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Research Paper

Optimization of Water Consumption and Evaluation of Selected Performance Indicators of Greenhouse Strawberry in a Vertical Aeroponic Cultivation System

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Extended Abstract

Introduction Traditional soil-based agriculture often suffers from limitations such as salinity, poor soil texture, and water inefficiency. These constraints have driven the adoption of controlled-environment agriculture, where techniques like hydroponics and aeroponics are utilized to overcome environmental variability and improve crop performance. Among these, aeroponics has emerged as a highly efficient method, offering distinct advantages by delivering nutrient-rich mist directly to the plant roots suspended in air. This technique not only ensures enhanced oxygenation and faster root absorption but also leads to remarkable reductions in resource usage up to 99% in water and 50% in nutrients compared to conventional methods. Furthermore, aeroponics allows for vertical farming setups, making it suitable for urban agriculture and space-limited environments. Strawberries, known for their high nutritional value, flavor, and economic potential, are increasingly cultivated in greenhouses to meet growing demand. Their shallow root systems and sensitivity to precise water and nutrient delivery make them an ideal candidate for aeroponic research. However, to achieve maximum productivity and resource efficiency, technical parameters such as nozzle diameter and misting duration must be carefully optimized. The primary objectives of this study were to evaluate the influence of different nozzle diameters and misting durations on the growth and productivity of strawberries, develop statistical models (first-order and second-order) to identify optimal operational conditions, and determine the most effective settings that enhance yield and water-use efficiency in a vertical aeroponic system.

Methods The experiment was conducted in a greenhouse at the Islamic Azad University of Kerman, Iran. Nine identical vertical aeroponic systems, each consisting of a five-level polyethylene column with 20 planting holes, were constructed. Nutrient solution was stored in an 80-liter tank at the base, and distributed via submerged pumps to three types of misting

nozzles (diameter: 25 µm, 50 µm, 75 µm). A full factorial randomized complete block design was implemented, featuring two factors including Nozzle diameter (25, 50, 75 µm) and Misting duration (10, 15, 20 minutes). Each treatment was replicated five times, yielding 45 experimental units. Strawberry seedlings were germinated in rock wool and transplanted into the aeroponic systems. Hoagland's nutrient solution was used throughout the 65-day growth period. Parameters measured included plant height, root dry weight, total fruit yield, and water-use efficiency (calculated as kg fruit per m^3 water). Data were analyzed using Minitab 2018, with LSD tests at 5% and 1% significance levels. Both first- and second-order regression models were applied to evaluate factor effects.

Results and Discussion The highest average plant height (265.62 cm) was observed in the treatment with a 50 µm nozzle and 20-minute misting duration. The lowest (152.4 cm) was recorded with a 75 µm nozzle and 10-minute misting. The second-order regression model showed excellent fit (R^2 = 99.43%), indicating strong predictability of plant height based on these parameters. Root dry weight varied significantly with nozzle size and misting duration. The highest dry weight (56.5 g) was observed with a 75 µm nozzle and 10-minute misting, while the lowest (38.8 g) occurred with a 50 µm nozzle and 20-minute misting. Interestingly, heavier misting or larger droplets appeared to reduce oxygen availability, negatively impacting root development. Yield performance was highest (61 kg per system) with a 50 µm nozzle and 20-minute misting, and lowest (41.5 kg) with a 75 µm nozzle and 10-minute misting. Yield was most responsive to nozzle size, supporting the notion that optimal droplet size is crucial in delivering nutrients efficiently without causing runoff or oversaturation. The most efficient water usage (128 kg/m^3) was achieved with a 50 µm nozzle and 20-minute misting. The results demonstrated that misting time had a positive effect on WUE, but nozzle size played a more dominant role. Second-order models for WUE had high predictive accuracy (R^2 = 96.28%). Second-order polynomial regression models proved superior to first-order models in estimating plant performance and WUE. Multi-response optimization using the Desirability Function Approach (DFA) revealed that the best operational setting was a 50 µm nozzle combined with a 16-minute misting interval at a nutrient mist rate of 212 mL/min. Under these optimized conditions, the average yield per plant was 1.56 kg, and water-use efficiency reached 98.17 kg/m^3.

Conclusion This study confirms that fine-tuning key technical parameters in vertical aeroponic systems significantly boosts the productivity and resource efficiency of greenhouse strawberry cultivation. Specifically, a nozzle diameter of 50 µm and a misting duration of 16 minutes were identified as optimal. These settings enhanced both biomass accumulation and water-use metrics without compromising root health or nutrient uptake. The research highlights the value of aeroponics as a sustainable cultivation method in water-scarce environments and controlled greenhouses. Future research should focus on seasonal and climatic variability assessments, economic viability and energy consumption modeling, and optimization of nutrient solution compositions for other high-value crops. Through such efforts, the potential for commercialization and large-scale deployment of aeroponic technology can be significantly enhanced.

Keywords: Nozzle diameter size, Foliar spraying, General full factorial.

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