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Implementation of an Efficient Automatic Monitoring of Aeroponic Indoor Cultivation System

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ABSTRACT

This paper describes a unique construction and implementation of a low cost soilless agricultural system namely Aeroponics cultivation system. The main feature of this proposed system is that it can be continuously monitored using a web application and can be operated automatically. Cultivation of plants with soil has drawbacks such as most likely attack of pests, requirement of more manual labor, and continuous monitoring through the cultivation periods. Aeroponics cultivation method is a well-organized and effective practice for growing plants without the usage of soil environment. In this proposed work, the automatically monitored and controlled aeroponic soilless agricultural cultivation system is implemented using Arduino due board on Arduino's free software platform. Various sensors such as ambient light sensor, ultrasonic sensor LV maxsonar, liquid pH sensor, humidity and temperature sensor are interfaced with the main controller for measuring different physical parameters. The measured physical data can be stored in a memory card and can be accessed and explored in real time on ThingSpeak channel. A hardware prototype has been designed, tested and monitored in real-time scenario. The values measured from different sensors have been recorded and graphs have been drawn and presented in this work. The results attained indicate that the Aeroponics agricultural system is the most efficient, substantial, suitable and appropriate crop growing system other than the soil based crop growing systems.

Keywords: *Microcontroller, Sensor, Nutrient, Indoor, Land, Soilless cultivation and Crop yield.*

1. INTRODUCTION

Agriculture sector is the pillar and plays a very significant role in the development of Indian economy. Even at present the Indian economy remains to be dependent upon the agriculture sector and so the scenario is unlikely to vary in the coming next fifty years also. Currently the agriculture supports approximately 62% of the whole population, as compared to about 78% during the year 1950.

India has the tenth biggest cultivable land in the world, twenty agro-climatic regions, retains 46 of the 60 different soil types in the world and the entire fifteen main climates occurring in different parts of the world occur in India. During the late sixties, the country witnessed remarkable achievements in agriculture sector due to the beginning of green revolution. This assisted the country to overcome the general hunger and starvation, achieve adequate food, generate novel techniques of production, and bring socio-economic transformations in large farmer population.

However, the situation, started to decline when it came around mid-nineties. It includes inadequate investment, unhealthy atmosphere in rural areas and congestion in agriculture, lack of proper irrigation facilities and electricity, insufficient investment, inadequate non-farm amenities, size of holdings and insecurity of cultivable land tenure. Also the degradation of ground water resources and lack of availability of cultivable land due to the increasing urbanization accounted for the decline in the growth of agriculture productivity. Hence the deceleration of agricultural sector needs to be stopped and has to be increased to a larger extent to fetch the needs of growing population for the coming decades. However, the demand for agricultural productivity is escalating rapidly with increase in human population and growing demand from the industry sector. Thus, there is a specific need to change the scenario related to agricultural productivity and put it back on higher growth rate trajectory.

Conventionally, agriculture has been described as the exercise of growing plants in soil, in outside environment with enough nutrient mixed water facilities. These conventional methods have undesirable effects such as requirement of large cultivable land, inefficient use of nutrient rich water, large usage of chemical fertilizers and soil degradation. Under these situations it becomes very much indispensable to develop or create novel technologies to improve the agricultural productivity by utilizing fewer ingredients. Soilless agriculture is a new encouraging method for improving the agricultural productivity. This system has numerous benefits such as efficient usage of water consumption, less nutrient consumption, higher crop yield, very less fertilizer requirement and the entire growing process functions in a tight and controlled dust free environment. Soilless agriculture is a controlled method of growing plants without the use of soil medium; rather the plants absorb the key nutrients via roots when dipped in nutrient rich liquid medium. The main purpose of soilless agriculture is to supervise and regulate the water levels, temperature levels, dissolved oxygen levels, light intensity, pH levels and mineral salts which are prime specification in the stimulation of the plant growth.

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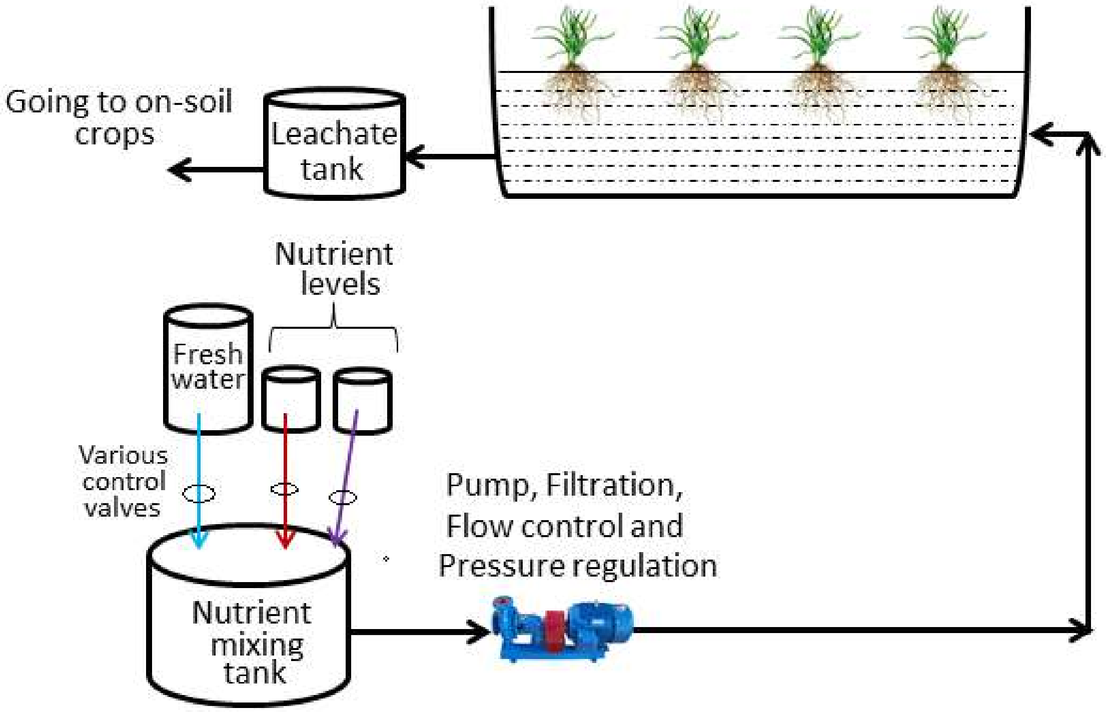

Fig.1: Over view of Open Soilless agricultural system

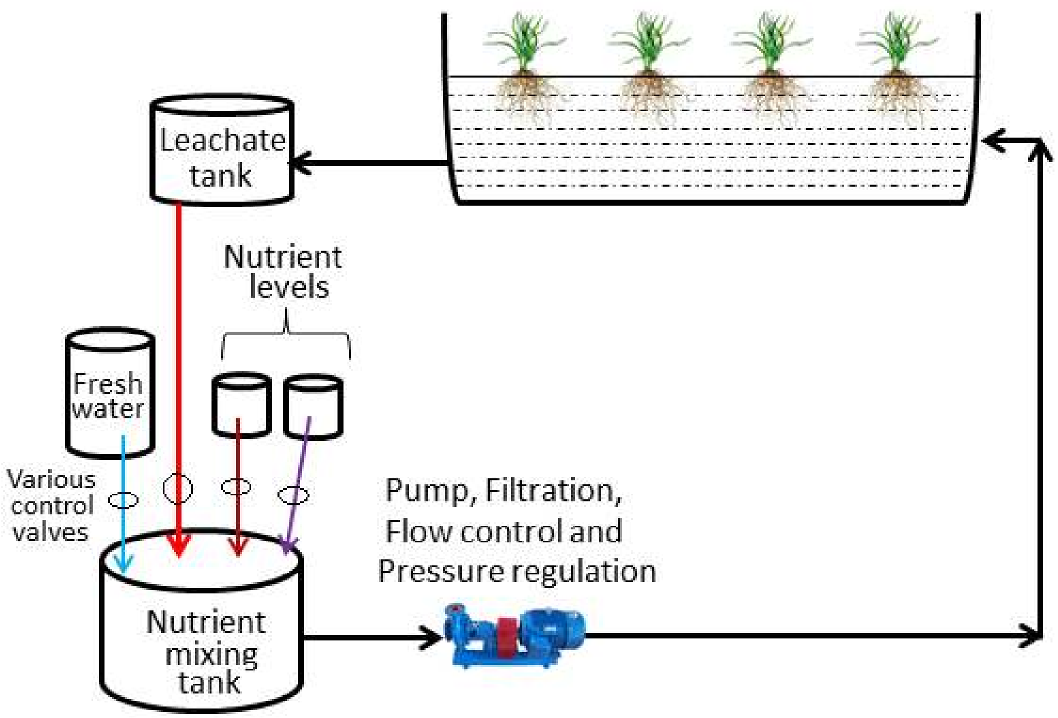

Fig.2: Over view of Closed Soilless agricultural system

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Hence the farmer should be able to judge and balance the nutrient levels, water level, optimum levels of temperature, humidity, carbon dioxide, light intensity, pH and ventilation for achieving higher crop yield of good quality. The essential minerals required for plant growth in soilless agriculture are Phosphorus (K), Sulphur (S), Manganese (Mn), Nitrogen (N), Calcium (Ca), Iron (Fe), Zinc (Zn), Boron (B), Chlorine (Cl) and Molybdenum (Mo).

In general there are two types of soilless agriculture methods. (i) Open soilless agriculture method and (ii) Closed soilless agriculture method. In open soilless agriculture method shown in Fig.1, essential minerals are mixed in the water and supplied to the plant roots just like in a conventional on-soil crop and the unutilized water is drained out of the complete system. This solution i.e. leachate can be recycled to fertilize the on-field crops. The water should be properly mixed with mineral rich nutrients taking into the type of plants to be grown. Also a drip system may be used for recirculating the mineral rich nutrient solution. Some of the techniques that come under this category are root bagging technique, hanging bag technique, and trench method. In closed soilless agriculture method, essential minerals are mixed in the water and sprayed to the plant roots and the unutilized water is recovered, re-filtered and recycled once again to the plants. Compared with the open soilless agriculture methods, the closed soilless agriculture methods shown in Fig. 2 necessitate the need for more exact and frequent control of the mineral rich nutrient solution. Improper usage of nutrients leads to the damage of the plants. The returned leachate solution must be properly treated i.e. to remove any foreign substances, to restore to its original nutrient element composition. Also some times the liquid should be sterilized enough to kill pathogens. Finally it is emphasized that the liquid levels must be tested at regular time interval in order to get best growth rate of plants. Some of the techniques that come under this category are Hydroponics technique, Aeroponic technique, Aquaponics technique and Nutrient film technique.

At present there is a lack of scientific data pertaining to the implementation of low cost automatic aeroponic system using microcontrollers for the measurement of different parameters. Some of the works exist in literature such as: M.I.Sani *et al.* described the design procedure and implementation of a hardware prototype aeroponic growing chamber. Different parameters such as ambient light, chamber temperature, water pH value were measured and controller was used to operate the actuator using relay circuits [1]. A review of soilless cultivation namely aeroponic technique and hydroponic technique is described in [2]. The paper explains the components and atomizers required for aeroponic system, potential challenges, advantages and disadvantages and future applications prospects of aeroponic systems. G. Salachas investigated the root zone size on quality and plant yield of aeroponically cultivated sweet basil plants [3]. The system is housed in a fully automated glass house plant growing with different widths, lengths and depths of canals for nutrient rich water to flow. The results confirmed that aeroponically grown basil plants shown higher nutritional values. W. P. Kalungi et al. described about the design and implementation of a ZigBee based low cost wireless liquid level controller [4]. It utilized a highly sensitive ultrasonic sensor for precisely measuring the different types of liquid levels. I.Idris et al. designed an aeroponic cultivation system that can be automatically monitored and controlled for growing potatoes [5]. A control system was designed using a microcontroller that will automatically regulate motor pump and nozzle for distribution of water and fan and ultrasonic mist maker for mixing the nutrients. The design of ZigBee based environmental monitoring; alerting and controlling system for green house agriculture based cultivation is presented in [6]. The proposed system employs various sensors for measuring physical signals, ZigBee communication module and a microcontroller such as ARM7 processor. A high density aeroponic system for Cherry type tomato hybrids cultivation is presented in [7]. M.Pala et al. described a unique automatically monitored and automated aeroponic and hydroponic system [8]. The system consists of a sensor network, motors and actuators implemented in a greenhouse space. J.L.Reyes et al. presented and proposed different structures, better plant monitoring and caring techniques in [9]. E.Mohareb et al. investigated various concerns regarding demand for food system products for urban agriculture [10]. Compared to the existing works, this work describes the implementation of aeroponic cultivation system.

The proposed aeroponic work implementation details are planned as follows. The architecture of soilless aeroponic agricultural system is explained in Section-II. The block diagram is elaborated in Section- III. Section-IV gives hardware prototype and its measured results. Lastly, Section-V gives the conclusions of the presented work.

2. AEROPONIC CULTIVATION SYSTEM

Aeroponics agriculture technique is a very well-organized and effective way of growing plants without the need of soil resources and with minimal usage of water. With this method, the plants can be grown horizontally row-wise or vertically column-wise. The aeroponics is one of the most advanced types of hydroponics system. The plants are suspended in the air and the nutrient rich water is squirted on the roots of the plants that are placed inside the plant growing chamber. The roots of the plant are covered with polystyrene or any other materials with holes located inside it. A short cycle timer circuit present inside the plant chamber regulates the nutrient pump for controlling nutrient levels in the water.

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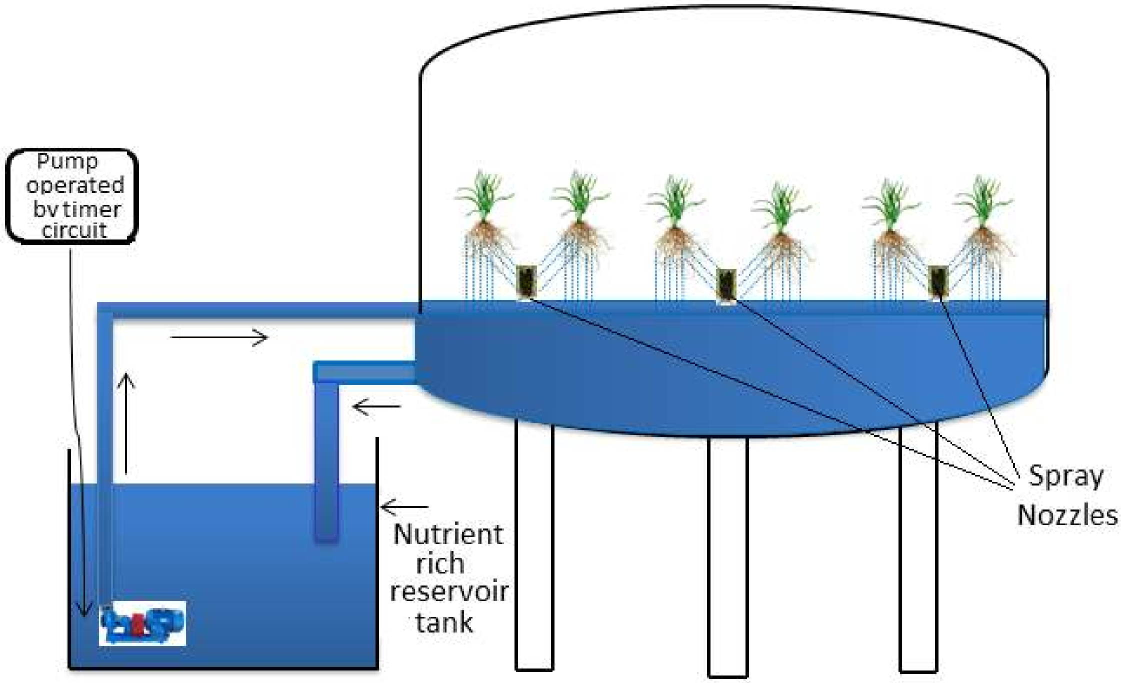

Fig. 3: Typical view of a Aeroponic System implementation

This nutrient pump is made to work precisely for ten to twenty seconds for every ten minute interval. Using this technique the temperature, humidity, pH and water conductivity levels are monitored accurately and controlled precisely. Also since the roots are suspended in the air inside the chamber, it is possible to grow the plants practically anywhere inside the chamber as the water is sprayed uniformly inside the chamber. This technique is mainly suited for growing different vegetable crops. The basic functional diagram of Aeroponic cultivation system is shown in Fig.3.

The benefits of soilless aeroponic agriculture method include such as reduced labor cost through automation, consumes very less water (almost ten percent compared to other systems), completely programmable with less power consumption, moisture control for improved plant growth, easier to harvest in the absence of soil, yields high quality crops in a very controlled environment, reduced risk of leaf disease and pest infection, roots are better exposed to oxygen level concentration, more crops can be grown as compared to other systems, and the implemented systems can be made scalable. The disadvantages include expensive material for the design and construction of plant growing chamber, the farmer must have proficiency about the correct quantities of nutrients required for good plant growth, requires advanced equipment’s such as accurate atomization nozzles, pH measuring devices, constant operating high pressure pumps, precise temperature sensors, accurate timer systems, precise humidity, passive infrared sensors and regular cleaning of plant growing chamber.

3. IMPLEMENTATION OF INDOOR AEROPONIC SYSTEM

In this proposed work, all the sensors namely ambient light sensor, ultrasonic sensor, humidity and temperature sensor, and liquid pH sensor are interfaced to the Arduino due board. Fig. 4 shows the block diagram of the proposed Aeroponic implementation. The sensors used in the proposed implementation are listed in Table 1.

Table 1: Various sensors used

S.No:	Name of the Item	Sensor used
1	Ultrasonic Sensor	LV MAXSONAR
2	Ambient Light Sensor	TEMT6000
3	Humidity and Temperature	RHT03
4	Precise Real Time Clock module	DS3231
5	Four Channel Relay Module	SCPLRBA
6	Bilge pump	1100GPH 12V

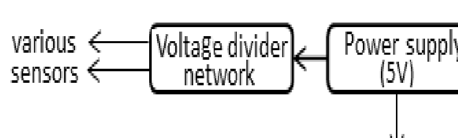

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Fig. 4: Block diagram of the proposed implementation

The low cost automated aeroponic agricultural system was carried out in a special facility (i.e. box) with an area capacity of (8X6) meter; height is 3 meter, assembled in steel structure with a thickness gauge of 1cm. The constructed box is displayed in Fig. 5. The other materials required for the implementation are an 8 meter glass plate of 1cm thickness for closing the box and with required number of holes for plant growing, a 2 inch diameter larger PVC pipe of 6 meter length with five rows in the box, an adjustable wrench, and two valves.

Fig. 5: Box with glass plate at the top side

The system can have a maximum capacity of total of 60 plants each. The box is equipped with bilge pump, nutrient rich water tank operated by electronic timer circuit, and 10 water sprinklers. The hardware prototype is presented in Fig 6. For monitoring and automation, Arduino controller was used. The Arduino IDE (Integrated Development Environment) is an OSS (Open Source Software) with in-built library functions from the arduino library that is mainly used for writing and compiling the code into the arduino module. Fig. 7 displays the initial stages of the plant growing in a controlled growing chamber.

Fig. 6: Hardware connections

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Fig. 7: Preliminary stages of the plant growing

Fig. 8 and Fig. 9 present the measured values of pH and conductivity (µS/cm) against a period of time. The readings have been recorded over a period of 45 days at regular intervals of time.

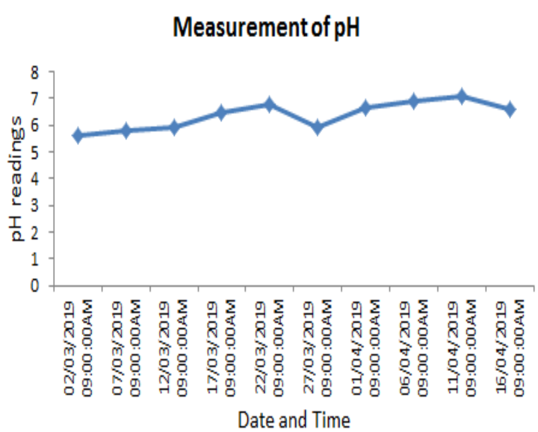

Fig. 8: Measured pH values of nutrient rich water

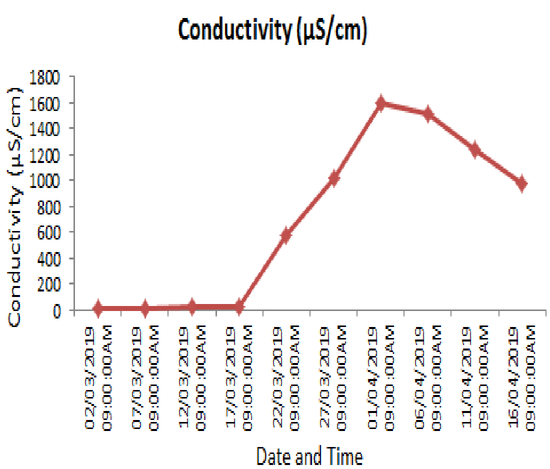

Fig. 9: Measured conductivity of nutrient rich water

Fig. 10 and Fig. 11 present the measured values of temperature (°C) and humidity against a period of time.

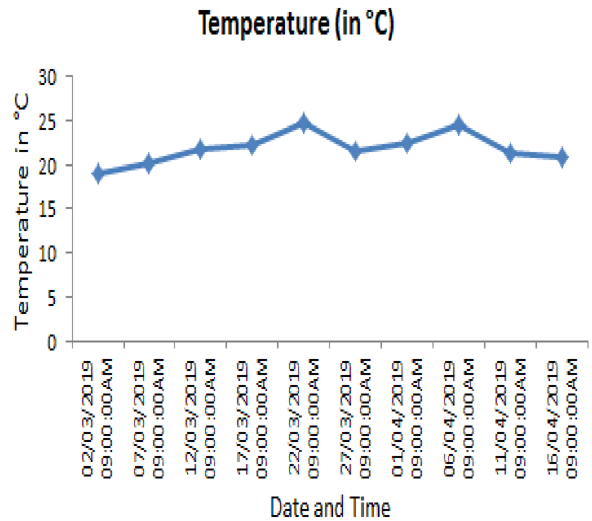

Fig.10: Measured Temperature

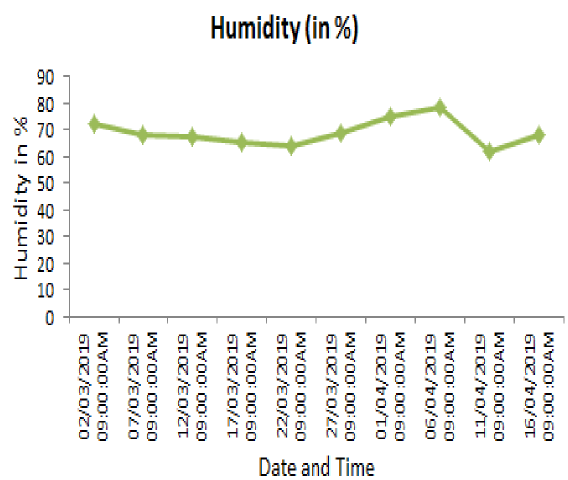

Fig. 11: Measured Humidity values

5. CONCLUSION

The demand for hygienic and garden-fresh food products are growing at an alarming rate with the rapid rise of human population over the last decade. Under these circumstances, it turns out to be necessary to develop soilless based agricultural methods to meet the growing nutritional-rich food requirements. In this presented paper, a unique design and implementation of a low cost soilless agricultural system namely Aeroponics cultivation system is proposed. Aeroponics is a modern and innovative soilless plant growing technique. The advantages of aeroponics cultivation include almost zero environmental pollution, saves 90% of irrigation water and can be recycled at all times, plants can be grown in areas hostile for ordinary farming, produces better crop yield

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with no damage to the fruits and plants grow upto three times faster as compared to soil based cultivation. All the measured physical data from various sensors were interfaced to Arduino due board. The entire system was first tested using bread-board connections and finally a hardware prototype has been prepared. The sensors worked with good stability and various readings have been taken at regular intervals during a period of 45 days. After implementation, the plants continued to display signs of healthy growth. The proposed work could be further extended to multi-language support for different regions in the country.

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