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IoT Based Automated Hydroponics Greenhouse Monitoring

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Abstract: *Hydroponics refers to the art of growing plants in water without soil (land). Nutrients for the plants are supplied to the roots in the form of solution that can be either in the form of static or flowing. Hydroponics can be cultivated both in green house and glass house environment. The limitation in green house environment is to maintain the temperature, pressure, humidity value at a particular level. In addition to that, monitoring on PH value and electrical conductivity in hydroponics is another challenge that has to be monitored and maintained. Manual monitoring is in practice which is a very trivial task else the plants may die out. This project, focuses on two tasks, the first one is to automate the greenhouse environment monitoring. The subsequent is automation of PH level, temperature, turbidity and electrical conductivity maintenance. IOT is used to transfer the retrieved data to the internet (mass storage) and mobile app is used to communicate the current status to the user through the use of internet to their mobile phones, so that monitoring & maintenance will be easier. This Hydroponics system requires less manual intervention, water and space than traditional agricultural systems.*

Keywords: Hydroponics, IOT, Sensors, monitoring and controlling.

I. Introduction

Greenhouse engineering and hydroponics are two very rapidly developing sectors of agriculture and are strongly linked with each other. Computational intelligence, mainly in the form of automatic monitoring and control, is a major tool of this development. Highly developed instrumentation and 'intelligent' control in hydroponics provides an opportunity for maximizing both quality and quantity of production through the advanced management of all involved processes. The production systems are continuously monitored and precisely controlled. An important issue in these highly computerized and automated systems is the quality of information provided by the sensors, as well as the quality of decisions passed to the actuators. The quality of information received from or passed to the system is not checked in the vast majority of automated greenhouse or hydroponic facilities.

The major milestone in the development of economic and commercial 2 hydroponics was the NFT concept, which stands for Nutrient Film Technique, developed by Allen Cooper in 1965. NFT system is a water cultivation technique in which plants grow with their roots within a channel (impermeable walls) through which a nutrient solution (water and nutrients) circulates. Most hydroponic crops are unsuccessful, mainly due to the lack of nutritional aspects in this production system, which requires adequate preparation and management of the nutrient solution and the chemical content of the hydroponics. The use of hydroponic growth conditions for broccoli and the application of stress factors at head induction and during development may serve the purpose of enhancing its nutritional quality to deliver a health promoting food.

II. Related Work

In order to acquire wide knowledge about hydroponics greenhouse farming using IOT, many research papers of various authors related to this project have been studied thoroughly. The papers listed below will give brief explanation of the whole theme.

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2.1 Fault Detection and Diagnosis in Deep-Trough Hydroponics Using Intelligent Computational Tools

In 2003, K.P. Ferentinos, used feedforward neural networks and genetic algorithms to develop a real-time detection and diagnosis system of specific mechanical, sensor and plant (biological) failures in a deep-trough hydroponic system. The capabilities of the system are explored and validated. In the process of designing the fault detection neural network model, a new technique for neural network designing and training parameterization is developed, based on the heuristic optimization method of genetic algorithms. Sensor and actuator faults are detected and diagnosed in sufficient time that the fault detection model can be applied online as a reliable supervisor of the operation of an unattended deep trough hydroponic system. Biological faults were not detected in general. While these microenvironment conditions (as they are represented by the measurable variables) are not influenced in the same degree by the conditions of the plants. Finally, the genetic algorithm system developed here can be successfully applied to a combinatorial problem such as deciding the best neural network architecture, activation functions and training algorithm for a specific model

2.2 Treatment Of Hydroponics Wastewater Using Constructed Wetlands In Winter Conditions

In 2010, Vincent Gagnon studied about hydroponics culture that generates large amounts of wastewater that are highly concentrated in nitrate and phosphorus but contains almost no organic carbon. Constructed wetlands (CWs) have been proposed to treat this type of effluent, but little is known about the performance of these systems in treating hydroponic wastewater. In addition, obtaining satisfactory winter performances from CWs operated in cold climates remains a challenge, as biological pathways are often slowed down or inhibited. The main objective of this study was to assess the effect of plant species (Typha sp., Phragmites australis, and Phalaris arundinaceous) and the addition of organic carbon on nutrient removal in winter. The experimental setup consisted of 16 subsurface flow CW mesocosms (1 m2, HRT of 3 days) fed with 30 Ld1 of synthetic hydroponics wastewater, with half of the mesocosms fed with an additional source of organic carbon (sucrose). Carbon addition had a significant impact on nitrate and phosphate removal, with removal means of 4.9 g m-2d-1 of NO3- N and 0.5 g m-2 d-1 of PO4-P. Planted mesocosms were generally more efficient than unplanted controls. Furthermore, we found significant differences among plant treatments for NO3-N and COD (highest removal with P. australis/Typha sp.). Overall, planted wetlands with added organic carbon represent the best combination to treat hydroponics wastewater during the winter.

2.3 Internet Of Things For Planting In Smart Farm Hydroponics Style

In 2016, Jumras Pitakphongmetha saw that the farmers gain more profits by producing the quality product. The effects of the global warming make more difficult planning in uncontrolled environment. On the other hand, the yield does not match customers' needs. For these reasons, planting in a greenhouse is easy to maintain and to control important factors such as light, temperature, and 12 humidity. Using of sensors coming in a greenhouse as Wireless Sensor Networks System are one efficiency of technology used in agricultural development by sending data to the cloud and controlling values such as temperature, light, etc. The results of this study will be useful for the farmer and related organizations applying in the farm. The IoT's devices contain Radio Frequency Identification, various sensors, and computing node. various phenomena on the network such as light, temperature, and pressure Promoting agriculture on several aspects in developing countries, technology has crossed hurdles by using wireless technology, networking, mobile, etc. to utilize energy and power consumption by equipment, which is helpful in the agricultural development, making more profit to the farmers. The development of ICT in various domains has driven substantial interest according to rising investments by private sectors towards the growth of ICT in agricultural research

2.4 Automated System Developed To Control Ph And Concentration Of Nutrient Solution Evaluated In Hydroponic Lettuce Production

In 2012, Diego S. Dominguesa, found that lettuce is one of the most widely consumed leaf vegetables. In hydroponic the growth depends upon the composition of nutrient solution. Due to its nutrient absorption, the conductivity and pH suffer continuous variations. This paper describes the development of a system completely managed by a lab-made software. It monitors the conductivity and pH throughout 24 h during the whole cycle of production. Also, allows adjust automatically any variation, through solenoid valves which dispense solutions of acid/base or nutrient. The efficiency of the proposed instrumentation was 13 evaluated by simultaneously cultivation of same kind of lettuce (Vanda) in two different ways, hydroponics in greenhouse controlled with the developed devices, and grown conventionally in soil, adopted as referential. Agronomic and chemical parameters of commercial interest were analyzed for both crop, attesting the precocity in harvest (64 against 71 days) with reduced labor, better control and higher productivity, especially in fresh and dry matter of aerial parts, presenting 267.56 and 13.33 g plant−1 respectively, using the developed system. The data sequence regarding the concentration of nutrients for the automated hydroponic system was like those obtained by the mentioned researchers, as follows: K > N > Ca > P > Mg > S > Fe > Zn > Mn > Cu. This similarity highlights the efficiency of controlling the parameters of conductivity and pH in the instrumental system applied to hydroponics, offering the producer an effective and viable alternative in the production of lettuce.

2.5 Dynamic Optimization Of Solution Nutrient Concentration To Promote The Initial Growth Of Tomato Plants In Hydroponics

In 2014, Diyah Yumeina proposed about a speaking plant-based optimal control system was proposed and applied to promote the initial growth of tomatoes in hydroponics. The control system consisted of a feedback control system and a decision system. The decision system consisting of neural networks and genetic algorithms was used to determine the optimal l-step set point of nutrient concentration which maximizes the initial growth of tomatoes. In the decision system, the growth rate of plant height to nutrient concentration was first identified using neural networks and then the optimal 6-step set points were determined through simulating the identified model using genetic algorithms. One step is 7 days. The optimal value (6-step set points) was 1.0 for the 1st step, 0.5 for the 2nd step, 0.8 for the 3rd step, 0.9 for the 4th step, 1.1 for the 5th step, and 1.2 dS m-1 for the 6th step during the initial growth stage. There was a 14 significant reduction (0.5 dS m-1) in nutrient concentration in the second step and this significant reduction corresponds to nutrient stress. Actual plant growth for optimal control was about 1.15 times larger than that for conventional control. We suggest that this control technique is suitable for optimizing hydroponic cultivation processes and the control strategy, including nutrient stress application, is effective in promoting plant growth.

2.6 Evaluation Of A Recirculating Hydroponic Bed Bioreactor For Removal Of Contaminants Of Emerging Concern From Teritary-Treated Wastewater Effluent

In 2021, Mathew S. Recsetara, proposed that a recirculating hydroponic bed bioreactor can significantly reduce the concentration of CECs found in tertiary effluent from a WWTP was correct. Sixteen detectable CECs in tertiary effluent from a municipal wastewater treatment were significantly reduced with a recirculating hydroponic bed bioreactor over a five-day treatment period. While there was evidence that plants were taking up some of the contaminants to varying degrees, it appeared to be only a minor pathway for removal. Removal rates of the 16 detectable contaminants except DEET were above 80% in all treatments, with or without plants, after five days. In a control with no LECA media or plants, removal rates were near zero after five and ten days for nearly all contaminants. Only atenolol appeared to significantly degrade on its own after five days. It is possible that in planted treatments, root exudates contributed to contaminant removal in addition to sorption to roots as suggested by previous literature. However, it is more likely that removal can be most attributed to the properties of the media substrate, LECA, as well as the microbiome that was able to form on it after 30 days acclimation in a hydroponic nutrient solution. The rich media environment developed pre-experiment coupled with optimal aerobic conditions and continuous water flow likely allowed for microbiota to maximize their removal capabilities when compared to similar 15 studies. It is possible that the LECA was able to adsorb some of the positively charged contaminants since clay carries a negative charge, and that needs to be investigated further. The mutual symbiosis of the plants and the substrate media microbiome need to be further examined to optimize contaminant removal rates on a larger scale and select plants that will significantly impact removal rates. Different water temperatures should also be tested to see how removal of CECs by the microbiome as well as by plants will be affected.

2.7 Modeling Ph And Electrical Conductivity In Hydroponics Using Artificial Neural Networks.

In 2006, Konstantinos proposed a model for predicting pH and Electrical Conductivity (EC) responses of a deep trough hydroponic system is developed. Artificial Neural Networks are used as the method of modeling. The Feedforward Neural Network Model has 9 inputs (pH, EC, nutrient solution temperature, air temperature, relative humidity, light intensity, plant age, amount of added acid and amount of added base) and two outputs (pH and EC of the next time step). The most suitable and accurate combination of network architectures and backpropagation training algorithms was the one-hidden-layer with 9 hidden nodes architecture trained with the quasi-Newton backpropagation algorithm. During the testing of the model using new input data, one step ahead predictions of pH were within 0.01 and EC within 5 microS.cm-1

2.8 Designing And Implementing The Arduino-Based Nutrition Feeding Automation System Of A Prototype Scaled Nutrient Film Technique Hydroponics Using Total Dissolved Solids Sensor

In 2017, Dania Eridani presented a naval solution about the nutrients. Hydroponics is a new breakthrough in farming because it no longer uses soil as a planting medium, and uses water instead. In the hydroponic system, the 16 fertilizer used is mixed into water, which is then referred to as hydroponic nutrition or nutrient solution. The nutrient concentration in the solution, which is then indicated by the electrical conductivity (EC), is very influential on crop production. The nutrient concentration usually mixed manually by combining the fertilizer and the water in the right amount. Therefore, through this research, a nutrition feeding automation system of a prototype scaled Nutrient Film Technique (NFT) hydroponics is prepared. The system is designed with a control center using the Arduino UNO R3 board. The system is equipped with GP2Y0A21 proximity sensor as a water level detector, TDS sensor as a detector of electrical conductivity of the nutrient solution, and servo motor as an opening device of the faucet in the nutrient container. The research resulted that the system is capable of performing water delivery automatically when the water level is less than the minimum level, and add the nutrients automatically when the nutrient solution concentration is below 800ppm

III. HYDROPONICS FARMING

3.1 Hydroponics

Farming with the use of soil medium consumes a lot of space and water; not on that, but it is also prone to pest attacks, resulting in higher use of pesticides. Hydroponic system means growing plants without soil with better results, especially in areas where, the environment is where seasonal changes are not promising or face drought conditions. Instead of soil, coco peat, rock wool, vermicompost are used. The growing system depends on the type of plant you want to grow in your hydroponic farm. If you are planning to crops like lettuce, kale, the DWC system will be suitable, and if you need to grow vegetable crops like tomato and cucumber, the Dutch bucket system will be fit. Our approach is to make an Automated Hydroponic System reducing labor cost as well as improving the quality of plants cost effectively. Our contribution is to make an Arduino based project the plant will be planted indoors and parameters such as pH level, temperature, turbidity will be monitored. Based on the monitored data, the automated part includes sprinklers for crops, humidity adjustment unit and pH up/down pump accordingly. This again is interfaced with a web-based server making data easy to monitor on mobile. This Hydroponics system requires less manual intervention, water and space than traditional agricultural systems. This may be stacked in order to limit the space usage. This makes them optimal for use in cities; where space is particularly limited and populations are high-self-sustaining city-based food systems mean a reduced strain on distant farms, the reduction of habitat intrusions, fewer food miles, and fewer carbon emissions.

3.2 Methodology

Soilless is a methodology used for plant cultivation in nutrient solutions with or without the use of an organic or inorganic medium to provide mechanical support. Water culture technique is used for this purpose. It is a hydroponic method of plant production by means of suspending the plant roots in a solution of nutrient-rich, oxygenated water. The proposed system is based on Embedded System aims to detect the pH level, temperature, turbidity level of water. Here we are using STM32 as a hardware-software interface.STM32 microcontrollers offer a large number of serial and parallel communication peripherals. pH sensor senses the value of pH level of the water.DHT11 sensor has the features to measure temperature & humidity value of the water. DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. Temperature is also continuously monitored using temperature sensor. When, there is change in the temperature, pH values the solenoid value opens and allows the water. Solenoid valves are control units which is electrically energized or de-energized, either shut off or allow fluid flow. The data will be stored in IOT. Through IOT, we can see the data of the water which will be clouded in the server. And it can be viewed in mobile are laptop using a website.

3.3 Working

The plant selected for hydroponics farming is spinach. Spinach grows well in our natural climate and the harvest time required is also very less when compared with other plants. First step to be done is to germinate the seeds. For that purpose, first coco peat must be soaked well in water. Leave it for 10-15 minutes. Then in a seeding tray seeds must be sowed and it has to be closed using a polythene cover. Open it after 3 days. Small sprouts of spinach can be found. After sprouting allow it to grow in the seeding tray itself for few more days. Then the sapling can be transplanted into the hydroponic setup. For the plant to stand erect in this setup net pots and leca clays are used. Leca clay stands for lightweight expanded clay aggregate. Nutrients has to be given in water by dissolving it.

Figure 1: Transplanting of plants into net pot

Nutrients must be provided only in a required amount. Excess nutrients deposition is harmful to the plants. Sensors used are pH sensor, temperature sensor, turbidity sensor and water level sensor. These sensors sense the values in water and if there is a variation of values than the normal required values then there come the use of solenoid valve. Using the outlet in the solenoid valve the water is send outside and through the inlet new pure water will be send inside. The variations in temperature are send directly to the cloud. These values can be monitored by anyone using the weblink provided from any part of the world.

3.4 Deep Water Culture

Deep water culture often abbreviated DWC, is a popular hydroponics method used by many hobby hydroponic gardeners. Not only it is effective, but it is an extremely easy hydroponics system to assemble and maintain. For beginners, deep water culture hydroponics is a great place to start. A great example of this system is the 5-gallon hydroponics bucket, also called as bubble bucket system. In deep water culture hydroponics plant's roots are suspended in a reservoir full of nutrient solution and oxygen is provided to the root system via an air stone or air diffuser. The oxygen and air source are very important to deep water culture. It is so effective since the plants receiving abundant of everything it needs to grow. The combination of sitting in nutrient water and oxygen causes the plant root system to explode in growth to become a large mass. The amount of oxygen the plant's roots receive is a major factor that makes deep water culture hydroponic system so successful. . The upside to DWC, as mentioned, is the accelerated growth resulting from superior uptake of nutrients and oxygen.

3.5 Planting Process

As we know hydroponic cultivation does not require soil. So, to make the plants stand straight some other material must be done. The support system is provided using two materials namely leca clay and the net pot. The hydroponic setup will have holes of 2-inch size for the plants to grow through it. So that net pots of 2-inch size have to be bought and it should be kept inside the hole. It should be filled with leca clay for providing support. The small plant which is sprouted must be kept into the net pot surrounded by the leca clay in such a way that the roots are completely immersed inside the water.

3.6 Pipe Setup

The pipe setup used commonly for hydroponic farming is called the pipeline. The method used here is deep water culture. PVC pipes are used for the construction of these kinds of setup. There will be holes in a way to keep net pots inside. According to the size of hydroponics farming pipe can be done. For this project 5 spinach plants are decided to be grown.

Figure 2: Pipeline setup

3.7 Plant Selected

Spinach is selected for this hydroponic project. The reason behind this is spinach germinate faster when compared with other plants. Spinach grows rapidly in a hydroponic system, mainly when using the Deep-Water Culture methods that keep the nutrient solution highly oxygenated. Green leafy vegetables are more suited for hydroponic farming for beginners. Temperature required for spinach also matches with the normal temperature of our surroundings. It will also use far less water than in the ground garden. It is easy to start these plants from seed and a week after sprouting, move them into your system.

3.8 Germinating Process

Spinach seed germinates in 3 to 5 days but sometimes seed can take up to 3 weeks to germinate in cold soil. Seeds of spinach must be soaked in water for half an hour. For germination purpose seeds should not be sown in the soil because after germination it will be difficult to remove the plant roots from the soil without any damage. For this purpose, coco-peat is used. Coco-peat must be broken down into small bricks. It should be soaked in water for a minimum time period of 1 hour. Water will be completely absorbed by the coco-peat. This keeps the seeds wet for the complete germinating period without any requirement of additional water .Inside the seeding tray small amount of coco peat has to be kept and then seed should be kept above it. Then an additional layer of coco peat has to added to cover the seed. It should be covered using cloth or any polythene cover and should be kept undisturbed for complete 3 days. After 3 days open the cover, germinated saplings of spinach can be found. Allow it to grow in the seed tray itself for few more days. After germination the saplings must be kept in such a way that they get good ventilation and sunlight.

IV. Experiment and Results

Spinach seeds are sown in the seed tray using coco-peat. It starts to germinate after 5 days. The germinated sapling must be grown in the same medium for few more days till the growth of third leaf. The germinated sapling is shown in the image given below.

Figure 3: Germinated spinach seedling

4.1 Hardware Setup

Circuit connection is given as per the block diagram. Power supply provides 230v AC supply. It is converted into 12v AC by using step down transformer. Using bridge rectifier, it is converted into DC which provides pulsating dc. Followed by this, capacitive filter is used. This converts pulsating dc into pure dc. Then it is connected to IC7805, which has three ports 12v, Gnd, and 5v. To this, sensors and STM32 microcontroller connections are given

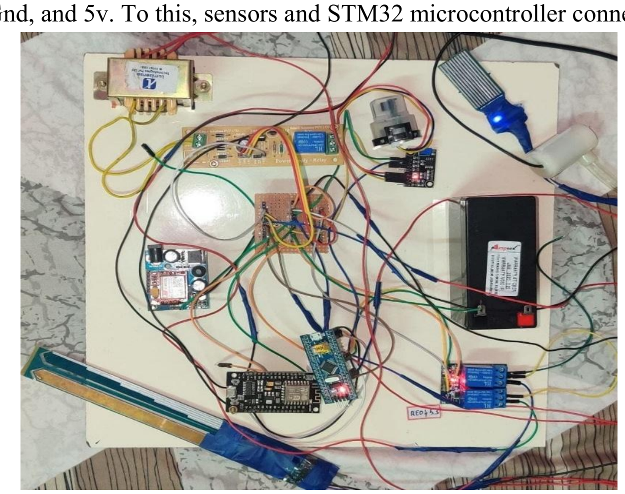

Figure 4: Hardware Setup (Experimental Setup)

4.2 Project Setup

This is the entire project setup in which all the sensors are attached to the hydroponics pipe in which plants grow in a hydroponics system.

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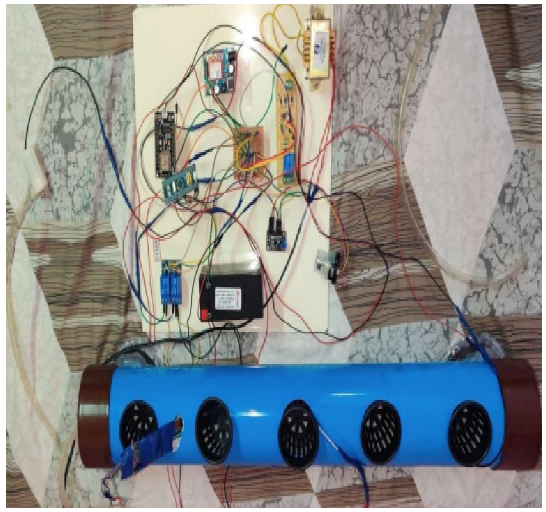

Figure 5: Entire Setup of the project

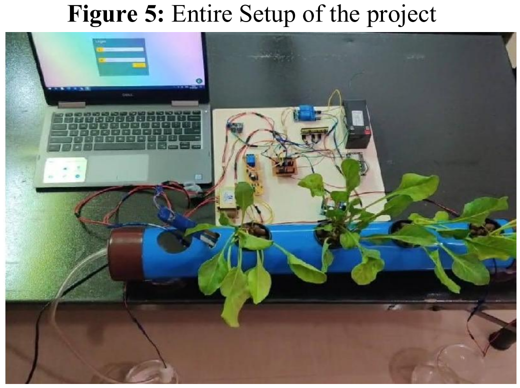

Figure 6: Spinach grown in hydroponics system

This is the project setup in which we grow spinach plant in the hydroponics system.

4.3 Results

A. Monitoring in Website

The resultant data of the sensed data is sent to the cloud and it is viewed in a webpage. For security purpose username and password is used. It is shown below.

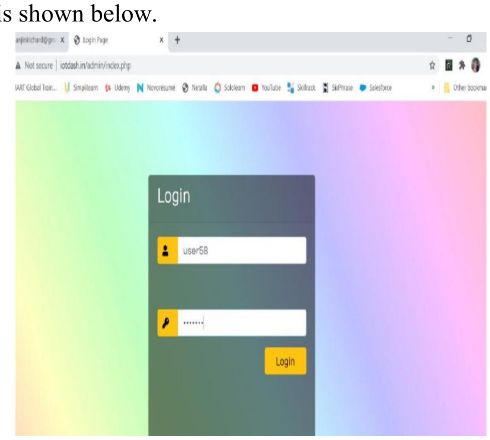

Figure 7: Webpage login

B. Data Stored in the Cloud

The sensed result will be tabulated along with validity time, and date in a tabular column pattern.

PH Value 11.37 water level =3357 turbidity level =3 Temperature = 31	03/21/21	2:01:28 PM
start	03/21/21	2:01:30 PM
PH Value 9.41 water level =3450 turbidity level =3 Temperature = 31	03/21/21	2:01:35 PM
start	03/21/21	2:01:37 PM

Figure 8: Data stored in the cloud

V. Conclusion

In this project automatic control and management of hydroponic cultivation is done. This system is designed in a way to control several parameters which are necessary for hydroponics cultivation. pH value is automatically controlled. If the pH value goes above normal level new water will be sent inside through inlet valve and other water will be sent out using the outlet valve. Several sensors are used which includes water level sensor, pH sensor, temperature and turbidity level sensors respectively. The sensed data will be sent to the cloud via NodeMCU. It can be continuously monitored using the web link. we conclude that this project is very easy to monitor and manage data, It presents stable connectivity and durable as portable equipment. Thus the system will be a good alternative for the users.

In future, this can be enhanced in a way to recycle the water that is sent out through the outlet valve. At present situation there is a lot of water scarcity problem. By recycling water and using it again this problem can be solved. This will highly improve the chance growth of many plants even in houses. Even in cities by following this method farming can be done. This can be lead to a healthy society. The ability to grow indoors allows farmers to control temperatures and lighting schedules to improve plant production. System can be designed to make use of vertical space and increasing planting density.

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