

OPTIMIZATION OF WATER CONSUMPTION IN MULTILEVEL GREENHOUSES USING AN AUTOMATED IRRIGATION SYSTEM WITH RECIRCULATION OF HYDROPONIC NUTRIENT SOLUTION

Vinnytsia National Technical University

Annotation

Automated irrigation systems with drainage recirculation can reduce water and fertilizer consumption by up to 60%. This approach opens new opportunities for optimizing technological processes in modern greenhouses and facilitates the transition to more efficient and environmentally sustainable agricultural methods.

Keywords: automated irrigation system, drainage recycling, water consumption optimization, greenhouses.

Анотація

Автоматизовані системи зрошення з рециркуляцією дренажу дозволяють зменшити споживання води та добрив до 60%. Такий підхід відкриває нові можливості для оптимізації технологічних процесів у сучасних теплицях і сприяє переходу до ефективніших та екологічно стійких методів сільського господарства.

Ключові слова: автоматизована система зрошення, рециркуляція дренажу, оптимізація водоспоживання, теплиці.

Introduction

Modern agricultural automation technologies enhance resource efficiency, particularly in water and fertilizer use, which is critical for greenhouse farms where moisture loss impacts profitability. Automated irrigation systems with feedback mechanisms reduce costs, enhance nutrient absorption, and improve crop quality.

By analyzing tank liquid levels, drainage return was optimized, showing potential for reducing water and solution use through automation. This paper explores ways to implement these technologies in urban vertical farms and autonomous agricultural systems [1].

The paper examines the features of growing early and remontant strawberry varieties in greenhouse conditions. The study was conducted using small-scale technology on a coconut substrate, which allowed assessing the influence of microclimatic parameters on plant development and the efficiency of greenhouse production. Therefore, analyzing tank liquid level data and assessing water resource efficiency help determine the optimal parameters for the automated irrigation system.

Description of the experiment

The study used an automated tank level control system that recorded changes in water level throughout the day [2]. Irrigation was carried out through 30 capillary feeds that operated according to the following schedule:

- Five irrigations of 6 minutes each
- One watering for 3 minutes

During this time, 12.5 liters of solution were consumed. Over the entire strawberry growing cycle (3 months), the greenhouse consumed 1125 liters of aqueous solution.

During the recirculation of the hydroponic nutrient solution, various methods were applied for cleaning and disinfection, as the accumulation of root exudates led to autotoxicity and the growth of harmful microorganisms. To address these issues, MycoHelp, colloidal silver, ultraviolet irradiation, and hydrogen peroxide were applied, contributing to improved strawberry growth and yield [3].

The study was conducted on a mini-farm for growing strawberries, with a 1.43 m × 1.43 m indoor greenhouse and two plant levels. The irrigation system consists of 30 needles, each delivering 50 ml of solution every 6 minutes, resulting in a daily water consumption of 12.5 liters [4].

Conducting research

An automated greenhouse management system uses technology to optimize plant growth conditions. This automation ensures optimal plant health, reduces manual labor, and maximizes yield. By automating tasks such as watering, greenhouse operators can achieve consistent and efficient plant growth, which leads to improved product quality and reduced resource consumption [5].

The HC-SR04 sensor measures the distance to obstacles using ultrasonic waves, determining the time of return of the echo signal. In this system, it monitors the solution level in the tank in real time, allowing the liquid level with the solution to be measured to estimate the amount of drainage return, as well as automating the liquid supply by pump to avoid critical low or overflow.

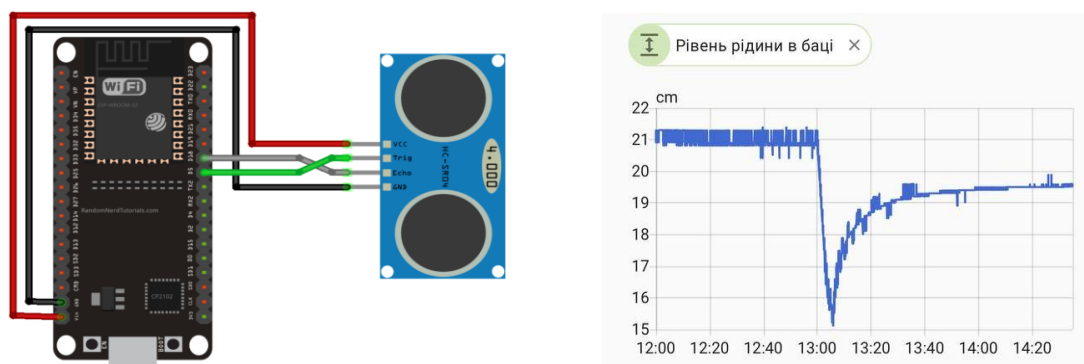


Fig. 1. Measurement device ESP32-S3 with HC-SR04 sensor and graph of the solution level in the tank during the day

The graph in Fig. 1 shows the change in the liquid level in the recirculating irrigation system and allows you to evaluate the effectiveness of drainage return. The initial liquid level was 20.8 cm, and after irrigation it dropped to 15.1 cm, which means a loss of 5.7 cm of solution. After the drainage returned, the level rose to 19.6 cm, which allows us to determine the final loss of liquid - 1.2 cm. Thus, the returned drainage volume amounted to 4.5 cm, which is approximately 79% of the lost fluid.

Such a high level of drainage return compared to the average of 60% may indicate overwatering. If a significant portion of the applied liquid returns, it means that the substrate does not have time to effectively retain moisture, and the plants do not fully utilize it. One of the reasons was the low water consumption by plants due to decrease in water consumption caused by pruning the mustache with young strawberry bushes. Removing the whiskers reduced the load on the plants, which reduced their need for water.

Practical application

The results obtained are of great importance for commercial use in modern greenhouses, in particular: urban vertical farms – allow you to grow products in megacities with minimal use of

resources, automated closed-cycle greenhouses – reduce water consumption and improve yields, autonomous agricultural systems – can be used in places with limited water supply or to create closed life support complexes [6].

Conclusions

Irrigation automation can reduce water and fertilizer consumption, which is vital for sustainable agriculture. There are two key savings:

Return of unused solution: Monitoring the tank and drainage shows that about 60% of the solution is not absorbed by the plants. Reusing this solution reduces water and fertilizer usage without harming plants.

Optimize irrigation frequency: Reducing irrigation frequency can lower drainage by up to 30%, but uneven moisture distribution can harm plants due to pressure changes or clogging. Thus, the main savings come from returning drainage, not strictly reducing irrigation cycles.

The automated system promptly halts watering when the solution level approaches the minimum threshold, preventing air intake by the pump and immediately notifying the farmer via a chatbot.

The most effective solution is implementing a drainage collection system, enabling significant resource savings and stable plant growth without moisture deficiencies.

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Суворін Олег - аспірант 174-ї спеціальності, факультет інтелектуальних інформаційних технологій та автоматизації, Вінницький національний технічний університет, м. Вінниця, e-mail: 00-24-048.stud@vntu.edu.ua

Науковий керівник: **Кабачій Владислав** – канд. техн. наук, доцент кафедри автоматизації та інтелектуальних інформаційних технологій, Вінницький національний технічний університет, м. Вінниця, e-mail: kabachij.v.v@vntu.edu.ua

Suvorin Oleg - Department of Intelligent Information Technology and Automation, Vinnytsia National Technical University, Vinnytsia, e-mail: 00-24-048.stud@vntu.edu.ua

Scientific Supervisor: **Kabachii Vladyslav** - Cand. Sc. (Eng), Assistant Professor of Intelligent Information Technology and Automation, Vinnytsia National Technical University, Vinnytsia, e-mail: kabachij.vv@vntu.edu.ua