Plant Growth Optimization Using Internet of Things for Self-Sustaining Indoor Farms

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1 Introduction

Background India is the second most populous country in the world and one of the fastest growing economies, next only to China and USA. Agriculture, with its allied sectors, accounts for the livelihood of over 70% of its rural population. Although India has achieved self-sufficiency in food production, agriculture's contribution to the gross domestic product (GDP) of India has steadily declined over the years and so is the total land area under agriculture [1]. Whilst one reason for this may be the diversification of the economy, as it grew, from being an agriculture-based economy to an urbanised industrial and service oriented economy, the resource-intensive unsustainable farming practices pose major threats to the agriculture in this country. Desertification, land degradation and climate change also expedite the problem, and there is a need to shift from a conventional to a more sustainable farming practice that is resilient to the above-mentioned threats.

Problems and Solutions Transforming from a soil-dependant farming practice to a soilless farming practice aided by modern technology and precision farming techniques can help mitigate most of the problems that affect conventional agriculture. A variety of interconnected sensors can be used to monitor and control crop growth, in an indoor environment. Alternative and smart farming technologies like hydroponics [2–4], vertical farming [5–7] make use of Internet of Things (IoT) to monitor the crop environment and optimise plant growth. IoT consists of devices with built-in sensors to collect and transfer data over a network without manual intervention. IoT can be used to monitor all the plant parameters to make the environment conducive for plant growth. Also, an extensive review of related works can be found in [8–15].

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P. H. J. Chong et al. (eds.), *Emerging Electronics and Automation*, Lecture Notes in Electrical Engineering 937, https://doi.org/10.1007/978-981-19-4300-3_18

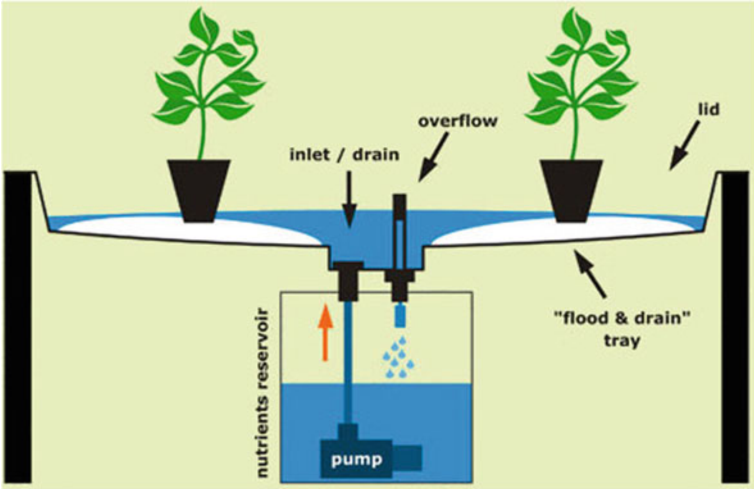

Fig. 1 An example hydroponic system [16]

Proposed Solution Hydroponic farming is a farming method that involves growing plants without using traditional soil medium, using mineral nutrient solutions mixed in a water substrate, that acts as the growth medium. Plants need food, water, light, air, temperature and when broken down to these five things, it becomes simple to give plants only what they need. The hydroponic farmer controls the growing environment of plants by using a network of interconnected sensors. The plants thrive on the nutrient solution alone—the medium merely acts as a support for the plants and their root systems. We discuss such a prototype, of a smart soilless farming setup in an indoor environment monitored and controlled by IoT sensors for optimising plant growth. And thus, the main idea of this paper is to explore the possibility of controlling plant growth parameters to achieve desired results in terms of fruit yield, stem growth, leaf density, etc. (Fig. 1).

2 Methodology

2.1 IoT Prototype System Architecture

The IoT indoor prototype system comprises of a Raspberry Pi connected to a temperate/moisture sensor, hydro system containing a water pump and to the LED Lights, through relays. The system was programmed in Python and the code measured the temperature/moisture levels and to turn on and off, the LED Lights and water pump at periodic intervals (Fig. 2).

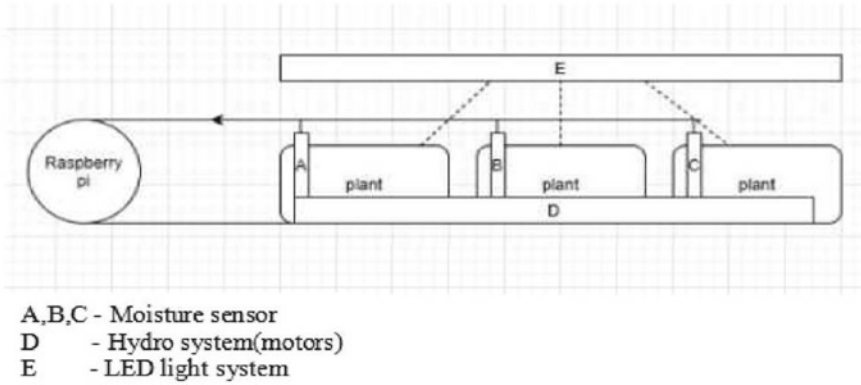

Fig. 2 Plant growth in indoor environment

2.2 The Experiment

Coriander was grown in a nutrient mixed water solution as shown in the experimental setup given in figure in a nutrient mixed water medium. Temperature, humidity, and the level of lighting were controlled by sensors. Nutrient mixed water medium was pumped using a motor through a series of pipes.

The implementation was carried out as two cases—outdoor and indoor under natural sunlight and under artificial LED Light. The two cases were to compare the variance in the growth parameters of the plants under sunlight and artificial light.

Plants in the outdoor environmental setup were grown in a well ventilated space with adequate sunlight and wind. They were manually watered. In the indoor environment, the plants were setup in a dark space with artificial lighting, and the temperature was maintained at 25°. The seeds were placed in three support mediums—cocopeat, sponge and rockwool. The LED light in the room was turned on for 12 h of a day, and darkness was maintained during the other 12 h of the day. Nutrient solution was pumped through the pipes in the indoor environment for every 3 h with a gap of 1 h in between.

Both the indoor and outdoor setups were monitored continuously for a distinct comparison on the differences in growth and quality. The proposed prototype system was carried out on the indoor plants. Coriander was selected because of the lower harvest time and because it was easier to grow without much manual intervention. The plants were observed consistently at regular intervals on a daily basis so as to identify and pinpoint their phase of growth. In both the setups, ideal conditions were attempted, and the seeds were sown on the same day (Fig. 3).

The coriander plants showed no sign of crowning in the outdoors until day 4, and whereas in indoors, there was a single plant that crowned towards the end of day 3. On day 4, the outdoors and the indoors showed multiple crowning although there were more crowns in the indoor environment than outdoors.

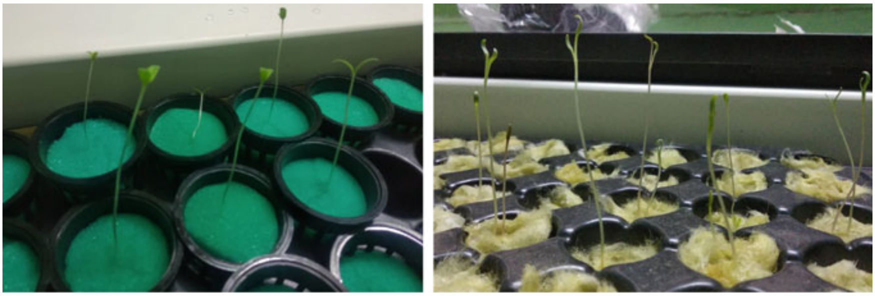

Fig. 3 Plant growth in indoor environment

Fig. 4 Indoor plants tilting towards the direction of LED light

By day 10, the outdoor plants reached a growth of 3 cm whilst this growth was achieved by day 7 in the indoors. On the 10th day of growth, we observed that the plants in indoor environment started tilting towards the direction of LED Light placed in the room. The shoot bearing the first leaves (plumule) started getting elongated in indoors, whilst in the outdoors, the growth pattern was normal (Fig. 4).

On day 15, the indoor plant has reached a growth of 8 cm with long plumule leaves mostly, whereas in the outdoors, the length of the plants was 5 cm in average but had more branches with small leaves. Some of the long elongated shoots in the indoor plants started to fall on the sides due to lack of support.

On day 20, the plants kept in outdoors had branched out significantly well and leaves dense and healthy. The edges of the plants in the indoor environment showed signs of browning on the edges. Some of the leaves also started to turn light yellow. This cell damage in plants was due to the lack of nutrients in the water medium because the plants had used up the nutrients for growing. Hence, on this day, the nutrient solution was topped up with additional nutrients.

On addition of nutrients and after providing adequate support for the indoor plants, they started to grow and pick up pace. By day 25, the plants in the indoor setup had as much growth as the plants kept in outdoors.

The plants in the indoor environment started to grow considerably faster than the ones in the outdoors and on day 30, the day of the harvest we observed that the growth of indoor plants was around 10% greater than the plants in the outdoor environment.

From the final observation, the plants grown indoors with the proposed system provided much distinctive and satisfactory results. The results obtained on the health of the leaves and yield were greater than the actual estimate.

3 Results and Discussion

As observed from the above experiment, the plants grown with the help of the indoor prototype system grew at a pace 10% faster than the plants grown externally. There were some drawbacks and flaws in the system initially and were overcome as the learning process was gradual. The plants started tilting towards the direction of light, and hence, we had to reassemble the lights and place them closer and directly on top of the plants. The length of the stem was also elongated. This could have been overcome with the additional of nutrients more frequently and with a closer placement of LED lights. Signs of yellowing and browning could have been overcome with calculating the exact value of nutrients that have to be mixed in the water medium. Previous knowledge of this would have helped us achieve much higher growth rates.

4 Conclusion and Future Enhancements

The system was successfully implemented with a functionality equivalent to a typical to how a farmer grows it traditionally. By this method, the plants grown indoors grow at a pace 10% faster than that of the same plants grown externally. This system can be further enhanced by adding and modifying more parameters to stimulate growth such as sounds, changing LED colours [17]. As maintaining the desired temperature can seem economically inefficient, in the long term, it might seem as a smart investment, and focussing on the frequency of LED lights [18] can also give promising results.

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