy soil from the UNESP campus area, “Carolina Soil” plant substrate, and vermiculite in a 1:1:1 ratio.

A randomized block design was used for the second experiment, with three treatments and 10 replicates. The three treatments were as follows: control, without photoconverter screen; red photoconverter screen with 50% shading; and silver photoconverter screen with 50% shading. The pots were placed next to each other, with the screens installed at a height of 10 cm. Irrigation was performed by microsprinkling three times per day.

The following parameters were evaluated: number of shoots; stem diameter in cm, using the Zaas Precision digital caliper, 76 days after the first height measurement; leaf length, length of the largest root and largest stem and height, in cm, using a transparent standard ruler; and root weight and total weight, using a precision scale. Plant growth in a given time interval was expressed as relative growth rate (RGR). The heights of the plants were measured at intervals of 5 days to obtain the data. RGR was calculated using Equation (2) as follows:

$$RGR = (\ln P_n - \ln P_{n-1})/(T_n - T_{n-1}), \qquad (2)$$

where $\ln P_n$ is the accumulated dry biomass at evaluation n, $\ln P_{n-1}$ is the accumulated dry biomass up to evaluation n−1, T_n is the number of days after emergence at evaluation n, and Tn_{-1} is the number of days after emergence at evaluation n−1, according to Benincasa (2003).

The data obtained in both experiments were subjected to the analysis of variance at $p \leq 0.05$, and when the differences were significant, the data were subjected to the Tukey's test ($p \leq 0.05$) using the SISVAR software (Ferreira, 2014). Regarding the analysis for determining the optimal GA3 dose, when the means were significant, they were adjusted for a second-order polynomial regression, which presented the highest *R*-squared value.

Results and Discussion

The results of the experiment for the determination of optimal GA_3 dose are shown in Table 1. The results revealed no significant differences in the first and second counts of germinated seeds, performed 4 and 7 days after the treatments were setup, respectively. However, the highest dose of 500 mg L^{-1} resulted in 100% seed germination by the seventh day, ensuring the uniformity of germination an important aspect for the commercial production of flowers. Similar results were reported by C. A. C. Santos et al. (2012), where the use of plant regulator mixtures containing GA_3 in sunflowers led to greater plant growth in seeds pre-soaked for 4 h. A similar pattern was observed in the present study for seedling length, where the highest dose presented the highest value, with a significant difference from the values obtained at other doses, as shown in Figure 1a. However, Rosisca et al. (2010), who used GA_3 to break dormancy in wild sunflowers, reported that a dose of 200 mg L^{-1} showed a significant difference compared with that in the control, which was not observed in this study.

Moreover, the percentage of normal seedlings (PNS) and the percentage of abnormal seedlings (PAS) also presented significant differences between treatments at the highest dose and those at the other GA_3 doses. At the highest GA_3 dose (500 mg L^{-1}), PNS exhibited an increase of 13% compared with that at the dose of 250 mg L^{-1}, with no significant differences in PNS between the treatments at the three lower doses. As shown in Figure 1b, from the inflection point of the curve, PNS increased with the increase in the treatment dose. Similar findings were reported by Souza et al. (2022), where umbu tree seeds immersed in 1,000 mg L^{-1} GA_3 for 48 h demonstrated increased germination percentage and plant vigor, resulting in more normal plants.

Table 1
Agronomic aspects of *Helianthus annuus* L. seeds subjected to the germination test with different doses of gibberellic acid

Treatment	FC	SC	PNS	PAS	SL	FM	DM	GSI
0 mg L^{-1}	94	94	79 b	12 ab	13.76 ab	8.51	0.59 b	9.23
100 mg L^{-1}	95	96	76 b	18 a	13.20 b	8.06	0.60 b	9.30
250 mg L^{-1}	91	91	84 b	7 ab	15.97 ab	9.36	0.56 b	8.94
500 mg L^{-1}	99	100	97 a	2 b	16.86 a	8.61	0.77 a	9.76
C.V. (%)	3.22	3.17	3.46	34.93	9.83	16.22	8.37	5.97
Mean	94.75	95.35	84	9.75	14.95	8.64	0,63	9.31

Means followed by the same lowercase letter in a column do not differ from each other, according to Tukey's test at 5% significance. FC, percentage of germinated plants in the first count (4 d); SC, percentage of germinated plants in the second count (7 d); PNS, percentage of normal seedlings (%); PAS, percentage of abnormal seedlings (%); SL, seedling length (cm); FM, fresh mass (g); DM, dry mass (g); GSI, germination speed index.

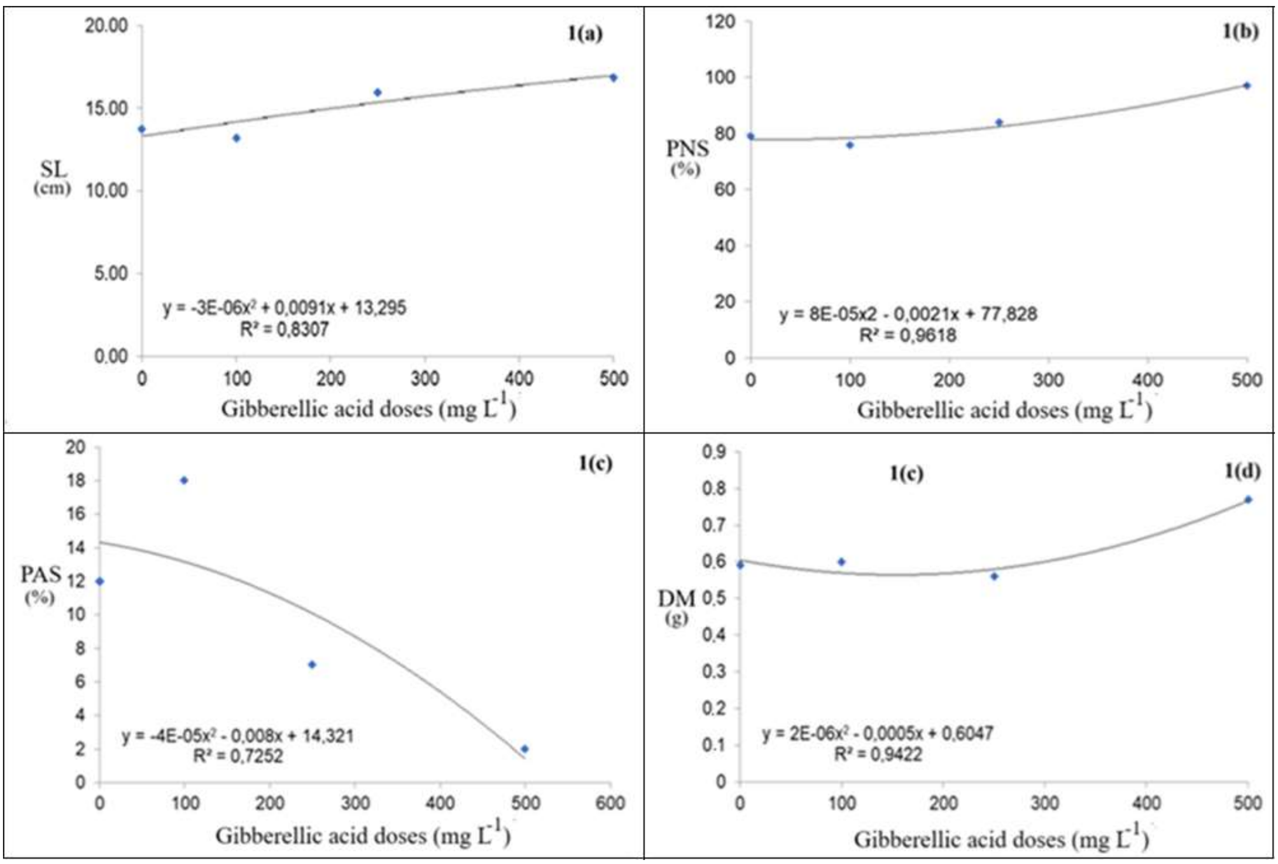

Figure 1. Second-order polynomial regression analyses for (a) seedling length (SL), (b) the percentage of normal seedlings (PNS), (c) the percentage of abnormal seedlings (PAS), and (d) dry mass (DM).

The same trend was observed for PAS, where the highest dose presented the lowest percentage of abnormality, with a significant difference from the values obtained at the three lower doses. Interestingly, the 100 mg L^{-1} dose presented a higher percentage of abnormality than that in the control treatment. Figure 1c shows the inflection point at 100 mg L^{-1}, i.e., as the dose increased, the abnormality of the germinated seedlings decreased. C. A. C. Santos et al. (2012) have reported that pre-soaking sunflower seeds for 4 h results in relatively few abnormal plants, which explains the results of the present study.

Fresh mass did not differ significantly between the treatments. Like the other parameters analyzed, dry mass presented better results at the dose of 500 mg L^{-1} than at the other GA3 doses (Figure 1d). This finding differs from the results reported by T. P. Santos (2021) for pitaya crops, where doses ranging from 150 to 300 mg L^{-1} of GA3 improved seedling emergence and vigor, both in terms of length and dry and fresh masses.

There were no significant differences in the GSI calculated for the different treatments; however, it followed the trend of other parameters, with the highest dose presenting the highest index. V. F. Silva et al. (2014) reported a GSI of 4.80, which indicates the most optimal treatment; therefore, the growth results obtained in the present study were optimal, even in the control treatment, which contrasts with the observations of Beidacki (2021) for alfalfa seeds, where the increase in GA_3 doses decreased GSI.

The results of the experiment with photoconverter screens (Table 2) showed no significant differences in the number of shoots (NS), leaf length (LL), root weight (RW), and total weight (TW) between treatments in full sun and with screens. Notably, the red and silver photoconverter screen treatments revealed significant differences in height, stem diameter (SD), stem length (SL), and root length (RL) compared with those in the control treatment. RL presented better results for the silver screen treatment than for the red screen treatment.

Table 2
Agronomic aspects of *Helianthus annuus* L. plants grown under photoconverter screens and under direct sunlight exposure

Treatment	H	NS1	SD	LL	SL	LR	RW	TW
Control	17.40 b	3.00	2.72 b	4.02	5.56 b	3.91 a	0,07	0,71
Silver	32,00 a	2.70	3.71 a	4.71	8.15 a	6.92 a	0,11	0.83
Red	34.35 a	3.20	3,89 a	4.07	7.86 a	5.69 ab	0,09	0.79
C.V. (%)	41.55	12.04	19.57	34.98	27.90	32.06	68.28	40.86
Mean	27.92	2.97	3.44	4.27	7.19	5.55	0.09	0.78

Means followed by the same lowercase letter in the column do not differ from each other using the Tukey's test at 5% significance; [1]values transformed by the equation $\sqrt{(x+0,5)}$. H: height (cm); NS - Number of shoots; SD: stem diameter (cm); LL: leaf length (cm); SL: stem length (cm); LR: length of largest root (cm); RW: Root weight (g); TW: total weight (g).

However, no significant differences were observed in height between the red and silver screen treatments, differing only from that in the control treatment. This result is consistent with the results of Nascimento et al. (2016), who obtained higher values for the stem height of the dwarf sunflower in treatments involving red- and silver-colored screens than those in the control. Guerra et al. (2020) obtained the same results with significance, but for basil crops, observing an increase in height of 36.03% and 31.31% for the red and silver colors, respectively, which was superior to the treatment in full sun. Therefore, the use of photoconverter screens with 50% coverage increases plant height.

According to Nomura et al. (2020), for cherry tomatoes, the use of red photoconverter screens did not influence SD, height, RL, or fresh and dry root masses. In other words, even though the light was diffused by the screen, the plants did not show the expected responses to an increase in the variables. However, the red screen obtained superior results for fresh mass, unlike in the present study, where SD and RL showed significant differences with the use of screens. Thus, the use of photoconverter screens has resulted in greater development of dwarf sunflower plants. Alves et al. (2024), in a study on *Talinum fruticosum* (L.) Juss., reported significant differences in SD and fresh and dry root mass, with the use of red and silver photoconverter screens, though no difference was noted in height. The most optimal results were obtained under the red mesh, corroborating the findings of the present study. The spectral quality of radiation impacts the response of plants to light stimuli (Taiz & Zeiger, 2013), stimulating their development.

The use of photoconverter screens improved the microclimate and quality of development of dwarf sunflower plants by diffusing sunlight, consistent with the results reported by D. F. Silva et al. (2020) in the cultivation of *Physalis* plants.

Regarding RGR, the control treatment (Figure 2a) showed an increase in RGR from the 10th day onwards, which continued until the 15th day. A similar trend was observed for silver and red photoconverter screen treatments (Figure 2b and 2c), where the inflection point of the curve was on the twelfth day, presenting a higher RGR than that in the control in full sun. This result is consistent with the results of Almeida (2023), who reported that seedlings of *Cichorium endivia* L. grown under red screens displayed a relatively high RGR at 10 days after emergence and superior plants at 20 days. Similarly, Novelli et al. (2015) obtained improved RGR in cupuaçu trees under 50% photoconverter screens. However, Gonçalves et al. (2017) have reported a decrease in RGR for lettuce crops with the use of photoconverter screens, which does not corroborate the results of the present study.

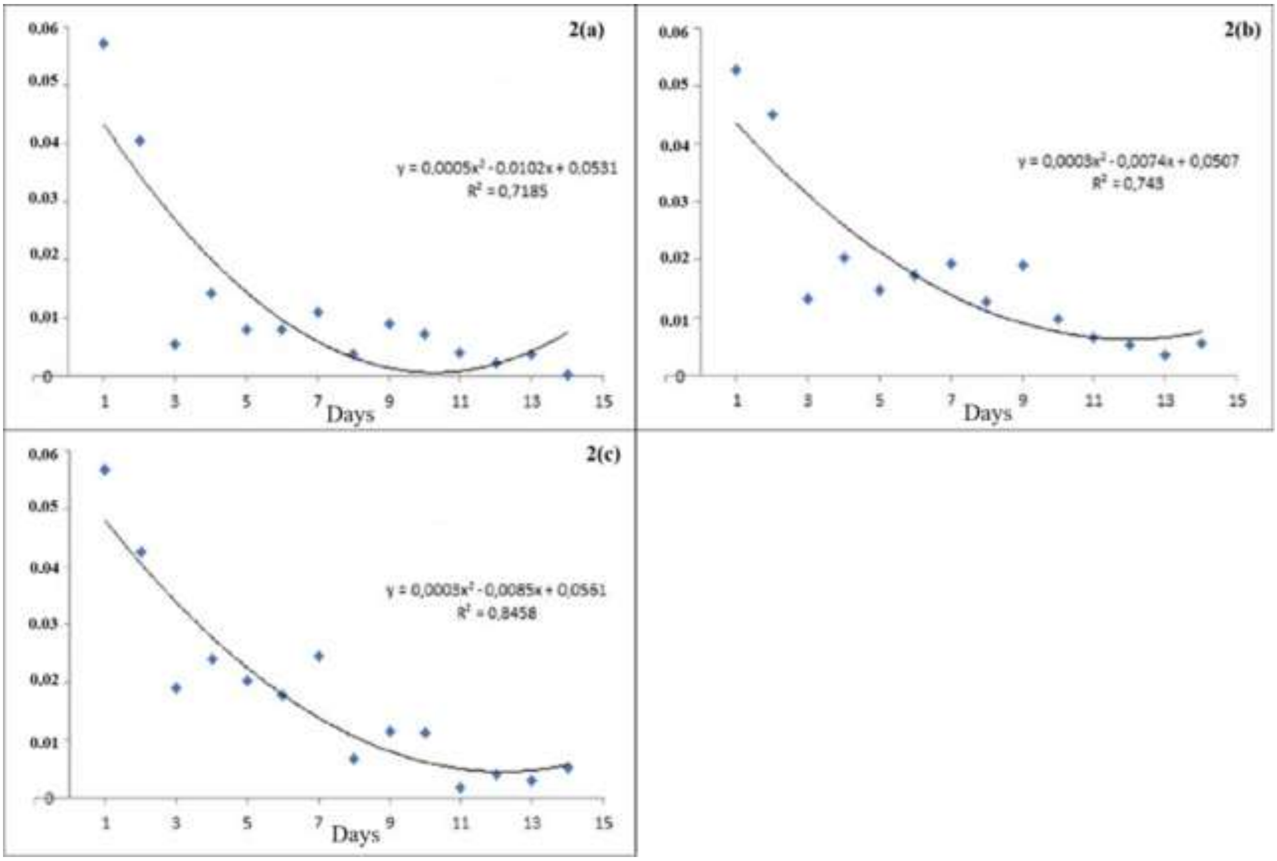

Figure 2. Relative growth rate of *Helianthus annuus* L. in (a) the control treatment, (b) the silver photoconverter screen treatment, and (c) the red photoconverter screen treatment.

Conclusions

The dose of GA_3 that presented the best agronomic benefits for dwarf sunflower seeds was 500 mg L^{-1}. The use of red and silver photoconverter screens in dwarf sunflower crops has been observed to improve the agronomic characteristics of the ornamental plant market by increasing the height, diameter, and length of the stem, indicating that the plant develops better with the absorption of diffused light provided by these screens.

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