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Aeroponic cultivation of chrysanthemum: Influence of misting intervals on morphological, physiological, and nutrient uptake responses

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Abstract
The present study investigates the impact of misting intervals on the growth, physiology, yield, and nutrient uptake of cut chrysanthemum cultivated under an aeroponic system. Two misting treatments—3 minutes on and 5 minutes off (S1), and 2 minutes on and 5 minutes off (S2)—were applied to five chrysanthemum varieties. Significant differences were observed across varieties and treatments for all morphological, physiological, and yield parameters. Among the varieties, V2 consistently outperformed others in plant height (up to 58.34 cm), leaf area index (2.225), flower yield (67.18 flowers/plant), and vase life (16.84 days) under the S2 treatment. Nutrient uptake analysis revealed that V3 and V5 showed superior potassium (up to 3.05%), phosphorus (1.69%), and micronutrient accumulation under S2. Enhanced misting frequency significantly improved root development, chlorophyll content, and enzymatic activity. These findings underscore the potential of optimizing misting intervals in aeroponics to improve floricultural productivity and resource use efficiency.

Keywords: Chrysanthemum, aeroponics, misting interval, nutrient uptake, flower yield, physiological parameters, precision agriculture, soilless cultivation

1. Introduction

Chrysanthemum (*Chrysanthemum morifolium* Ramat.) is one of the most economically important ornamental crops, widely cultivated for cut flowers, potted plants, and landscaping due to its diversity in form, color, and extended postharvest life [1]. In recent years, the demand for high-quality cut chrysanthemums has increased globally, emphasizing the need for advanced cultivation techniques that ensure higher yields, uniformity, and longer vase life.

Traditional soil-based systems often face challenges such as inconsistent nutrient availability, poor water use efficiency, and susceptibility to soil-borne pathogens, which collectively hinder optimal crop performance [2]. As a solution, soilless cultivation systems—particularly aeroponics—have gained attention for their ability to deliver nutrients and water directly to the root zone in a controlled manner. Aeroponics enhances root oxygenation, nutrient absorption, and overall plant productivity, making it a viable technique for precision floriculture [3].

Misting frequency in aeroponic systems plays a crucial role in regulating the root microenvironment. The misting interval directly influences nutrient availability, root hydration, and physiological responses such as transpiration, photosynthesis, and stomatal conductance [4]. However, limited research has been conducted on the impact of misting schedules on flowering behavior, nutrient uptake efficiency, and postharvest quality in ornamental crops like chrysanthemum.

Furthermore, genotype × environment interactions play a pivotal role in determining crop adaptability under aeroponic conditions. Varietal responses to microenvironmental cues such as misting frequency can influence morphological traits, physiological performance, and nutrient dynamics [5, 6]. Identifying varieties that perform well under specific misting intervals can help optimize aeroponic systems for commercial flower production.

This study aims to evaluate the effects of two misting intervals—3 minutes on and 5 minutes off (S1) and 2 minutes on and 5 minutes off (S2)—on morphological, physiological, yield, and nutrient uptake parameters in different chrysanthemum varieties under aeroponic cultivation. The objective is to determine the optimal misting schedule that maximizes flower yield, nutrient use efficiency, and overall crop performance.

2. Materials and Methods

2.1 Experimental Site and Design

The experiment was conducted under controlled environmental conditions in an aeroponic cultivation unit. The study followed a Factorial Completely Randomized Design (FCRD) with three replications.

Two misting intervals were evaluated:

- **S1:** 3 minutes on and 5 minutes off
- **S2:** 2 minutes on and 5 minutes off

Five chrysanthemum varieties were selected for the study, labeled as:

- V1**,** V2**,** V3**,** V4, and V5

These treatments were observed at three growth stages: 30, 60, and 90 Days after Transplanting (DAT)**.**

2.2 Aeroponic System Setup

The aeroponic system consisted of a closed-loop, recirculating nutrient delivery system equipped with high-pressure nozzles capable of atomizing the nutrient solution into fine mist. Plants were supported in neoprene collars in a horizontal platform above the misting chamber, ensuring the root systems remained suspended in air.

Environmental conditions were monitored and maintained as follows:

- Day temperature: 25-28 °C
- Night temperature: 18-22 °C
- Relative Humidity: 65-75%
- Photoperiod: 12 hours light/12 hours dark
- Light intensity: ~500 µmol m^{-2} s^{-1} (provided by LED grow lights)

2.3 Nutrient Solution

A standard Hoagland's nutrient solution (modified for floriculture crops) was used. The solution was monitored for electrical conductivity (EC ~1.8-2.0 dS m^{-1}) and pH (5.8-6.2) and was replaced every seven days. The nutrient reservoir was oxygenated continuously using an aquarium air pump to maintain dissolved oxygen levels conducive to root respiration.

2.4 Observations and Parameters Recorded

Observations were recorded at 30, 60, and 90 DAT for the following parameters:

- **Morphological Parameters:** Plant height, stem diameter, number of leaves, internodal length, root length, root fresh/dry weight, plant fresh/dry weight
- **Physiological Parameters:** Leaf area and Leaf Area Index (LAI), chlorophyll a, b, and total chlorophyll, photosynthetic rate, stomatal conductance, transpiration rate, soluble protein content, catalase and peroxidase activity
- **Yield Parameters:** Days to first harvest, number of flowers per plant, number of harvests per plant, flower stalk length, stalk girth, cut stem weight, flower diameter, and vase life
- **Nutrient Uptake (% or ppm):** Macronutrients (N, P, K, Ca, Mg), and micronutrients (Fe, Zn, Cu, Mn, B)

2.5 Analytical Procedures

- Chlorophyll content was estimated using Arnon's method.
- Photosynthetic rate, stomatal conductance, and transpiration were measured using a portable Infrared Gas Analyzer (IRGA; Model LICOR-6400).
- Soluble protein content was determined by the Bradford method.
- Catalase and peroxidase activities were measured spectrophotometrically at specific absorbance wavelengths.
- Nutrient uptake was analyzed using standard wet digestion and quantified via atomic absorption spectrophotometry (AAS) for micronutrients, and Kjeldahl and colorimetric methods for nitrogen and phosphorus, respectively.

2.6 Statistical Analysis

The data were subjected to analysis of variance (ANOVA) using [Insert Software, e.g., SPSS, R, or SAS]. Treatment means were compared using the least significant difference (LSD) test at a 5% probability level ($p \leq 0.05$).

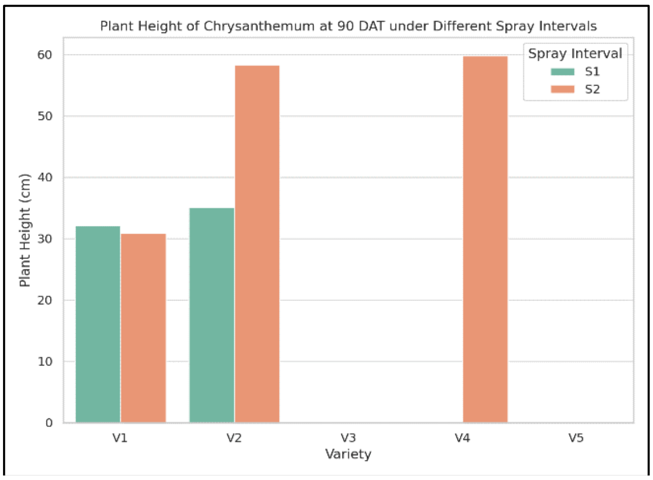
3. Results and Discussion

3.1 Morphological Parameters

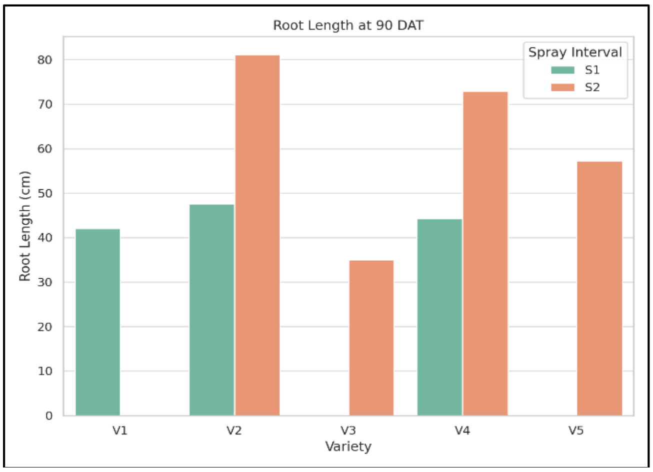
Significant differences were observed in plant height, root length, stem diameter, leaf count, and internodal length among the varieties and misting intervals. The S2 treatment (2 min on/5 min off) consistently outperformed S1 in promoting vegetative growth. At 90 DAT, the highest plant height was recorded in V4 S2 (59.83 cm) followed by V2 S2 (58.34 cm), while V1 S1 showed the minimum (32.09 cm). The improved shoot elongation under S2 can be attributed to sustained nutrient misting, enhancing nutrient and oxygen availability to the roots [1].

Root length followed a similar trend, with V2 S2 recording 81.18 cm, indicating that fine misting intervals stimulate root proliferation. Increased misting frequency in S2 likely maintained consistent hydration and oxygenation, crucial for aeroponic root development [2].

Leaf area and leaf area index were also highest in V2 S2 (1779.73 cm² and 2.225), while V5 S1 recorded the lowest. This highlights the effect of genotype × misting interaction on canopy development and potential light interception efficiency.



Plant Height of Chrysanthemum at 90 DAT under Different Spray Intervals

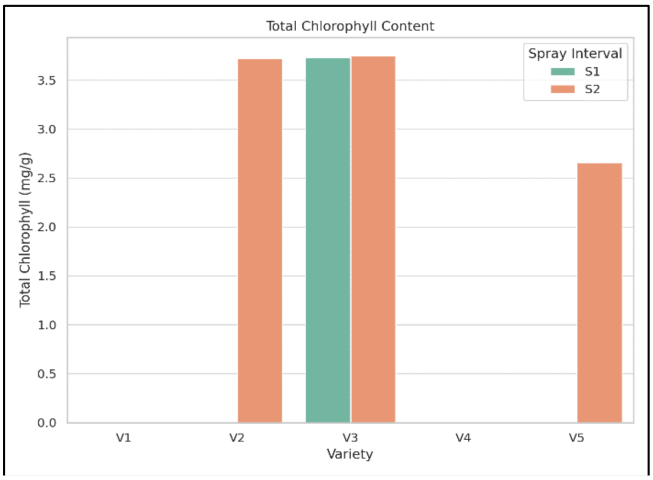


Root length at 90 DAT

3.2 Physiological Responses

Physiological parameters showed strong varietal variation under misting treatments. Total chlorophyll content peaked in V3 S2 (3.75 mg g^{-1}), followed closely by V2 S2 (3.72 mg g^{-1}), suggesting improved pigment biosynthesis due to enhanced water and nutrient availability under S2.

The photosynthetic rate was also highest in V2 S2 (1.48 µmol CO_2 m^{-2} s^{-1}), indicating that frequent misting improved carbon assimilation. This was supported by higher stomatal conductance in V3 S2 (481 mmol m^{-2} s^{-1}), reflecting a conducive microenvironment for gas exchange. These results align with Walters and Currey [3], who reported that optimized misting improves physiological functioning in leafy vegetables under controlled environments.

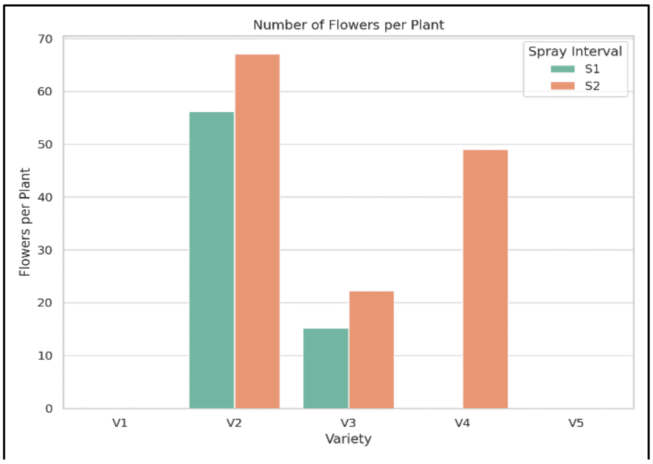


Total Chlorophyll Content

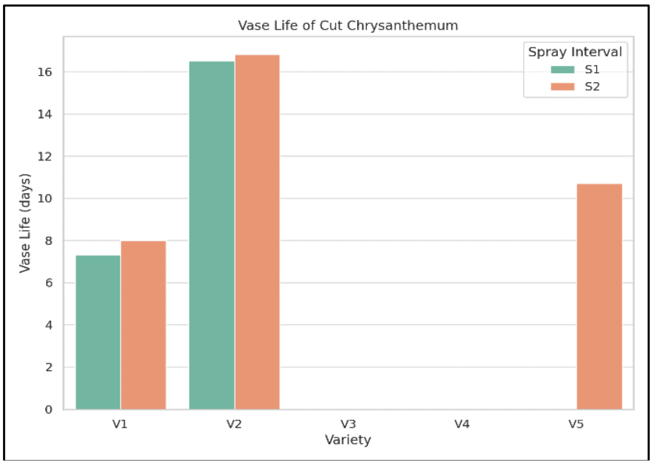
3.3 Yield Parameters

Yield-related traits, including the number of flowers per plant, harvest frequency, flower diameter, and vase life, exhibited marked improvements under S2. V2 S2 was the top performer with 67.18 flowers per plant, 3.97 harvests, and vase life of 16.84 days. In contrast, V3 S1 had the lowest flower count (15.18), and V1 S1 the shortest vase life (7.33 days).

The improvement in flower yield and longevity under S2 may be due to better resource allocation and reduced abiotic stress, which is supported by Chandra *et al.* [4], who emphasized misting intervals as key in extending flowering cycles in ornamentals.



Number of Flowers per Plant



Vase Life of Cut Chrysanthemum

3.4 Nutrient Uptake

Nutrient uptake patterns confirmed that S2 treatments supported superior absorption of macro and micronutrients. For instance, nitrogen uptake was highest in V5 S2 (2.53%), phosphorus in V3 S2 (1.69%), and potassium in V3 S1 (3.05%). These trends affirm that frequent misting promotes nutrient solubilization and root membrane activity, as outlined in studies on aeroponic fertigation by Medina *et al.* [5].

Micronutrients such as Fe, Zn, and Mn also exhibited increased uptake under S2. For example, Fe peaked in V2 S2 (266.20 ppm) and Zn in V1 S2 (85.3 ppm), supporting the theory that mist-induced root environment improves cation exchange and nutrient flow [6].

4. Conclusions

The present study demonstrates that optimizing misting intervals in aeroponic cultivation significantly influences the growth, physiology, yield, and nutrient uptake of cut chrysanthemum. Among the two misting treatments evaluated, the 2 minutes on/5 minutes off interval (S2) proved to be superior in enhancing plant height, root development, chlorophyll content, photosynthetic efficiency, and flower yield across all five varieties tested.

Notably, variety V2 consistently exhibited the best performance under S2, recording the highest values for key traits such as flower number (67.18 per plant), vase life (16.84 days), root length (81.18 cm), and leaf area index (2.225). Nutrient uptake was also markedly improved under S2, particularly for nitrogen, phosphorus, and potassium.

These findings confirm that misting interval is a critical factor in precision aeroponic systems and can be strategically managed to maximize resource efficiency and flower quality. The integration of aeroponic cultivation with optimal misting schedules offers a sustainable and high-efficiency approach to commercial chrysanthemum production, especially under controlled environment agriculture (CEA).

Future research should explore cultivar-specific nutrient formulations and real-time misting adjustments using automation and sensor-based feedback systems to further improve productivity and input-use efficiency.

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