EFFECT OF *ARTHROSPIRA PLATENSIS* ON ALLEVIATION OF DROUGHT STRESS IN *HELIANTHUS ANNUUS* L.

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Drought stress is a major constraint limiting sunflower (*Helianthus annuus* L.) productivity, reducing germination, growth, and biomass accumulation. This study evaluated the potential of *Arthrospira platensis* as a biostimulant to enhance drought tolerance in sunflower seedlings. Seed treatments and foliar applications of *A. platensis* were applied under controlled conditions, with drought stress induced by 15% polyethylene glycol (PEG-6000). Drought significantly reduced plant height, root length, and fresh biomass, while dry biomass remained largely unaffected. Treatments with *A. platensis* mitigated these effects, with combined seed and foliar applications increasing plant height to 123% of non-stressed controls and 138% of PEG-stressed controls, root length exceeding 150%, and fresh biomass rising from ~57% in stressed controls to over 300%. Seed priming primarily enhanced root growth, whereas spraying alone improved plant height and fresh biomass. These results indicate that *A. platensis* effectively enhances sunflower seedling growth under water deficit, highlighting its potential as a sustainable biostimulant for improving drought resilience.

Keywords: *Arthrospira platensis*, sunflower, drought stress, biostimulant

1. INTRODUCTION

Actual climate change poses a major challenge by exacerbating drought stress, which can reduce major crop yields by over 50%. Plant adaptations to drought include root elongation to enhance water uptake, leaf rolling to minimize water loss, and upregulation of regulatory proteins involved in stress signaling. Drought induces the expression of stress-responsive genes and transcription factors, along with carbohydrate accumulation, reactive oxygen species (ROS) production, and antioxidant enzyme activity (Adzigbe et al., 2025).

Although sunflower (*Helianthus annuus* L.) is moderately drought-tolerant, its productivity is highly sensitive to water deficit, particularly during critical growth stages such as germination, flowering, and achene filling (Ahmad et al., 2009). Drought stress reduces germination, seedling growth, leaf area, biomass accumulation, and ultimately seed and oil yield (Oraki and Aghaalikhana, 2012). Given these limitations, the use of biostimulants has emerged as a promising strategy to enhance drought resilience.

Cyanobacteria- and microalgae-derived products have gained attention as multifunctional biostimulants in agriculture, improving nutrient uptake, crop performance, and tolerance to abiotic stresses like drought and salinity (Chiaiese et al., 2018; Kusvuran, 2021; Guzmán-Murillo et al., 2013). However, although there is evidence that their bioactive compounds positively influence plant growth, their effects on sunflower remain insufficiently explored. In this context, the aim of this study was to evaluate the effects of *Arthrospira platensis* on the physiological responses of sunflower (*Helianthus annuus*) seedlings under drought stress. Specifically, it investigated the potential of cyanobacteria as a potential biostimulant to enhance drought tolerance by assessing plant growth under PEG 6000-induced water deficit as a controlled drought model.

2. MATERIALS AND METHODS

A sunflower (*Helianthus annuus*) hybrid was evaluated to determine the effects of *Arthrospira platensis* on growth and development under drought stress conditions. The experiment was conducted under controlled laboratory conditions (25 ± 3°C) for 22 days, using a three-factor design: water regime, seed treatment, and foliar application.

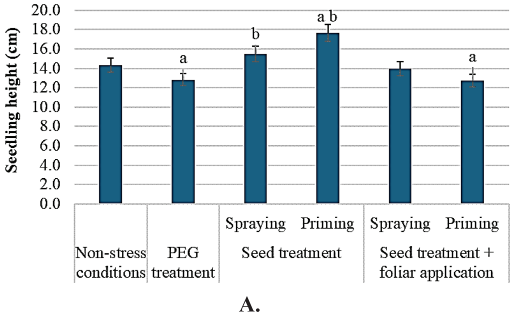
Seed treatment with *A. platensis* was performed either by soaking the seeds in an algal suspension (exponential growth phase) for 1 hour before sowing or by spraying them prior to sowing. All seeds were sown in soil-filled containers. Drought stress was imposed on day 15 by irrigating seedlings with 15% polyethylene glycol (PEG-6000), while control plants were maintained with distilled water. The stress was sustained for 7 days.

In treatments combining seed and foliar application, the algal suspension was sprayed four times during the early vegetative stage, beginning on the second day of drought stress and continuing until the end of the experiment. At the end of the stress period, growth parameters were measured on five plants per variant, including seedling height, root length, and fresh biomass. Dry biomass was determined by placing plant tissues in paper bags, sealing and labeling them, preheating at 105°C for 20 minutes, and then drying to constant weight at 80°C.

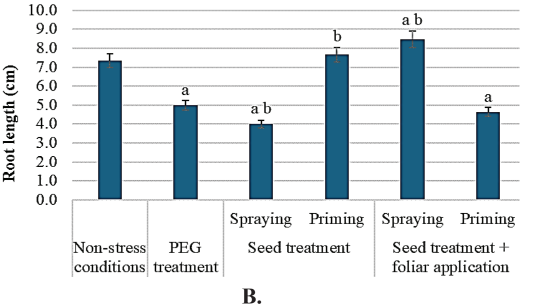
All experimental data were statistically analyzed, with significance accepted at $P \leq 0.05$. Data are presented as the mean ± standard deviation (SD), and error bars in figures represent the standard error of the mean.

3. RESULTS

The effects of *Arthrospira platensis* on sunflower seedling growth under drought stress were evaluated through plant height, root length, fresh biomass, and dry biomass (Figure 1). PEG-induced drought significantly reduced growth in untreated seedlings, with plant height, root length, and fresh mass declining from 14.3 to 12.8 cm, 7.3 to 5.0 cm, and 0.51 to 0.29 g, respectively, while dry biomass remained unchanged. *A. platensis* treatments mitigated these effects, increasing plant height to 17.7 cm, root length to 8.5 cm, and fresh biomass to 0.90 g, occasionally exceeding values of the non-stressed control. Dry biomass remained stable, indicating that cyanobacteria primarily enhanced fresh tissue accumulation.



A.



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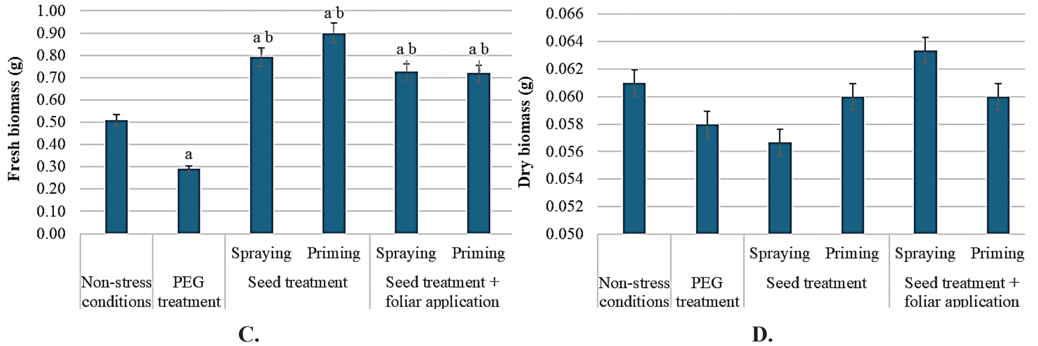

Figure 1. Effects of *Arthrospira platensis* application on sunflower (*Helianthus annuus*) growth under drought stress.

Panels show shoot length (A), root length (B), fresh biomass (C), and dry biomass (D). Data are presented as mean ± standard error (n = 3). Different letters indicate statistically significant differences: **„a"** compared to the non-stressed control, **„b"** compared to the PEG-induced drought-stressed control ($P \leq 0.05$).

Maximum values for plant height and biomass were observed in plants receiving combined treatments, indicating a synergistic effect on plant development. Thus, sunflower seeds sprayed with *Arthrospira platensis* culture, combined with foliar application, increased plant height to 123% of the non-stressed control and 138% of the PEG-treated control (Figure 2).

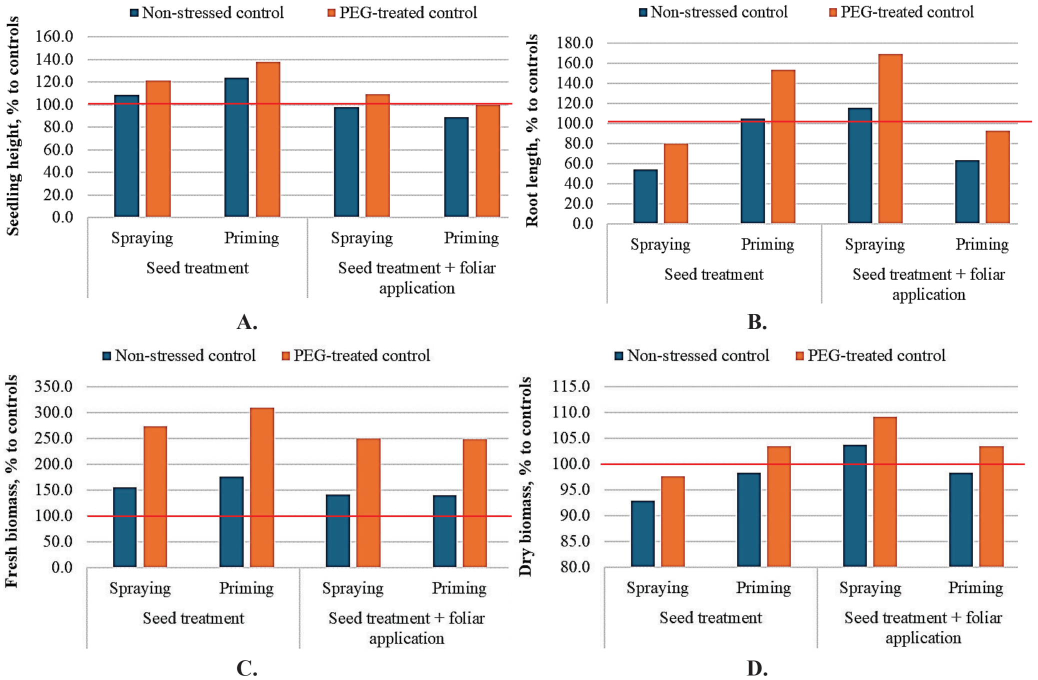

Figure 2. Effects of *Arthrospira platensis* on sunflower (*Helianthus annuus*) growth under drought stress, expressed as a percentage of the non-stressed and PEG-treated controls.

Panels show shoot length (A), root length (B), fresh biomass (C), and dry biomass (D).

Root length exceeded 150%, indicating enhanced root development and potential water uptake. Fresh biomass showed the strongest response, rising from ~57% in stressed controls to over 300% with treatment. Spraying alone also improved plant height and fresh biomass, whereas seed priming mainly enhanced root growth (116% relative to the non-stressed control and 169% relative to the PEG-treated control). The combination of priming and foliar application did not provide additional benefits.

4. DISCUSSIONS

Experimental studies under greenhouse and field conditions have shown that cultures or extracts of microalgae and cyanobacteria enhance seed germination, seedling development, root and shoot biomass, and photosynthetic pigment accumulation across crops such as leafy vegetables, tomato, pepper, wheat, and sugar beet (Abd-El Fattah, 2008; El Arroussi et al., 2018; Aly et al., 2008; Kholssi et al., 2019). Species including *Chlorella vulgaris* and *Spirulina platensis* contain phytohormones, amino acids, vitamins, and metabolites that support growth and stress resilience (Renuka et al., 2018). Their polysaccharides and bioactive compounds promote germination, root and shoot development, and biomass accumulation under challenging conditions, highlighting their value as biofertilizers and biostimulants (du Jardin, 2015; Farid et al., 2019). Consequently, priming sunflower with algal or cyanobacterial extracts offers a sustainable strategy to boost tolerance to drought (Kusvuran, 2021) and salinity (Abd El-Baky et al., 2010), while supporting productivity under stress.

The growth-promoting effects involve multiple mechanisms, including phytohormone production (auxins, cytokinins), exopolysaccharides that improve rhizosphere microbial communities, and the supply of bioavailable nutrients (Jäger et al., 2010; Renuka et al., 2018; Xiao and Zheng, 2016). Together, these factors enhance root architecture, water uptake, and photosynthetic efficiency, mitigating the impacts of water deficit or salinity. For example, foliar applications of *Chlorella vulgaris* (1–5% v/v) on drought-stressed broccoli significantly increased shoot length, fresh and dry weights, leaf area, relative water content, and photosynthetic pigments (chlorophyll-a, chlorophyll-b, and carotenoids) while reducing oxidative damage (Kusvuran, 2021). Polysaccharide extracts from *Spirulina platensis* and *Dunaliella salina* similarly enhanced antioxidant enzymes, secondary metabolites, and stress-related compounds, reducing oxidative damage in plants (Abd El-Baky et al., 2010; El Arroussi et al., 2018; Guzmán-Murillo et al., 2013).

5. CONCLUSIONS

The present study demonstrated that *Arthrospira platensis* treatments alleviated drought-induced reductions in sunflower growth. Seedling height, root length, and fresh biomass were markedly improved relative to PEG-stressed controls. Notably, the combination of seed treatment and foliar application produced the strongest stimulatory effects, suggesting synergistic benefits for water deficit tolerance. These findings support the potential of cyanobacteria-based biostimulants as a sustainable and effective strategy for enhancing crop resilience under drought conditions.

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DECLARATIONS: The authors declare that they have no conflict of interest. The authors confirm that this manuscript is original, has not been published previously, and is not under consideration elsewhere.

M.D. and S.C. designed the study; A.A., R.M., S.D. performed experiments; S.C. and A.A. analyzed data; M.D. and S.C. drafted the manuscript; all authors reviewed and approved the final version.

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