Implementation IoT (Internet of Things) Based Smart Agriculture Fertilizer System

Nithun Madanayaka[1], B.L.Sanjaya Thilakarathne[*2]

[1] *Department of Engineering Technology, University of Ruhuna, Matara, Sri Lanka*

[2] *Department of Engineering Technology, University of Ruhuna, Matara, Sri Lanka*

Abstract

This research focused an Internet of Things (IoT) based smart fertilizer system for green house. The android application was developed using android studio 4.0 by having facility to enter crop variety and suggested Nitrogen (N), Phosphorus (P) and Potassium (K) (NPK)value according to the plant height and width. For this experiment 20-40 days old Tomato (*Solanum lycopersicum* L.) were used. According to the in-vivo experiments conducted at greenhouse NPK (3: 1.1: 4) g dissolved in 40 ml was identified as the best ratio for one Tomato plant. However, the amount of water was increased according to height of the plant. This data from the greenhouse is collated and stored onto the server. On this available data, analysis was performed to calculate the NPK requirement of a Tomato plant. Based on the data the authors developed own algorithm to make the optimum crop production, basically plant height and width. In this project, sensors were used to measure various parameters of the field such as temperature, humidity and soil moisture. Further Raspberry microcontroller collected data from android application, camera, flow measure valve and sensor readings. Plant height and plant width were calculated daily by taking images using Pi-camera. Image processing system is coded using PyCharm Community Edition 2020.2. Using android studio 4.0, developed the easy accessibility user friendly mobile application. It provides the interface to the farmer and microcontroller and enable farmer information monitoring and controlling. Through the mobile application farmer can set fertilizer ratio, crop plantation area and the fertilizing scheduling time. Further mobile application monitors the environmental conditions in real time, such as temperature, humidity, barometric air pressure, soil moisture and lux value. Furthermore, through this mobile application farmers can check the history of data specially the plant growth according to amount of fertilizer used. All the data storage will be done in cloud database. As a result, farmers can easily access to data by using mobile applications. This smart agriculture fertilizer system will be implemented on a local scale where local farmers can utilize this IOT based analytics which provides new insights and improves decision making.

Keywords: *Internet of Things (IoT), Smart agriculture, Fertilizer system, Greenhouse cultivations, Plant growth*

Introduction

There are more sophisticated technological improvements can be found under agriculture with technology. To maintain the food security, we need to get good harvest. Fertilizing is necessary to obtain good yield. Fertilizers are changing according to the crop variety and the requirement of fertilizer amount depends according to the plant stages and conditions. Soil nutrients come in two basic categories, as macro and micro elements. Those macro-elements are Nitrogen (N), Phosphorus (P), Potassium (K) and micro elements or trace elements are Iron (Fe), Manganese (Mn), Zinc (Zn), Boron (B), Copper (Cu), Molybdenum (Mo) and Silicon (Si).A dividing line is drawn between macro and micro nutrients where nutrients required in greater quantities are as macronutrients, and those elements required in smaller quantities are as micronutrients. This division does not mean that one nutrient element is more important than another, just that they are required in different quantities and concentrations (Bond, 1952).

Any sort of nutrients deficiency or applying them improperly can be seriously harmful for the plant health. More importantly, excessive use of fertilizer not only results in financial losses but also creates harmful impacts to the soil and environment by depleting the soil quality, poisoning ground water, and contributing to global climate changes. Fertilization under smart agriculture helps to precisely estimate the required dose of nutrients, ultimately minimize their negative effects on the environment. Field data gathered from sensors can help to achieve a high level of accuracy in the calculation of fertilizer requirement. Well-planned irrigation is very critical for obtaining optimal crop yields. For proper irrigation scheduling, sound knowledge of the soil moisture status, crop water requirements, soil density, pH value of soil is prerequisite to maximize profits and optimize the use of water and energy (Kukal, 2014).

The objectives of this research project are to automate the fertilizing system according to the plant growth and to develop the system for farmer to fully control and monitor through mobile application based on IoT.

Materials and method

Seeds of Tomato (*Solanum lycopersicum* L.) cv. Platinum 701 F1 were obtained from the Department of Agriculture at Galle, Sri Lanka.

Sample preparation involved the following steps.

1. For the first four days, Tomato seeds were placed continuously in moist paper towels and germinated at a temperature of 25°C.
2. Seedlings were transplanted to 1.4 litres plastic pots (150 mm in depth and 110 mm in diameter) containing black soil with four seedlings per pot.
3. After 10 days, best plant was kept in the pot by removing other three.

Plants were grown in a greenhouse under a 12 h daylight period. The air temperature ranged from 25–28 °C during the day and 17–18 °C during the night. Relative humidity was maintained at 70±5% during the night and at 50±5% during the day. Light intensity at the top of the canopy was around 500-800 μmol m^{-2} s^{-1} (PPFD) (Zhang et al., 2005). Limited research was done to identify the best daily standard NPK ratio for Tomato. However, soil moisture, temperature, humidity and soil pH value effect for the NPK ratio (Rutledge, 2017).

According to the published data in Haifa website (*https://www.haifa-group.com/tomato-fertilizer/crop-guide-tomato-fertilizer-recommendations*) and verbal communication with the farmers four different NPK fertilizer ratios were investigated to select the best growth rate of the plants. Since four NPK ratio values were applied to 40 Tomato plants with sample of 10 plants (four fertilizer ratios). Twenty days old Tomato plants were used for the experiment. The following Table 1 shows corresponding ratios of NPK.

Table 1: NPK values added to each plant.

Sample name	NPK ratio (Kg/ha))	Amount of N: P: K (g)
E	200: 50: 365	4: 1.1: 7
F	150: 50: 200	3: 1.1: 4
G	150: 150: 200	2: 3.5: 5
H	330: 85: 570	7: 2: 11

Following data was collected for each plant in green house.

- Plant height
- Leaf count
- Largest leaf length
- Fertilizing amount for each plant
- Temperature
- Humidity
- Soil moisture
- Light lux

For the initial data collection, required NPK ratios were dissolved in 40 ml of water and added each plant on daily basis by using syringe. The amount of water was increased gradually by maintaining the constant NPK ratio. The data was collected for 20 days continually for each plant.

Based on the best NPK ratio to Tomato plant as 3:1.1:4, the liquid fertilizer was developed. To make each water tank it required to dissolve 10.5 g of Urea, 10.5 g of Diammonium Phosphate and 10.5 g of Potassium Chloride separately in 10 litters.

Same data set was collected after automating the above system.

Microcontroller

Fertilizer system used two microcontrollers which Arduino Nano used for monitoring the plant environment and Raspberry Pi 4 used as the main controlling unit. This main controlling unit is worked according to the following algorithm developed by the authors. Further this controlling unit get the data from reading data from Arduino Nano and send data to the mobile application through database. And through the Pi Camera V2.1 connected to the Raspberry Pi microcontroller measure the plant height using image processing system. According to the plant height, received input ratio and plant growth area calculated the required amount of Urea, Diammonium Phosphate (DAP) and Potassium Chloride (KCl). When the scheduled time reaches, first activated the agitator mechanism to mix well the soluble fertilizers in each tank. Then using flow measure valve, measured the three different soluble fertilizer amount and by valve controlling collect three fertilizer mixers to the main tank. After soluble liquid fertilizer pumps to the plants through drip irrigation method. All recoded process push to the mobile application through database.

Results & Discussion

The plant height, leaf length and leaf count were obtained with young Tomato plants (twenty to forty days old) by manually.

Daily fertilizer Vs Plant growth

Different ratios of NPK were added to each sample and measured the height, leaf length and leaf count of the plant daily for the 4 samples. Analysis was shown that all three parameters of the plant varied according to the fertilizer ratio. In Fig. 1 showed the average height plant for each NPK ratio. According to the plant growth it could identify that Sample F showed higher growth compared to others.

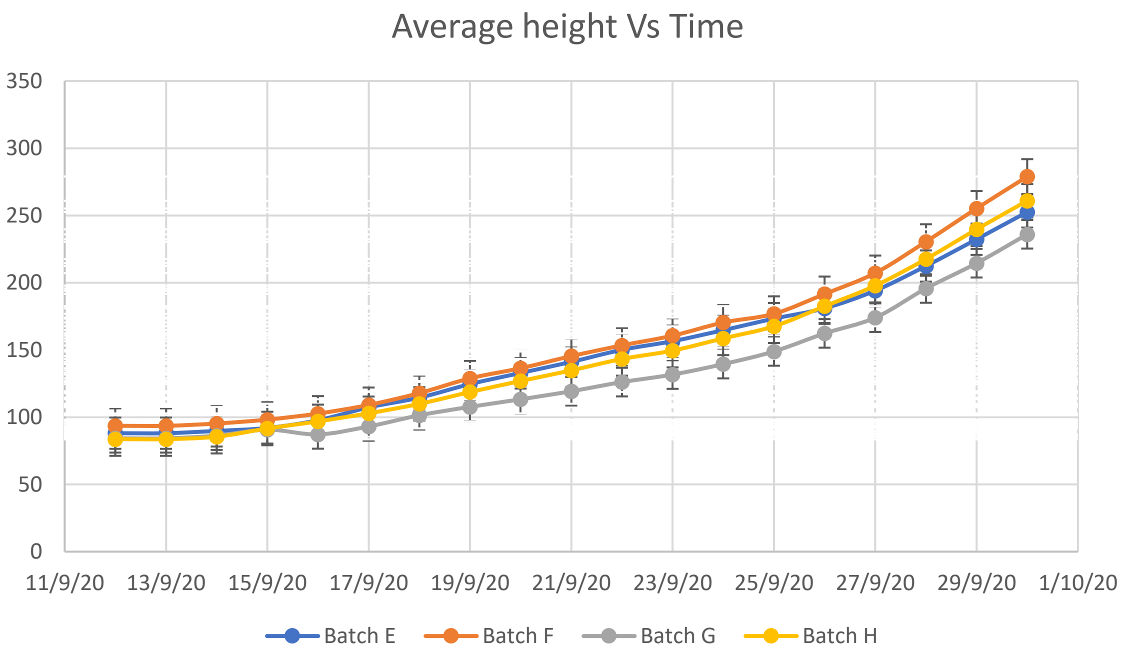

Figure 1: Plant growth of four samples

In Fig. 2 showed the average leaf count of plant for each NPK ratio. According to the leaf count it could identify that Sample F showed higher growth compared to others.

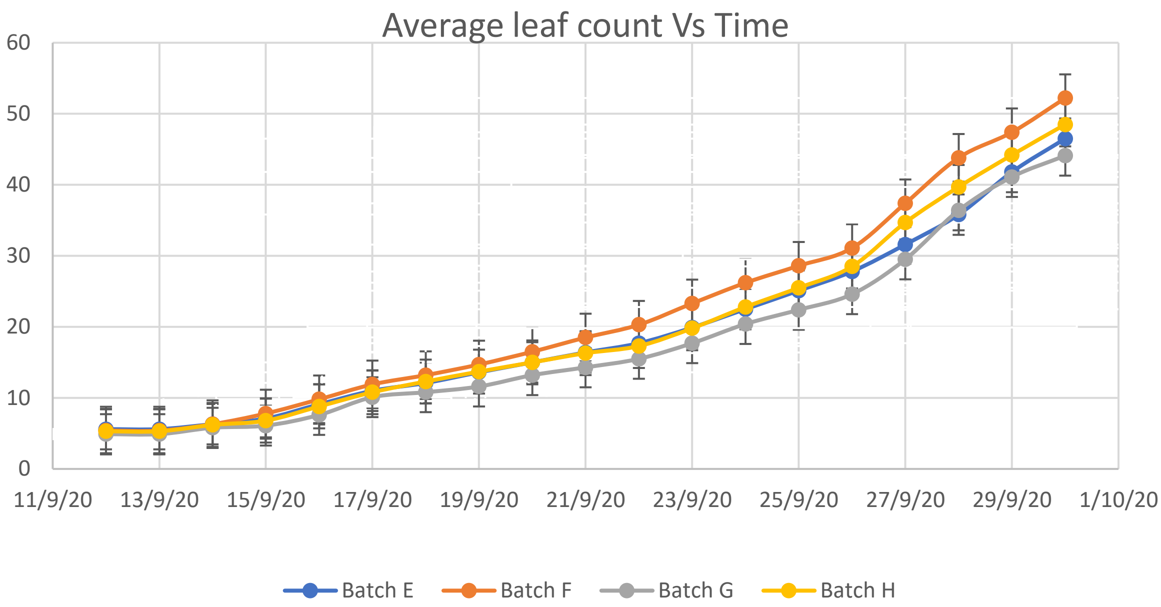

Figure 2: Plant leaf count of four samples

Finally in Fig. 3 showed the average leaf length of plant for each NPK ratio. According to the leaf length it could identify that Sample F and H showed higher growth compared to others.

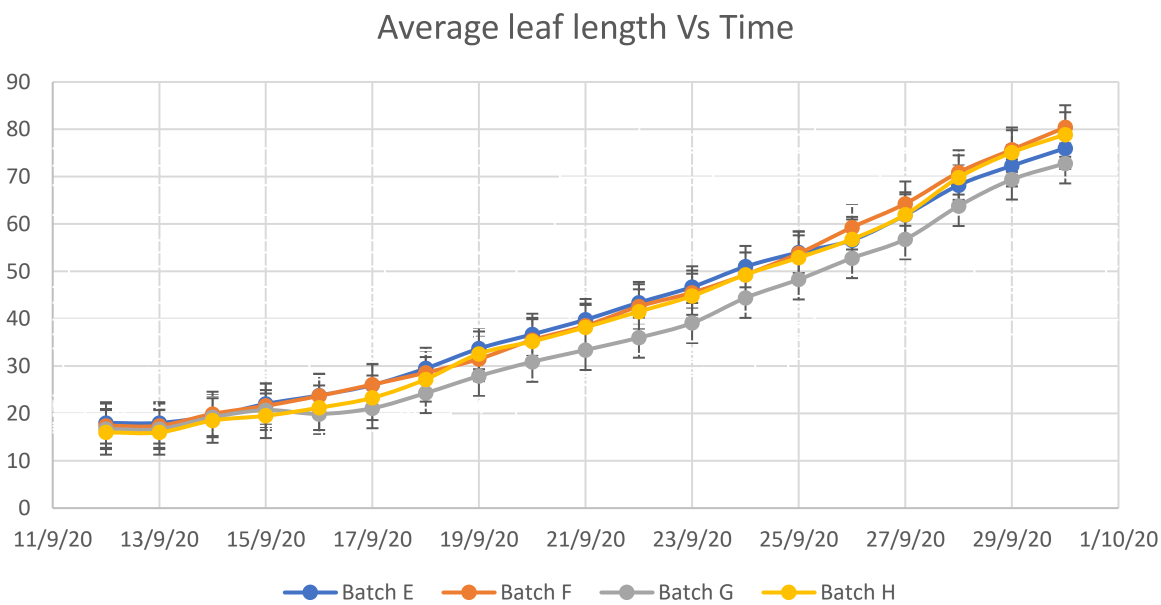

Figure 3: Plant leaf length of four samples

The three key macronutrients: nitrogen (N) for leaf growth; phosphorus (P) for root, flowers, and fruit development; potassium (K) for stem growth and water movements (Ayaz, 2019). According to Fig. 1 and Fig. 2 data clearly showed that addition of higher portion of N and K will lead to high growth rate and large number of leaves.

Mobile Application

Using android studio 4.0 easy accessibility user friendly mobile application was developed. It provided the interface to the microcontroller data and information monitoring to collect the data which are necessary for the controlling. The collected data were used to calculate the fertilizer ratio, plant growth area and fertilize time. Then real-time showed the plant environment conditions such as temperature, humidity, lux level and barometric pressure. Moreover, analytically showed how the plant growth were shown according to the fertilizer and showed all the recoded fertilized data and plant environment condition. Following Fig. 4 shows the operation of mobile application.

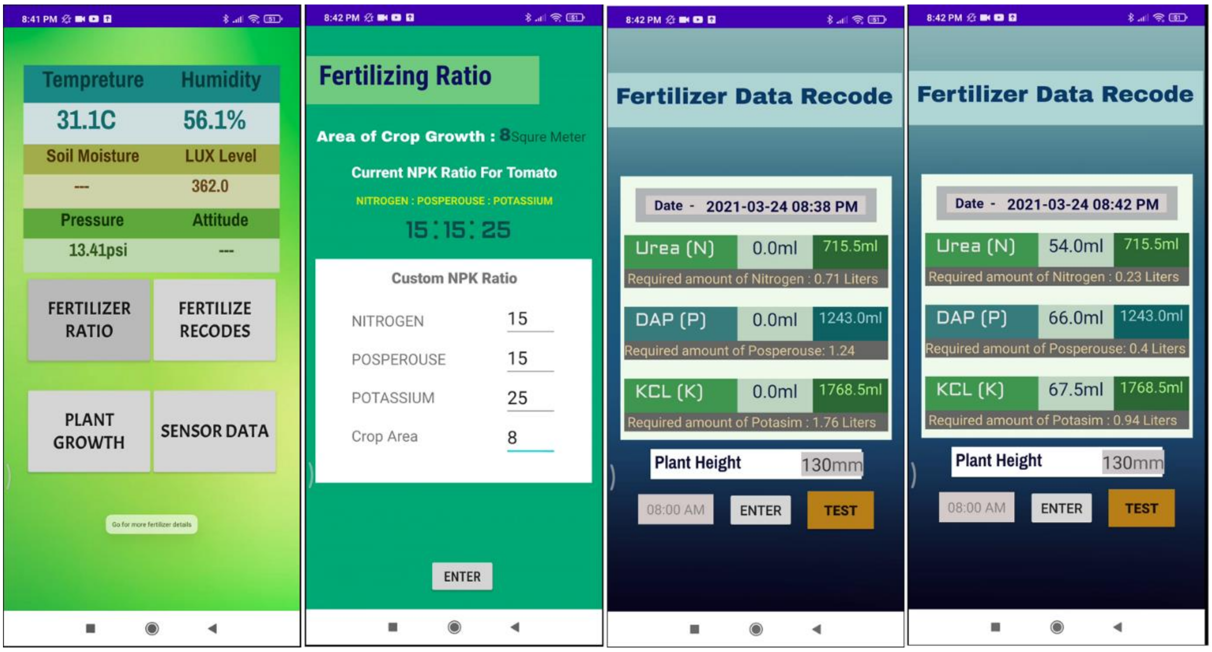

Figure 4: Operation of mobile application

Image Processing

Using PyCharm Community Edition 2020.2 developed the image processing system using OpenCV (Open Computer Vision). The light colour board was placed behind the plant which indicate known height and width before taking image. First using a selected colour rage mask, it filters the plant and remove background. Then identify the filtered image by drawing a contour and draw a box by surrounding the contours. Count the number of pixels of the known mark and by calculating surrounding box measure the plant height and width. Using those parameters area of crop and height can be calculated.

Algorithm development

140 mm height Tomato plant require water dissolve fertilizer amount = 40 ml/day

Amount of urea in 40ml dissolve fertilizer = 7.6 ml

Amount of DAP in 40ml dissolve fertilizer = 13.3 ml

Amount of KCL in 40ml dissolve fertilizer = 19.0 ml

$$\text{Urea amount} = \frac{Area\ of\ crop*4*Height\ of\ the\ plant*7.6}{140} --------(1)$$

$$\text{DAP amount} = \frac{Area\ of\ crop*4*Height\ of\ the\ plant*13.3}{140} --------(2)$$

$$\text{KCL amount} = \frac{Area\ of\ crop*4*Height\ of\ the\ plant*19.0}{140} --------(3)$$

Using the image processing data such as plant height and plant area, the microcontroller calculated the daily dissolved fertilizing amount base on the above algorithms. Set automated the fertilizing cycle by inputting the scheduling time. In every step gives feedback to the mobile application, to minimize the functioning errors.

Current system

This IoT-based fertilizing approaches help to estimate the spatial patterns of nutrients requirements with a higher accuracy and minimum labour requirements. However, to optimize the growth and yield of plants the above 3 equations has to modify. Now a days, because of cheaper smart phone available in market, farmers can easily have access to it. The android mobile application i.e android app helps to monitor and control the field from anywhere. The user interface for the application is designed in a way that enables both the monitoring and control of field from the device. The internet connection should be needed to monitor and control the field. On top of that farmers will be notified through smart phone in emergency condition arise at farms. Further using this method, water-soluble matters, such as soil amendments, and pesticides, can be applied through the irrigation system.

In Fig. 5 showed the comparison of height of two tomato plants for 3:1.1:4 NPK ratio in automated and manual systems. According to the plant height it could identify that manual process showed higher growth compared to automated system. The automated system is still in development and testing stage. Since the cause for the 24 mm reduction of growth on last day in automated system is erratic.

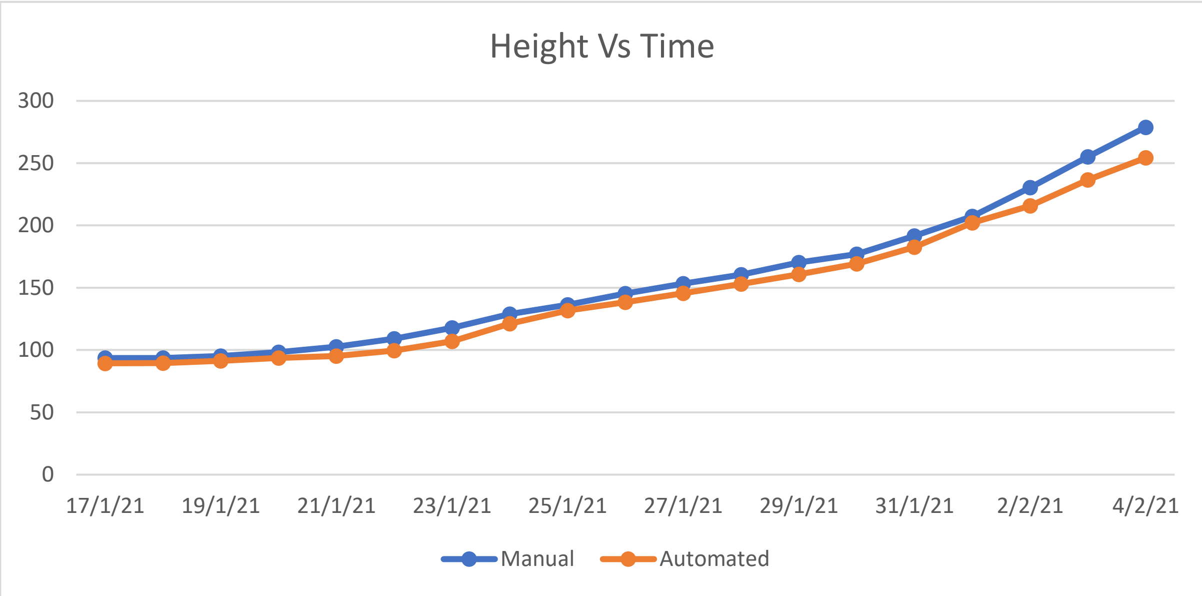

Figure 5: Plant height variation in manual and automated system

Conclusion

In this automated fertilizer system farmer has to add solid powder NPK fertilizer to the 10 litters of water tank. All other monitoring and controlling steps easily access with the user-friendly interface. Through this system the problems of excess water and fertilizers can be avoided and can obtain optimal yield. Further user can easily access and get a performance analysis of the plantation. Comparing conventional and IOT based method of farming, the efficiency of farming based on IOT is high. Collecting real time meaningful data is possible due to IOT based applications. Through the outcome of the project could get fully automated fertilizer system with based on the parameters according to the crop variety and plant height and width. That could be made to optimize the time and the cost.

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