Ornamental Horticulture
ISSN 2447-536X | WWW.ORNAMENTALHORTICULTURE.COM.BR

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Sociedade Brasileira de Floricultura e Plantas Ornamentais

ARTICLE

Chlorella sp.: a new sustainable alternative to preserve the quality of cut sunflowers

Chlorella sp.: nova alternativa sustentável para preservar a qualidade dos girassóis de corte

Tiago Ledesma Taira[1], Renan Marré Biazatti[1], Jackeline Schultz Soares[1], Carolina de Arruda Queiróz Taira[1], Bruno Lenhart Pinheiro[1], Isabelle Sabrina Azevedo Silva[1], and José Carlos Sorgato[1,*]

[1]Universidade Federal da Grande Dourados, Dourados-MS, Brasil

Abstract: This is the first study using the microalga *Chlorella* sp. in the postharvest treatment of cut flowers. This research aimed to evaluate the effects of different doses and application methods of *Chlorella* sp. on the vase life of cut stems of ornamental sunflower cv. *Vincent's Choice*. We conducted the experiment with the structure of the flower stem o different treatments of *Chlorella* sp. application (pulsing, spraying, and maintenance solution) in five doses (0; 5; 10; 15 or 20 mL L^{-1}). The results indicated that both spraying, and maintenance solution applications were beneficial. The calculated dose of 17.3 mL L^{-1} for spraying and 13.4 mL L^{-1} for the maintenance solution were the most effective in delaying the yellowing and rotting, preserving the flower stems' structure and color. Using *Chlorella* sp. as a floral preservative for this species represents a sustainable and efficient alternative, contributing to sustainable agricultural practices and opening new perspectives for future research and practical applications in ornamental horticulture.
Keywords: Bioinput, Cut flowers, *Helianthus annus* L., Ornamental horticulture.

Resumo: Este é o primeiro estudo utilizando a microalga *Chlorella* sp. no tratamento pós-colheita de flores de corte. Esta pesquisa teve como objetivo avaliar os efeitos de diferentes doses e métodos de aplicação de *Chlorella* sp. na vida de vaso de hastes cortadas de girassol ornamental cv. *Vincent's Choice*. Conduzimos o experimento com hastes florais submetidas a diferentes tratamentos de aplicação de *Chlorella* sp. (pulsing, pulverização e solução de manutenção) em cinco doses (0; 5; 10; 15 ou 20 mL L^{-1}). Os resultados indicaram que tanto a pulverização quanto as aplicações da solução de manutenção foram benéficas. As doses calculadas de 17,3 mL L^{-1} para pulverização e 13,4 mL L^{-1} para a solução de manutenção foram as mais eficazes em retardar o amarelecimento e o apodrecimento, preservando a estrutura e a cor das hastes florais. O uso de *Chlorella* sp. como conservante floral para esta espécie representa uma alternativa sustentável e eficiente, contribuindo para práticas agrícolas sustentáveis e abrindo novas perspectivas para futuras pesquisas e aplicações práticas na horticultura ornamental.
Palavras-chave: Bioinsumo, *Helianthus annus* L., Horticultura ornamental, Flores de corte.

Introduction

The flower industry is a promising and dynamic sector characterized by a growing demand for high technology and care in production, especially for more durable plants. These plants are widely marketed for various purposes, including cut flowers, pots, landscaping, and gardening (Tombolato et al., 2010; Ibraflor, 2022).

Among the valued species in the cut flower market, the ornamental sunflower (*Helianthus annuus* L.) stands out, appreciated for its exuberance and variety of shapes and colors. This species is versatile, suitable for cut flower production and pot cultivation. The sunflower inflorescence, a capitulum, comprises sessile flowers inserted in a discoid receptacle characterized by hairy and rough bracts. The diameter varies according to the species, climate, and soil. The flower, as an ornamental element, is the part of the highest commercial value (Tomiozzo et al., 2024).

One of the main challenges for the sector is postharvest management, where there is a gap in knowledge and technologies to minimize losses. The rapid degradation of cut flowers represents an additional challenge, requiring effective strategies to slow down quality loss before the products reach the final consumer. Flower longevity varies according to the species, demanding specific adaptations to its ecophysiological requirements (Costa et al., 2021; Tomiozzo et al., 2024).

Considering these aspects, establishing techniques to increase the vase life of cut flowers is important. Postharvest processes using microalgae have gained prominence, especially due to their potential to extend shelf life and maintain the quality of horticultural products such as mango, papaya, umbu, melon and cherries (Onias et al., 2016; Teodosio et al., 2018; Teodosio et al., 2021; Go et al., 2023; Yu et al., 2025). Among these organisms, *Chlorella* sp. has shown promise, as indicated by previous research (Oliveira et al., 2018a; Oliveira et al., 2018b; Teodosio et al., 2018; Teodosio et al., 2021, Oliveira et al., 2025; Žunić et al., 2024).

Although microalgae, particularly *Chlorella* sp., have demonstrated promising potential in extending the shelf life of various horticultural products, a notable gap in knowledge and specific application in the postharvest management of cut flowers is observed. Recognizing this need, this study stands as a pioneering effort by investigating the efficacy of *Chlorella* sp. in increasing the longevity and maintaining the quality of cut flower stems, thereby outlining new approaches for more sustainable postharvest practices in floriculture

Furthermore, Brazil has invested in the biofertilizer market, especially through the National Bioinput Program of 2020, to promote more sustainable agribusiness. This program opens several opportunities for producing and using bioproducts from microalgae (Soares et al., 2023). In addition, the UN's 2030 Agenda encourages biofertilizer production and commercialization, which may further increase interest in microalgae production.

Advancing postharvest technology for flowers and ornamental plants requires dedicated research to determine how applying preservative solutions can increase flower preservation. Thus, the application of *Chlorella* sp. in the post-harvest of cut flowers can be a promising way to increase the useful life and enhance floral quality, since this microalga may have the potential to increase the shelf life of cut stems. This study aimed to evaluate the effects of different doses and application methods of *Chlorella* sp. on the vase life of cut stems of ornamental sunflower cv. *Vincent's Choice*.

Material and methods

Production of flower stems

The cut sunflower cv. *Vincent's Choice* was grown for flower stem production used in this experiment. The cultivation was carried out in the experimental area of Jardinocultura (22°11' S; 54°56' W) of the Faculty

Corresponding author: josesorgato@ufgd.edu.br | https://doi.org/10.1590/2447-536X.v31.e312878 | Editor: Raissa Rachel Salustriano da Silva-Matos, Universidade Federal do Maranhão, Brasil | Received: Jan 13, 2025 | Accepted: June 30, 2025 | Available online: Sep 16, 2025 |

of Agricultural Sciences (FCA), Federal University of Grande Dourados (UFGD), in Dourados-MS, Brazil, from September to November 2023. The Dourados region is characterized by a humid subtropical climate (Cwa) according to the Köppen classification (Fietz et al., 2017), with dry winters and hot summers. The soil in the cultivation area is a dystrophic Red Latosol with a clayey texture.

Production was carried out according to the recommendations of the 'Flowers for All' Project, by the PhenoGlad Team of the Federal University of Santa Maria. To conduct the soil analysis, five samples were collected per bed, at a depth of 0 to 20 centimeters, which were combined to form a composite sample for physical-chemical analysis (Table 1).

Table 1. Chemical and particle size analysis of the soil of the experimental area in the layer of of 0.00-0.20 m.

pH	**P** (Mehlich)	**K⁺**		**Ca²⁺**	**Mg²⁺**	**Al³⁺**	**H + Al**	**CEC**	**O.M**	**V**
$CaCl_2$	mg kg^{-1}	...............................mmol$_c$ kg^{-1}............................						pH 7.0	g kg^{-1}	%
5.45	14.48	4.10		74.2	31.9	0.0	36.6	14.68	24.93	75.0
S	**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Sand**		**Silt**	**Clay**	
....mg dm^{-1}....................................						..........................g kg^{-1}.............................				
7.07	0.44	3.75	102.44	105.20	3.95	260		140	600	

P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; Al^{3+}: Aluminium; H + Al: potential acidity; CEC: cation exchange capacity; O.M: organic matter; V%: base saturation; S: sulfur; B: boron; Cu: copper; Fe: iron; Mn: manganese; Zn: zinc.

The beds were prepared using a rotary tiller, after plowing and harrowing the soil. Three beds were established, each measuring 15 m long, 1 m wide, and 0.2 m high. A spacing of 0.5 m between beds was adopted to facilitate plant monitoring and cultural practices.

For the initial nutrition of the plants, a fertilization formulation composed of urea (46% nitrogen), single superphosphate (20% P_2O_5), and potassium chloride (58% K_2O) was used, in the proportion that provided 50 g m^{-2} of NPK in the 05-20-20 formula. The fertilizer was distributed homogeneously over the prepared area and incorporated into the soil with the aid of a rake, before sowing the sunflower.

Sowing was carried out directly on the beds, in four parallel rows, with a spacing of 0.2 meters between seeds. The useful area for data collection was limited to the two central rows, excluding 0.5 meters from each end to avoid the edge effect. The planting density was set at 32 plants per square meter, totaling 1440 plants.

When the plants reached stage V10, characterized by the presence of the tenth true leaf with at least 2.0 cm in length - a criterion adapted from the development scale proposed by Schneiter and Miller (1981), topdressing was carried out. This fertilization consisted of 30 g m^{-2} of nitrogen, using urea as a source, applied by broadcasting around the plants.

Irrigation was carried out using drip hoses, with the frequency and duration of irrigation being determined based on the water needs of the crop, considering the climatic conditions and the stage of plant development. Weed control was carried out manually, whenever necessary. The phytosanitary management of the crop was carried out preventively, adopting measures to avoid the occurrence of pests and diseases.

Harvest and post-harvest of flower stems

Flower stems measuring 85 cm in length were harvested at stage R5, when the ligulate flowers were at a 90° angle to the capitulum disk. Harvesting was conducted in the morning. Immediately after cutting, the stem bases were immersed in distilled water and transported to the Flower and Ornamental Plants Laboratory at UFGD. There, they were standardized to 70 cm in length, with excess leaves removed, leaving only two leaves per stem. The stems were then placed in an air-conditioned room maintained at an average temperature of 25 °C and 70% relative humidity to begin the experimental period.

The experiment used a completely randomized design with five replicates, arranged in a 3 x 5 factorial scheme, totaling 75 flower stems. Treatments included three application methods (pulsing, spraying, and maintenance solution) and five doses of *Chlorella* sp. (0; 5; 10; 15 or 20 mL L^{-1}). The Microalgae agricultural fertilizer containing 20 million microalgae cells mL^{-1} served as the microalga source.

Pulsing treatment involved immersing flower stems for 24 hours in 200 mL of microalgae solution. Spray treatment consisted of uniformly applying 15 mL of microalgae solution to each flower stem, including leaves and flowers, using a manual sprayer. Stems from these two treatments were individually placed in PVC tubes, closed at the base, containing 200 mL of distilled water changed every 48 hours. For the maintenance solution treatment, stems were individually conditioned in PVC tubes, closed at the base, containing 200 mL of microalgae solution, changed every two days. The experiment continued until flowers were completely senescent (14 days), with daily evaluations.

The parameters evaluated included the onset of petal wilting (OPW), onset of petal fall (OPF), stem yellowing (SY), and stem rot (SR). Data were subjected to analysis of variance (ANOVA), meeting assumptions of normality and homogeneity of variance. Treatment means were compared using Tukey's test at a 5% probability level. Effects of *Chlorella* sp. concentrations were analyzed by regression using GENES software (Cruz, 2013).

Results and Discussion

The treatments used did not influence petal wilting (OPW) and the onset of petal fall (OPF) ($p > 0.05$), presenting an overall average of 9 and 11 days, respectively. For the variables stem yellowing (SY) and stem rotting (SR), there was a significant isolated effect of application methods and a combined effect of microalgae doses and application methods ($p < 0.05$).

Regarding the SY variable, the highest results were found in the treatment with spraying of *Chlorella* sp. solution. Concerning the interaction of the studied factors on the SY variable, it was verified that the spraying treatment at the calculated dose of 17.3 mL L^{-1} presented the highest results, taking an average of 8.4 days for the onset of stem yellowing (Fig. 1).

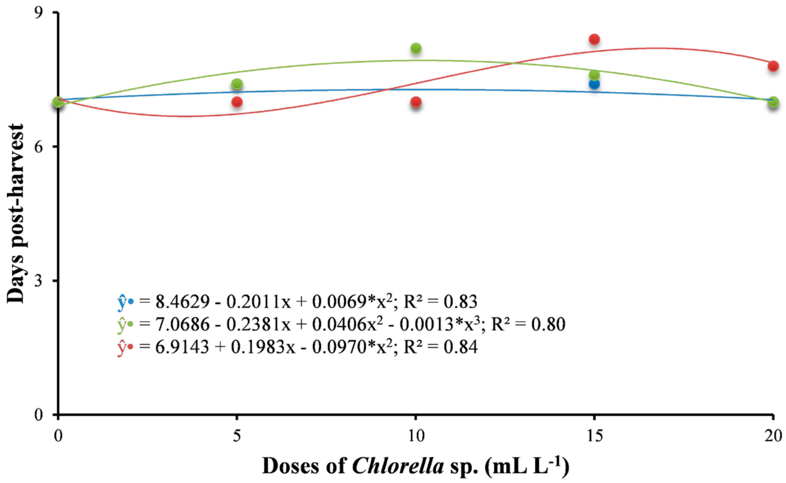

Fig. 1. Stem yellowing of cut sunflower cv. *Vincent's Choice*, as a function of application forms (• = Pulsing; • = Spraying; • = Maintenance solution) and doses of *Chlorella* sp. solution (mL L^{-1}).

These results show that the spraying of the solution was beneficial compared to the other treatments used. This fact may be related to the absorption of the solution by the leaves and possible formation of a microalgae film on all applied structures, since this was the only treatment where the leaves and flowers came into contact with the *Chlorella* sp. solution. It is worth noting that the pulsing and maintenance solution treatments are dependent on evapotranspiration for the translocation of the solution through the vascular bundles.

Teodosio et al. (2021), working with edible coating based on *Chlorella* sp. in postharvest conservation of umbu, observed a reduction in the ripening speed of the fruits and 12 days of shelf life. Kumar et al. (2017) reported that *Chlorella* sp. can reduce the plant respiration rate and, consequently, ethylene production and the activity of hydrolyzing enzymes, which are responsible for cell wall degradation. As sunflower is an ethylene-responsive crop, we can infer that spraying may have formed a protective film minimizing ethylene production and, consequently, increasing the shelf life of cut sunflower.

Regarding the stem rotting variable (SR), the highest average values were found in the treatment using the maintenance solution based on *Chlorella* sp., which increased the shelf life by about four days when compared to the other treatments. Regarding the interaction of the studied factors on the SR variable, it was verified that the use of the maintenance solution at the calculated dose of 13.4 mL L^{-1} presented the highest results, taking an average of 13.6 days for the onset of stem rotting of cut sunflower (Fig. 2 and 3).

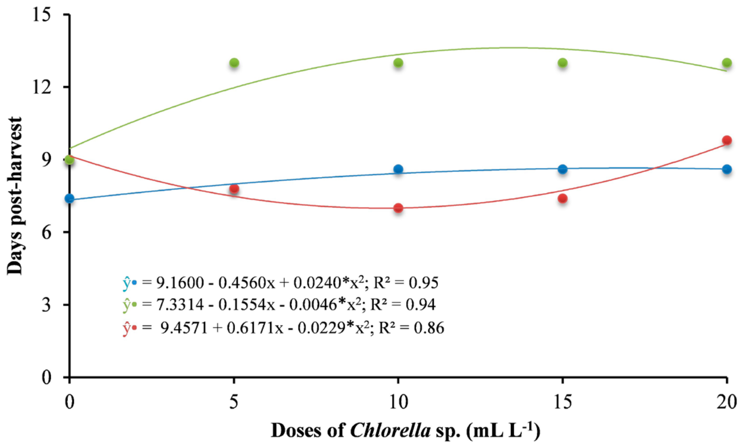

Fig. 2. Stem rotting of cut sunflower cv. *Vincent's Choice*, as a function of application forms (• = Pulsing; • = Spraying; • = Maintenance solution) and doses of *Chlorella* sp. solution (mL L^{-1}).

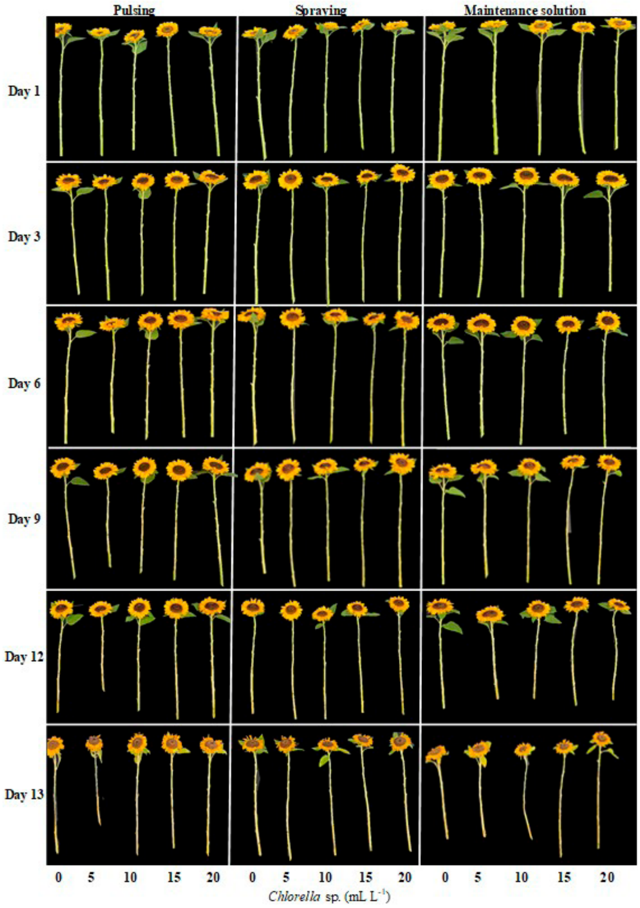

Fig. 3. Postharvest appearance of cut sunflower stems cv. *Vincent's Choice*, as a function of application forms and doses of *Chlorella* sp. solution.

These results show, in general, an increase of about four days compared to the control treatment (zero dose), demonstrating the biocidal action of the *Chlorella* sp. solution in the postharvest treatment of cut sunflower. The microalga *Chlorella* sp. has been widely studied for its antimicrobial, antifungal, and antioxidant properties. Several studies have shown that, due to its high fatty acid content, *Chlorella* sp. extracts exhibit significant antimicrobial activity against Gram-positive and Gram-negative bacteria, as well as various pathogens, making it a potential biological agent. Its potential to control or inhibit pathogen growth is also due to the production of biocidal compounds, such as benzoic acid and majusculonic or hydrolytic enzymes. Furthermore, *Chlorella* sp. extracts demonstrate high antioxidant activity, due to the presence of phenolic compounds, capable of eliminating free radicals, indicating its potential as a natural antioxidant (Santhosh et al., 2019; Mtaki et al., 2020; Vieira et al., 2021; Moussa et al., 2023; Sarkar et al., 2021; Tok et al., 2023; Oliveira et al., 2024; Yu et al., 2025).

Thus, the use of *Chlorella* sp. solution in postharvest treatments represents an innovative and sustainable approach for ornamental horticulture. The use of natural products such as *Chlorella* sp. not only meets the growing demand for more ecological agricultural practices but also offers an effective alternative to synthetic chemicals, contributing to food security and environmental preservation, aligning with SDGs 2, 12, 13, and 15 of the UN 2030 Agenda and with the National Bioinputs Program of 2020 of the Brazilian Ministry of Agriculture and Livestock.

Moreover, this is the first work using a solution of this microalga in postharvest of cut sunflower. The results found in this research highlight the antimicrobial, antifungal, and antioxidant properties of *Chlorella* sp. showing its promising potential as a natural agent in optimizing the quality and durability of ornamental plants in the postharvest period, opening new perspectives for future research and practical applications in ornamental horticulture.

Conclusions

The application of *Chlorella* sp. in the postharvest of cut sunflower cv. *Vincent's Choice* is effective in prolonging vase life and maintaining the quality of flower stems. The calculated dose of 17.3 mL L^{-1} for spraying, and 13.4 mL L^{-1} for the maintenance solution were the most effective in delaying stem yellowing and rotting, preserving structure and coloration.

Acknowledgments

The authors thank CAPES for the grants granted and UFGD (Brazil) for the technical and financial assistance.

Author Contribution

TLT: Conceptualization, Methodology, Data Curation, Writing - Review & Editing. **RMB**: Conceptualization, Methodology, Data Curation, Formal Analysis, Visualization. **JSS**: Formal Analysis, Writing - Original Draft, Writing – Review & Editing. **CAQT**: Methodology and Data Acquisition. **BLP**: Data Curation, Visualization. **ISAS**: Data Curation, Visualization. **JCS**: Formal Analysis, Supervision, Writing - Original Draft, Writing – Review & Editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

Data will be made available upon request to the authors.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors declare that the use of AI and AI-assisted technologies was not applied in the writing process.

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