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RS Mhatre
M.Tech, College of Agriculture Engineering and Technology, Dr. BSKKV, Dapoli, Maharashtra, India

ST Patil
Associate Professor, Department of Irrigation and Drainage Engineering, College of Agriculture Engineering and Technology, Dr. BSKKV, Dapoli, Maharashtra, India

US Kadam
Director Education, MCAER, Pune, Ex-Dean, FAE and Head, Irrigation and Drainage Engineering, College of Agricultural Engineering and Technology, Dr. BSKKV, Dapoli, Maharashtra, India

MB Patil
Assistant Professor, Department of Electrical and Other Energy Sources, College of Agricultural Engineering and Technology, Dr. BSKKV, Dapoli, Maharashtra, India

RV Dhopavkar
Deputy Director of Research, Dr. BSKKV, Dapoli, Maharashtra, India

Corresponding Author:
RS Mhatre
M.Tech, College of Agriculture Engineering and Technology, Dr. BSKKV, Dapoli, Maharashtra, India

Design and development of cost-effective automatic fertigation device

RS Mhatre, ST Patil, US Kadam, MB Patil and RV Dhopavkar

Abstract
This paper presents a study of automating the fertigation system by using locally available material which would be of low cost. The developed device was capable of applying pre-determined amount of fertilizers on the scheduled day. The ultra-sonic sensor was used to accomplish the task of applying fertigation on the basis of volume. The study showcased that the efficiency of the application of fertigation was 5-7% on an average. The device was tested for green amaranth crop under daily automatic fertigation and weekly manual fertigation. The yield produced by the crops under daily automatic fertigation was 9.31 t/ha and that of crops under weekly manual fertigation was 7.74 t/ha. The total cost incurred in development of the controller was Rs. 7556/-. The results promised that the developed device was cost-effective and farmer-friendly.

Keywords: Automation, fertigation, agriculture, irrigation, open field

1. Introduction
Today world's population has reached to 8 billion and India has now became the most populated country in the entire world. This has led to surge in the food demand. Food demand is expected to increase anywhere from 59% to 98% in 2050 [1]. To meet this demand the farmers often adopt excessive fertigation as a means to boost the yield. This results in depletion of quality and fertility of land. Also, this practice leads to reduced utilization of applied fertilizers. So to overcome this limitation the fertigation system is automated using modern equipment. This ensures adequate amount of fertilizers be delivered with minimum human interaction. Thus saves farmer time, money and drudgery. There are several automatic fertigation devices available in the market, but are either expensive or require skilled man power. Unavailability of spare parts in the local market and service adds to the problem. Even the maintenance of such systems is very costly. And more over many of these system are developed for a closed environment like poly-house, hydroponics etc.

Many automatic fertigation systems have been developed. Amongst it there are some that automated the fertigation based on the soil salinity by using Arduino Uno, pH sensor, GSM SIM900L etc. [2]. Some controlled the fertigation on the basis of volume using Arduino Uno as the main controller [3]. A system was developed to automate the fertigation by monitoring the nitrogen content of the soil using nitrogen sensor [4]. While some of the researchers used STM32F446RE microcontroller to control 10 nutrient solution using human interface [5]. An automatic hydroponic gardening system was developed to deliver the fertigation maintaining the EC and pH levels. The cost of the system was Rs. 45000/- [6].

In the market there are many costly fertigation system available. The XILEMA fertigation produces some controllers which have the capability to control about 5 to 27 nutrients solutions with operation mostly being time basis costing from Rs. 250000/- to Rs. 750000/- [7]. NUTRITEC Automatic Irrigation and fertigation device is capable of handling 10 nutrient solutions, operating on time/volume basis and have EC and pH control. It is compatible for Hydroponics only [8]. AGRIMIX series automatic fertilizer injector is available which allow mixing of 2 to 6 solutions and acid for pH control [9]. Another automatic fertigation device Aquafert Maxi having 9 fertilizers control along with acid/base for pH control which is suitable for hydroponics as well as open field is developed by Plastic-Puglia, Itlay [10]. Auto Aqua, an automatic fertigation system is capable of controlling 4 fertilizers and acid/base. It can operate on basis of time or volume and can communicate to user via mobile using GSM/Cloud/Web [11].

A common thing observed in the above available systems is that they are either costly or require skilled man-power for successful operation. Hence, in this paper we are presenting a

cost-effective automatic fertigation device that will be made of locally available parts. The operation of this device is farmer-friendly and is developed low-cost.

2. Materials and Methodology

The system uses Arduino Nano as the processing unit and GSM SIM800L as the communication unit. The components used in the study saved a lot of cost as compared to other components available in the market.

The device is equipped with ultrasonic sensor, pH sensor and current sensor. The following shows the block diagram of the developed device.

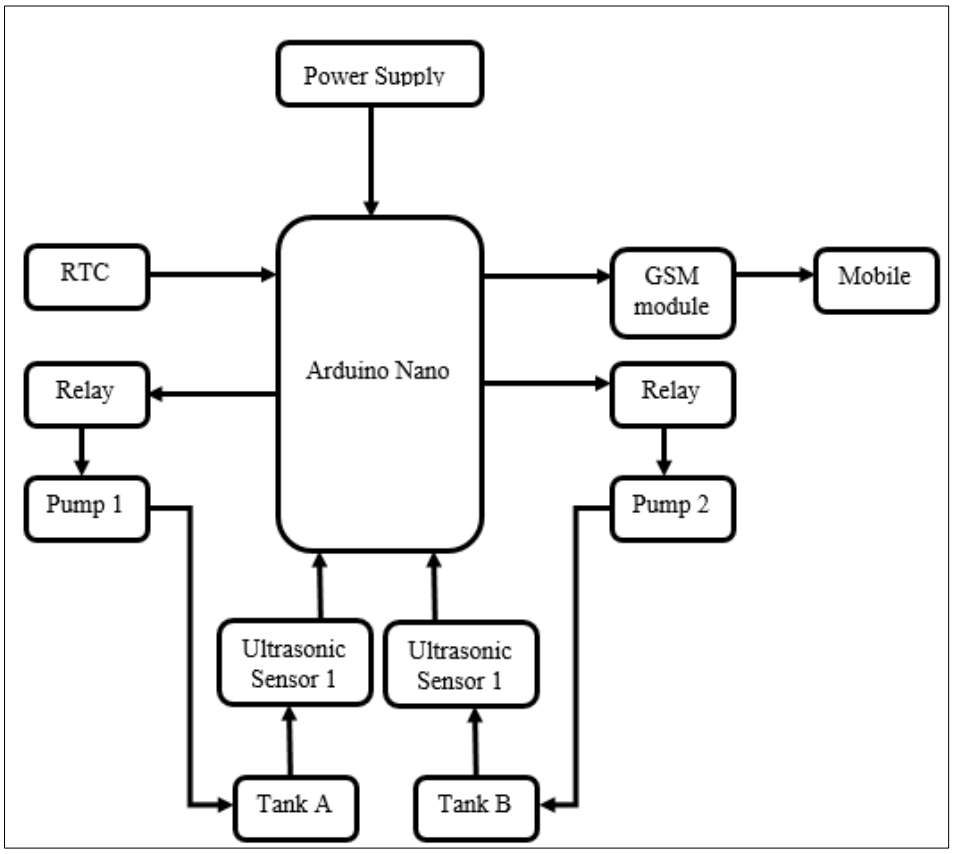

Fig 1: Block diagram of Automatic Fertigation Device

2.1 Components of the Device

Table 1: Components of the device

Sr. No.	Component	Specifications
1.	Arduino Nano	▪ 14 digital input/output pins ▪ 8 analog input/output pins ▪ Provide 3.3V, 5V and ground
2.	HC-SR04	▪ 5V DC supply ▪ range of 2-500 cm along with ± 0.3 cm accuracy ▪ frequency of 40k Hz which is not audible to human ears.
3.	SIM800L	▪ connect to mobile network to send and receive messages and receive call ▪ can connect to the internet using GPRS, TCP or IP.
4.	Tiny RTC I2C AT24C32 DS1307	▪ 8-pin device using I2C interface ▪ provides seconds, minutes, hours, day, date, month and year data
5.	AC S712 Current Sensor	▪ uses indirect sensing ▪ current flows through the onboard hall sensor circuit which detects the incoming current through its magnetic field generation
6.	Erma PE-03	▪ range of 0.00 ~ 14.00 pH with accuracy of ±0.01 pH
7.	Relay	▪ electronic switch that turn ON or OFF when a small external voltage is applied across its control terminals
8.	Non-return valve	▪ work on the pressure of water
9.	Pump	▪ controlled by the relay so as to irrigate the field as well as for fertigation purpose
10.	PCB	▪ connect the electronic components in a controlled manner one component to another ▪ connected by means of soldering

2.2 Working of the developed device

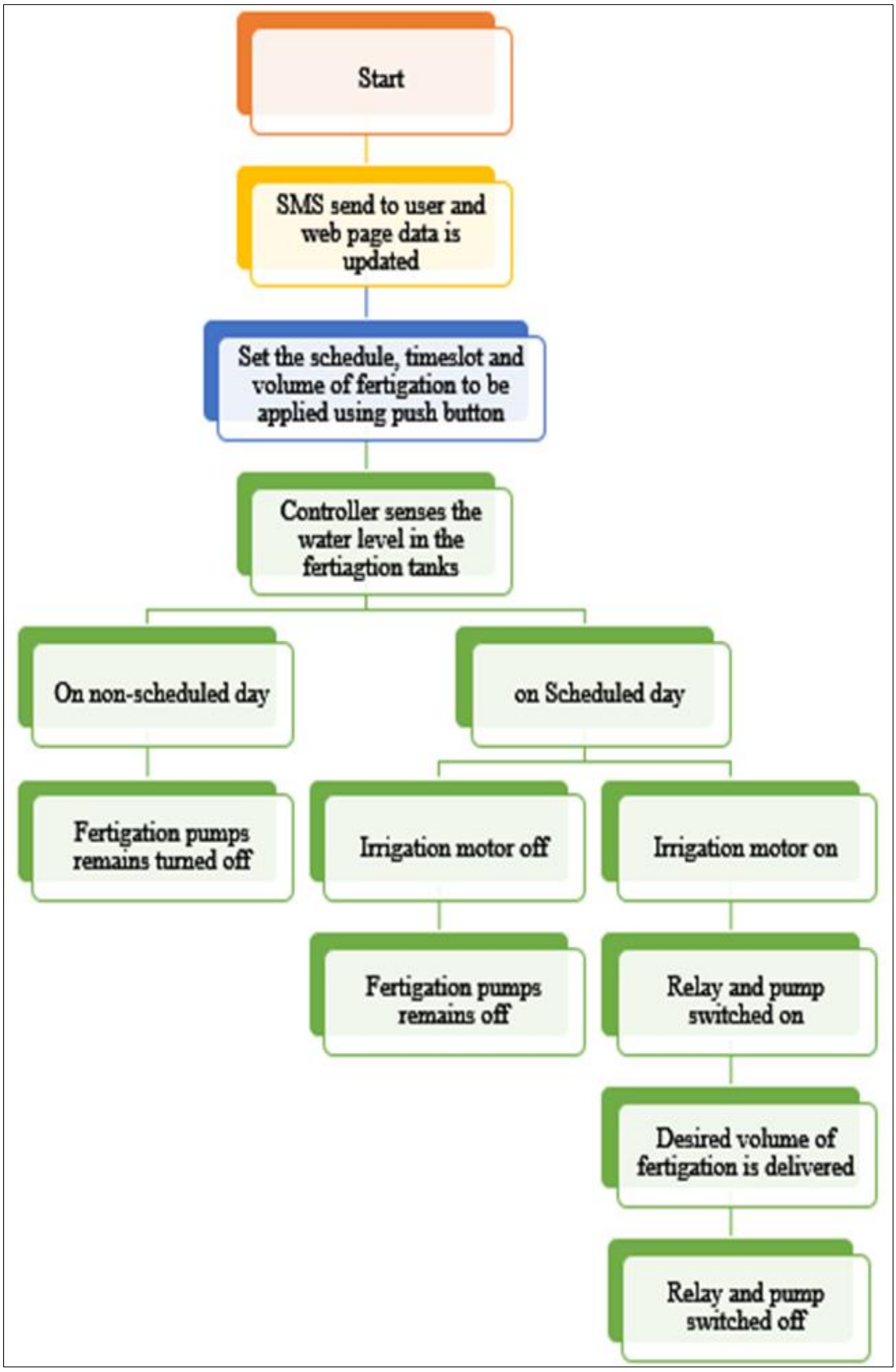

Fig 2: Working of the automatic fertigation device

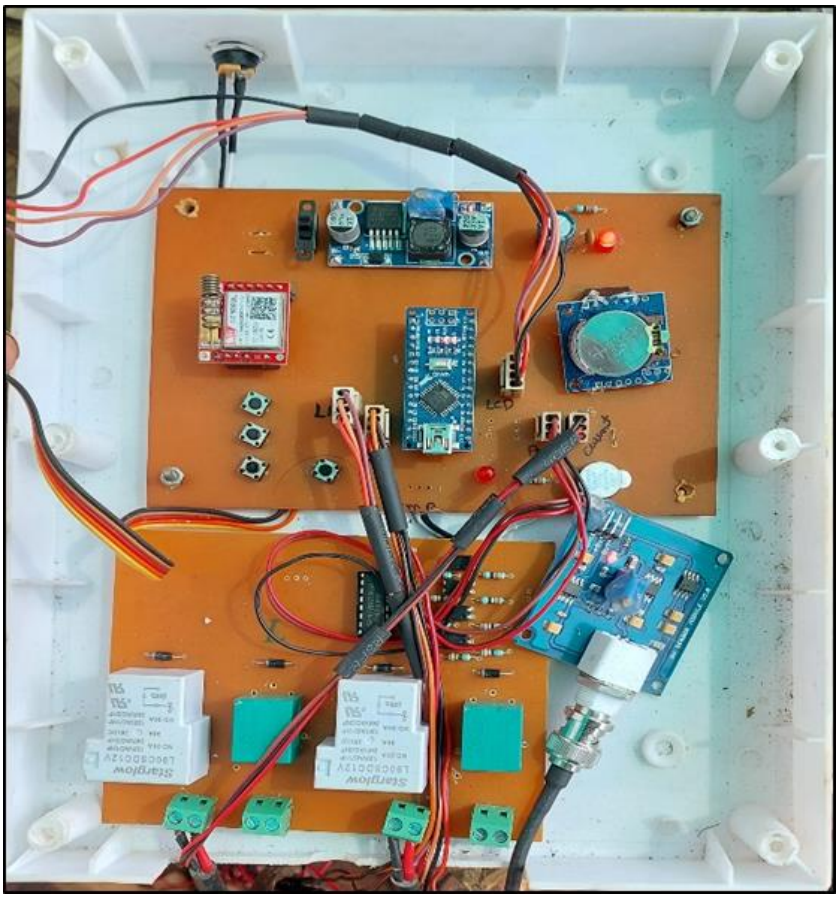

Fig 3: Inside view of the device

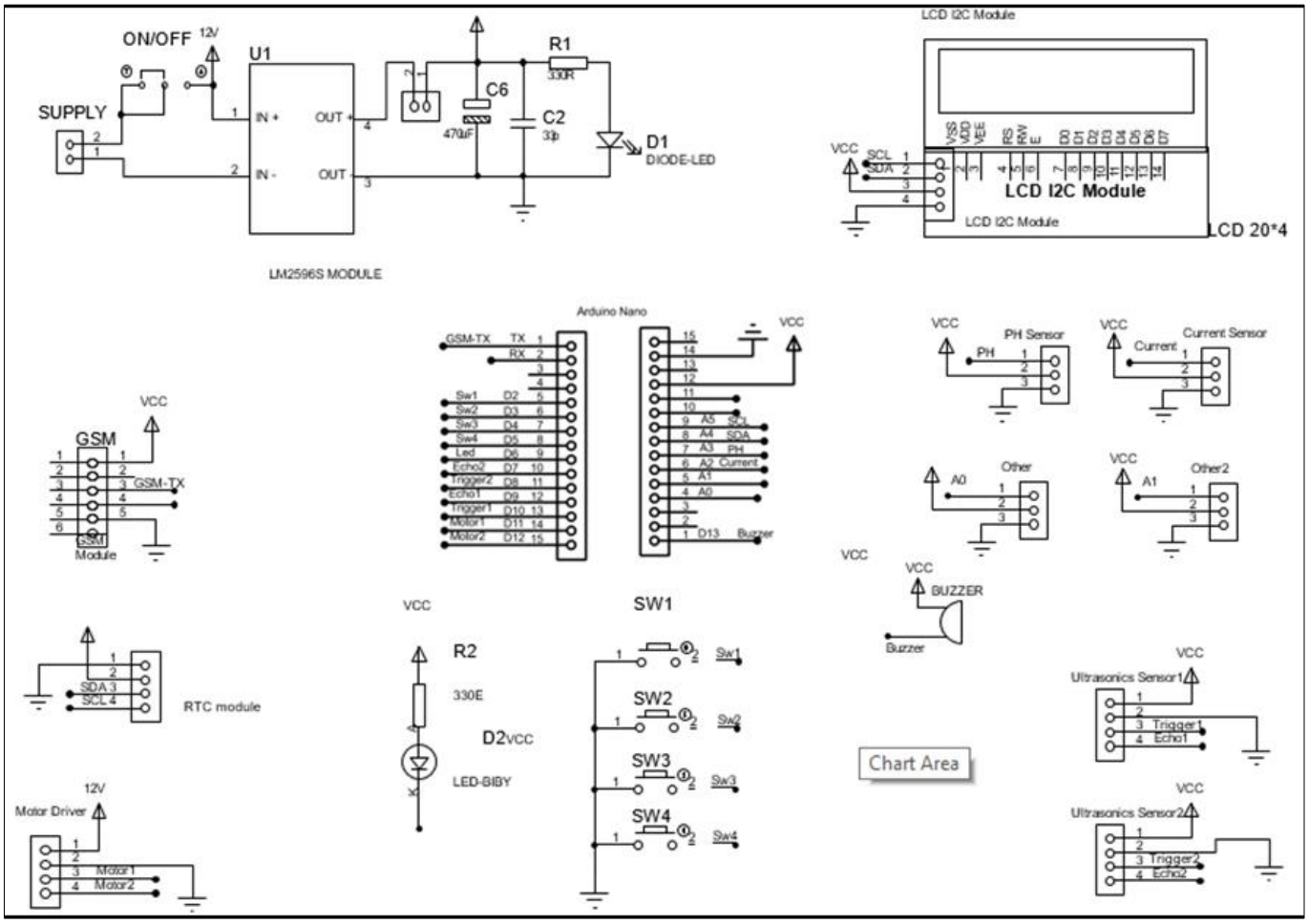

Fig 4: Circuit Diagram

3. Result and Discussion

The device was programmed to deliver the fertilizers on the basis of volume on the scheduled day. The field evaluation of the device was done by comparing the growth and yield of green amaranth crop under daily automatic fertigation and weekly manual fertigation. The volume of fertigation applied by the device was compared to actual volume to be applied. Also, the cost of the device was estimated and the economic analysis for the green amaranth crop was done.

3.1 Scheduling and Fertigation

The scheduling of the fertigation was performed using the push buttons on the device. The device was accessible through mobile or laptop using GSM over internet. The scheduling of the fertigation includes application of stock solution on volume basis. The volume was fixed from the area of the container and depth. The depth of stock solution to be injected was detected or governed by ultrasonic sensors. It is scheduled to inject 1.5 cm of stock solution every day after starting of irrigation.

3.2 Performance evaluation of the device

Percentage error in scheduled and actual volume of injection of fertilizers was observed to be 5-7% which was probably due to retention of stock solution in the pumps.

Then effect of daily fertigation was evaluated on green amaranth crop. The crop is grown and fertigated using developed device. The results are described below

3.2.1 Growth and yield of the crop

During the study various growth and yield parameters were recorded. It showed that the crops under daily automatic fertigation grew to a height of 57 cm with 31 leaves, whereas the crops under weekly manual fertigation grew to a height of 53 cm and had 22 leaves, on an average.

The crops under daily automatic fertigation produces a yield of 9.31 t/ha and those under weekly manual fertigation yield just 7.74 t/ha.

3.3 Cost Economics

The controller costed Rs. 7556/- for the development. The net profit earned from crops under daily automatic fertigation was Rs. 193968.16/- while those under weekly manual fertigation was Rs. 139960.82/-. The B:C was 2.09 and 1.83 respectively for automatic and manual fertigation.

4. Conclusion

The device delivered the fertilizers as per the requirement on the scheduled day efficiently. The device was farmer-friendly and developed low cost. The developed device is compatible for both manual and automation irrigation system. The automatic fertigation device was found to be superior in terms of yield and net income of the farmer over manual fertigation.

5. Future Scope

There is future scope to use another type of sensor which could deliver the amount of fertilizers to be applied more accurately. There could be modification to reduce/eliminate the use of fertigation pump to eliminate the excess cost. Also, there is scope of making the device operable using smartphone, without the use of push buttons.

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