Research on Efficient and Intelligent Regulation of Nutrients in Protected Soilless Culture

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Abstract. Green plants can effectively purify the air, release negative ions, and form a green field of vision to promote human physical and mental health. Nowadays, with the acceleration of the pace of life and the increase in the pressure of life, people do not have enough time and energy to take care of plants grown indoors in homes. Plants in large office places need to hire professionals to plant them. Raw intelligent control of flower pots can reduce energy consumption, save resources, and realize a smart life of health, environmental protection and low-carbon energy saving. At present, the effective combination of smart flowerpots and the Internet of Things makes smart flowerpots more distinctive and more obvious than traditional flowerpots. The purpose of this article is to study the efficient and intelligent regulation of nutrients in protected soil-less cultivation. In terms of methods, this paper first proposes fuzzy control and fuzzy self-tuning PID control. When the PID parameters of temperature and humidity are controlled by this control system, fuzzy rules, fuzzy reasoning and non-fuzzy processes are also used. In the soil-less cultivation control system, when the humidity in the greenhouse is too low for plant growth, you can choose to adjust the humidity in the greenhouse by starting the spray device or natural ventilation. As for the nutrient liquid level sensor, a light-weight, convenient, simple-to-use, and highly cost-effective water level recognition sensor is manufactured using the characteristics of liquid conductivity. In terms of experiments, between traditional soil-grown lettuce and container-less cabin-grown lettuce under the intelligent control system of soil-less cultivation yields comparative data and results. It is found that intelligent soilless cultivation is superior to traditional soil cultivation in terms planting effects, which reflects the effectiveness of the intelligent soil-less cultivation proposed in this paper.

Keywords: Green Plants, Intelligent Flower Pots, Fuzzy Control, Soil-less Cultivation

1. Introduction
With the progress of society and the improvement of the level of economic development, people's pursuit of material quality of life has gradually improved, and the demand and quality of fruits and vegetables have also increased accordingly. Traditional soil cultivation is difficult to meet people's
pursuit of high-quality green food, while soil-less cultivation uses artificially configured nutrient solutions instead of soil to provide plants with various nutrients needed for growth, which can avoid soil pollution or the large use of pesticides When it causes pollution to plants, it can increase yield, save resources, and reduce costs. Soil-less cultivation, as its name implies, refers to a cultivation method that does not use soil to provide nutrients to crops, but uses nutrient solutions instead of soil to provide nutrients to crops [1]. The key is to no longer rely on natural soil, but to allow the root system of the plant to directly contact the nutrient solution. At the same time, artificially create an environment suitable for the growth of the root system. Because it is artificially created, it can give crops various nutrients, dryness and humidity. And the optimal environment for oxygen concentration, and researchers can further control the growth and development of crops by controlling the environment, so that they are always in the best growth environment, and crops in this environment can better reflect their economic value. Some foreign scholars believe that soil-less cultivation techniques mainly refer to nutrient solution cultivation techniques. It breaks away from the shackles of land and saves space; the crops it produces are of high yield and good quality; prevent diseases and soil cultivation obstacles; save water, fertilizer and cleanliness: promote the modernization and automation of agriculture, save labor and labor, and facilitate management, etc. advantage.

The development time of intelligent flowerpots in China is still short, but there are many types [2]. In the early years, Tongda Lyjing Technology released the smart flowerpot, which focuses on "plant growth that saves trouble and worry". After repeated experiments, the cultivation substrate eliminates the steps of shovel and fertilization, and watering reminder is added at the same time. In the early years, Xiaomi's crowdfunding smart flowerpot was released. Xiaomi's "Mijia" grocery store was equipped with a flower planting artifact—a smart flowerpot with flowers and grass [3]. The design of the flower pot is simple and has easy-to-understand light instructions. The power of the flower pot, the imbalance of fertility and the water imbalance can be judged by reading the different indicator colors on the flower pot. In recent years, the "Tulipe" designed by Natalie King, a female college student in the Department of Industrial Design at Brunel University aims to make people and their potted plants have more communication, so that people know the place before planting potted plants. Life characteristics of planting plants. In the early years, the Parrot Pot smart flower pot exhibited by a US company at the CES International Consumer Electronics Show added an automatic watering function, which made the research in the field of smart flower pots go to full automation.

This paper first proposes fuzzy control and fuzzy self-tuning PID control. When the PID parameters of temperature and humidity are controlled by this control system, fuzzy rules, fuzzy reasoning and non-fuzzy processes are also used. In the soilless cultivation control system, when the humidity in the greenhouse is too low for plant growth, you can choose to adjust the humidity in the greenhouse by starting the spray device or natural ventilation. As for the nutrient liquid level sensor, a light-weight, convenient, simple-to-use, and highly cost-effective water level recognition sensor is manufactured using the characteristics of liquid conductivity.

2. Method

2.1. Fuzzy Control

The fuzzy controller is the core of the fuzzy control system. The fuzzy control algorithm is also implemented by a program. The working process is as follows: the sensor collects the real-time value of the controlled object and feeds it back to the system set value to obtain an error signal and use it as the input amount of the controller; the fuzzy amount is converted into fuzzy language after fuzzification The fuzzy decision language result is obtained by fuzzy inference from the input and output fuzzy language value subsets and fuzzy rules; the fuzzy decision language is obtained through non-fuzzy processing to obtain an accurate analog quantity to the executing agency, and the executing agency processes the controlled object [4-5]. Repeatedly, cyclic fuzzy control of the controlled object is realized.
2.2. Fuzzy Self-tuning PID Control
When the PID parameters of temperature and humidity are controlled by this control system, fuzzy rules, fuzzy reasoning and non-fuzzy processes are also adopted [6]. According to the temperature and humidity deviation value \( e(t) \) and the temperature and humidity deviation change rate \( a(t) \), the processor obtains the self-tuning values of each PID parameter from the constructed fuzzy control table, and acts on each output value to obtain a good two-Dimensional fuzzy self-tuning PID control [7-8]. The basic input-output relationship of temperature and humidity controlled by PID is shown in formula (1), and the input-output relationship of temperature and humidity at any time \( k \) is discretized in formula (1) as shown in formula (2) [9].

\[
\begin{align*}
    a(t) &= k_p e(t) + \frac{1}{T} \int_0^t e(t) dt + \frac{T d e(t)}{dt} \\

    a(k) &= k_p e(k) + k_i T \sum_{j=0}^{k} e(j) + k_d \frac{e(k) - e(k-1)}{T}
\end{align*}
\]

2.3. Control System
The main controller of the system first collects data outside the greenhouse through sensors to obtain the temperature, humidity, and carbon dioxide concentration parameters outside the greenhouse, and then obtains the temperature, humidity, and carbon dioxide concentration parameters in the greenhouse. Through fuzzy and PID hybrid control and related control strategies, the action is selected [10]. Considering high efficiency and energy saving, first compare the environmental factors outside the greenhouse with the best suitable range, prioritize the use of natural conditions for adjustment, and then use the internal auxiliary equipment for adjustment [11]. If the temperature is adjusted, the hot air blower, fan, natural ventilation can be started by control, or the temperature can be reduced by spray equipment. If the carbon dioxide concentration is adjusted, the carbon dioxide gas pump can be turned on through the control relay and natural ventilation is provided. If the humidity can be adjusted, control the spray device, ventilation, and fan. If the lighting time is regulated, only the switching time of the full-spectrum LED lamp can be preset to control [12]. When the humidity in the greenhouse is too low for plant growth, you can choose to adjust the humidity in the greenhouse by starting the spray device or natural ventilation. However, if the humidity outside the greenhouse is significantly greater than the humidity in the city, the humidity in the greenhouse can be adjusted without using a spray device and using natural ventilation. The same is true for temperature and carbon dioxide concentration, so setting the natural condition adjustment has higher priority.

2.4. Nutrition Liquid Level Sensor
The nutrient liquid level sensor is a lightweight, convenient, simple to use, and highly cost-effective water level recognition sensor made by utilizing the characteristics of liquid conductivity [13]. Although the measurement accuracy and accuracy are not very high, it fully meets the requirements for the business requirements of this system. Use a series of exposed parallel wires on the circuit board to determine the water level. The conversion of water signal to electric signal is easily completed, and the analog signal is output. The analog value is amplified by the subsequent triode. The signal can be directly collected by the system's digital-to-analog conversion module and used in the program [14]. At the same time, it has low power consumption and certain sensitivity. Its working voltage is DC5V, its working current is less than 20mA, and its signal type is analog signal output.

3. Experiment
3.1. Experiment Purpose
The feasibility of efficient and intelligent nutrient regulation technology for soilless cultivation of nutrients proposed in this paper is verified.
3.2. Subjects
Lettuce planted in traditional container-type cabins under the traditional soil-grown lettuce and soilless cultivation intelligent control system.

3.3. Experimental Design
First, the traditional lettuce selected in this paper is cultivated and grown on conventional land. The data were compared with lettuce grown under the condition of soilless cultivation intelligent control system. The soilless cultivation intelligent control system needs to divide the growth stages of the planted crops. The soilless cultivation process of the lettuce selected by this system is mainly divided into the following stages: The first is the nursery stage, which includes the soaking and germination processes. After successful seedling cultivation, the transplantation stage is entered. The lettuce seedlings need to be transplanted onto sponges and placed on seedling trays. When the seedlings grow six true leaves, they will enter the next stage. In the second transplantation stage, the sponge with lettuce seedlings was placed in the planting basket, and the planting basket was placed in the hole of the planting slot, and the full-spectrum LED lights were automatically controlled and the nutrient solution was circulated. When entering the lettuce's balling and fruiting period, the EC value and pH value of the nutrient solution ratio need to be detected, and the nutrient solution is often sterilized. During the period, the nursery facilities and the plantation facilities in the cabin should be disinfected regularly.

4. Discussion

4.1. Conditions of Soilless Cultivation Smart Greenhouse
This control system is aimed at the control of soilless cultivation of lettuce. The growth period of lettuce is short, and the starting point of the greenhouse is convenient construction. The container has a wide range of applicable environments. Due to its good thermal insulation properties, it can be used in extremely cold or hot areas. In addition, it has the convenience of transportation, and is more suitable for people who need to be replaced in the use area. The container-type cabin has good sealing, convenience, transformability, thermal insulation and durability. In this paper, the container-type cabin is used as the main body of the greenhouse, and the environment is set up. The list of relevant items for lettuce cultivation in the cabin is shown in Table 1 below.

| Table 1. Related items in the cabin |
|-----------------------------------|
| **Item list**                      | **Quantity** | **Effect**                      |
| ---------------------------------- |--------------|--------------------------------|
| Hydroponics pipeline              | Several      | Nutrient solution circulation   |
| Nutrient solution                 | A barrel of A and B liquid | Needed for lettuce growth |
| Planting basket with sponge heater | Several      | Lettuce grows fixed             |
| Spray equipment                   | 1 set        | Humidity control                |
| Internal circulation fan          | 2            | Ventilation                     |
| CO2 air pump                      | 1            | CO2 concentration adjustment    |

4.2. EC Value and Changes of Nutrients in Nutrient Solution
Since the analysis of the content of a nutrient element in the nutrient solution is tedious, and the nutrient solution is not supplemented by a single element, but is comprehensively supplemented according to the nutrient solution formula used, the electrical conductivity EC can reflect the total salt content in the nutrient solution, which can roughly reflects the nutrient level of the nutrient solution, and the detection is simple and intuitive. It is a better method for regulating the concentration of the nutrient solution. However, in actual operation, the relationship between EC value and nutrients in nutrient solution must be understood, so that the nutrient level in nutrient solution can be better regulated, and nutrient solution can be supplemented and replaced in time. Correlation analysis between the content of nitrate nitrogen, phosphorus and potassium in the nutrient solution and the
conductivity EC in the soilless cultivation period of lettuce showed that as the EC value of the nutrient solution decreased, the content of nitrate nitrogen and phosphorus in the solution decreased. The potassium content showed a significant downward trend, and the EC value showed a very significant linear positive correlation with the nitrate nitrogen content, phosphorus content, and potassium content.

4.3. Results and Analysis
Different cultivation methods have different degrees of influence on plant morphological indicators, as shown in Figure 1. It can be seen from Figure 1 that the plant height and stem thickness of the intelligent soilless cultivation of lettuce are significantly higher than that of traditional soil culture, and the plant growth is significantly better than that of traditional soil culture. During the experiment, soil cultivation requires regular and quantitative artificial water supply, and intelligent soilless cultivation of lettuce cultivation should be sprayed with nutrient solution every 5 minutes. The rhizomes will not be soaked in the nutrient solution, which saves a lot of manpower and time. During the planting period, yellow leaves appeared in the soil cultivation, and artificial remediation was applied to make the green plants grow normally in the later period. The traditional soil culture has problems such as difficulty in timely supply, insufficient light intensity to reach the ideal light intensity of the plant, and insufficient nutrients in the soil, which are not suitable for plant growth, so the plant growth is slow and weak. The intelligent soilless cultivation flowerpot can supply water to the plant in a quantitative and uniform manner, and the rotation to the light makes the plant grow evenly. The cultivation process is simple, convenient, and more suitable for plant growth.

![Figure 1. Comparison of the morphology of lettuce plants between traditional soil culture and soilless cultivation](image)

From the data in Figure 1 above, the average lettuce morphology in the intelligent soilless cultivation proposed in this paper is superior to traditional soil culture in five aspects: plant height, root length, leaf number, highest leaf length, and highest leaf width. In terms of average plant height of lettuce, the average plant height of lettuce cultivated by intelligent soilless cultivation is 35cm, and that of traditional lettuce cultured by traditional soil culture is 31cm; of which, in terms of average plant height of lettuce, intelligent lettuce cultivated by soilless cultivation The average highest leaf length is 33mm, and the average highest leaf length of traditional lettuce culture is 28mm.
5. Conclusion
In terms of methods, this paper first proposes fuzzy control and fuzzy self-tuning PID control. When the PID parameters of temperature and humidity are controlled by this control system, fuzzy rules, fuzzy reasoning and non-fuzzy processes are also used. In the soilless cultivation control system, when the humidity in the greenhouse is too low for plant growth, you can choose to adjust the humidity in the greenhouse by starting the spray device or natural ventilation. As for the nutrient liquid level sensor, a light-weight, convenient, simple-to-use, and highly cost-effective water level recognition sensor is manufactured using the characteristics of liquid conductivity. In terms of experiments, the comparison between traditional soil-grown lettuce and container-less cabin-grown lettuce under the intelligent control system of soilless cultivation yields comparative data and results. It is found that intelligent soilless cultivation is superior to traditional soil cultivation in terms of planting and planting effects, which reflects the effectiveness of the intelligent soilless cultivation proposed in this paper.

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