Automated fertigation system for efficient utilization of fertilizer and water

Cyril Joseph[1] I. Thirunavuakkarasu[2] Aadesh Bhaskar[3] Anish Penujuru

[1]Assistant Professor, ICE, Dept. ManipalUniversity

[2]Associate Professor, ICE, Dept. ManipalUniversity

[3] UG Student, ICE, Dept. Manipal University

[4] UG Student, ICE, Dept. Manipal University

***Abstract*— Fertigation is the process of delivering plants nutrients along with water to produce a quality crop with higher yields. Employing an automated fertigation system can help farmers by significantly improving water and nutrient usage. The objective is to automatically maintain the moisture level in the soil and to mix different nutrients to obtain the required NPK ratio and give it to plants along with irrigation. This work is carried out in two parts. One is maintaining the optimum level of moisture in the soil. A soil moisture sensor which senses the moisture content in the soil is used. The sensor output is given to the controller, which decides if more water needs to be pumped or not. Then a control system for the fertilizer mixing and delivery part is designed. The user will give the input in terms of how much amount of N, P and K is needed in Kg. The user will also input the concentrations of NPK fertilizer solutions used. Taking all these parameters into account, the system will prepare a fertilizer mixture that contains the required amount of nutrients needed by the plant. It will then deliver the mixture along with irrigation water. The preparation of fertilizer mixture will be done with specific intervals of time which will be decided by the user. The system is connected to internet by using Wi-Fi and the user can enter the parameters in a mobile application which will transmit the data to the system over internet.**

Keywords*— *Farm automaton, Moisture control, Automated fertigation sytem.

I. INTRODUCTION

The method of providing essential nutrients to plants by delivering fertilizer mixture along with the irrigation water is called fertigation. It is a modern agricultural technique that is being practiced extensively in commercial agriculture and horticulture. Fertigation ensures uniform distribution of fertilizers to all the plants and better absorption of nutrients. This paper deals with designing an automated fertigation system that will carry out the process of nutrient delivery and water management in a controlled and precise manner. Implementing an automated fertigation system will save time and resources because nutrients and water are given when required and in exact amount needed thereby further increasing the efficiency and outcome of agriculture.

Inefficient management of nutrient inputs has put a large constraint on the environment and human's health. Indiscriminate use of nitrogen and phosphorus fertilizers has led to ground water pollution. So the farmers have to pay close attention to nutrient and water management and incorporate the concept of balanced plant nutrition and moisture content of soil into their farming techniques. Therefore an automated fertigation system that reduces the water and fertilizer wastage thereby avoiding overuse is needed to overcome the above mentioned shortcomings.

Inappropriate use of N, P and K leads to the pollution of the ground water levels. [1]. with the help of this system it is possible to keep a tab on the amount of N, P and K supplied and can control the ground water pollution. Continuous water monitoring will lead to effective management of water and a lot of water can be saved. Various techniques of mixing N,P and K is given in the literature [2]. The techniques which are used to mix the N, P and K contents and to inject them into the irrigation line are:

1. Batch Method
2. Continuous Method

Depending upon the constraints, the batch method is used in this paper. [3] Gives information about the water and N, P and K scheduling of a brinjal crop and also the statistics on effect of different treatments on productivity and water use of brinjal. It gives an insight into how fertigation frequency and water intervals affects the crop growth.

In [4] Different models of fertigator have been discussed. A plastic tank instead of metal tank is used in order to overcome the chemical reactions occurring between fertilizers and the metal tank. Different injection methods to inject fertilizers into the irrigation line is discussed. Different injectors used are Venturi pump, by-pass flow tank, pressure differential system or injection pump. Advantages of the injection pump system are, it has got high degree of control of dosage and timing of chemical application, centralized and sophisticated control, portability, no serious head loss in the system, labour-saving and relatively cheap in operation. With this method the solution is normally pumped from an open unpressurized tank, and the choice of type of pump used is dependent on the power source. The pump may be driven by water flow, by an internal combustion engine, by an electric motor or by a tractor power take-off.

In [5] A computer algorithm was developed to perform replenishment and reuse of the drain nutrient solution in close hydroponic systems on the basis of dispensing as many nutrients and water in it as were needed to maintain a target electrical conductivity in the irrigation solution. To achieve this in each watering application, dilution ratios of the concentrated fertilizer solutions are automatically adjusted through a computer program based on this

978-1-5090-6477-9/17/$31.00

algorithm, in relation to the volume and the electrical conductivity of the drain solution.

In [6] An automatic control system was developed for real time preparation and application of nutrient solution for soilless tomato production. The control strategy was based on transpiration estimates by the Penman–Monteith model and on leachate concentration by measurements of electrical conductivity. The performance of the fertigation system was evaluated during tomato cultivation in sand substrate under greenhouse conditions.

Another method is drip irrigation method which permits the application of nutrients directly at the site of a high concentration of active roots and as needed by the crop, for optimum plant performances all the fertilizers mixture and water must be balanced. Implementing a fertigation system, calculating the actual water and nutrient requirements of the crops, together with a uniform distribution of both water and nutrients, are very important parameters.

For proper nutrient application, good knowledge of crop nutrient requirements during the growing season is needed.

To estimate the nutrient supplying power of the soil, chemical analysis on representative soil samples is very important

For the selection of the proper type of fertilizers, solubility, purity, soil pH and salinity as well as the cost should be considered.

NPK fertilizers.

NPK should be present in right amount in the soil. Excessive presence of any of the nutrients will cause problems in plant growth. The amount of NPK in the soil varies with region and different plants require different amounts of NPK. The necessary amount of NPK can be determined by a soil test. The farmer has to enter the amount as input to the fertigation system. The fertilizers used in the system should have the NPK ratio as X-0-0 (fertilizer with only nitrogen compounds), 0-X-0 (fertilizer with only phosphorous compounds) and 0-0-X (Fertilizers with only potassium compounds). Fertilizers are chosen like this to make mixing easier for the system. The fertilizers used should be soluble in water.

Table 1: Water soluble fertilizers.

Major nutrient present	**Fertilizer name**	**NPK ratio**
Nitrogen	urea	46-0-0
Phosphorous	Triple superphosphate	0-46-0
Potassium	Muriate of potash	0-0-60

II. SYSTEM DESIGN

The Fig. 1gives an overview of the fertilizer flow and water flow between the tanks and connections between microcontrollers, pumps, sensor and Wi-Fi module.

There are 3 tanks to store the fertilizers of known concentrations and each one is rich in N, P or K. There is a mixing tank where the fertilizers are mixed and then given to crops along with the water. There are 5 pumps in which pump 1, 2 and 3 are to pump N, P and K respectively to the mixing tank, pump 4 to pump out the mixed fertilizer from the mixing tank and pump 5 to pump out water.

All the pumps are being controlled by the microcontroller and the soil moisture sensor's output (both analog and digital) is given as input to the microcontroller. The user will enter the parameters in the app which will then be transmitted over the internet and received by the microcontroller. A Wi-Fi module is used to connect microcontroller to internet. The microcontroller can also send soil moisture status to the user in the same way.

a. Soil moisture monitoring and control.

There are two ways of maintaining the moisture content in the soil. In one mode, the digital output from the soil moisture sensor is considered and in the other mode the water is pumped according to the time parameters entered by the user. Thus there are two modes among which one is closed loop involving the signal from sensor.

If it is in closed loop mode, the program will check if the analog output from the sensor is zero. If it is zero then it implies that the sensor is not working. Therefore the alternate watering method will be followed by the system. In case the sensor is working properly, the system will pump the water when the digital output from the sensor is high and will stop watering if the digital output goes low. The digital threshold can be adjusted using the potentiometer in the sensor module.

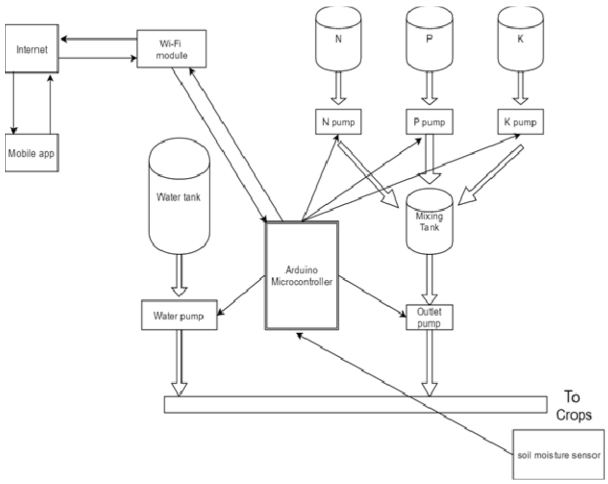

Fig. 1: Automated fertigation sytem.

In the alternate method, two inputs are required for the system. One is the time for which the pump should be activated and the other is the time interval between successive watering of crops. For example: the pump ON time can be given as 5 minutes and time interval as 12 hours. Then the crops will be watered for 5 minutes twice a day. This mode is best suited when the soil moisture sensor is not available or not functioning.

Looking out for any malfunction in the sensor module by checking the analog output will save the crops from damage. Since the decision to switch on the water pump will be taken by the system depending on the sensor output, a zero volt output from sensor can result in a situation where the crops will not be watered till the user realizes that the sensor is not working and changes the mode or installs a new sensor. Therefore this feature is very essential to ensure the safety of crops. The flowchart for the soil moisture monitoring and maintaining part is given below as Fig. 2.

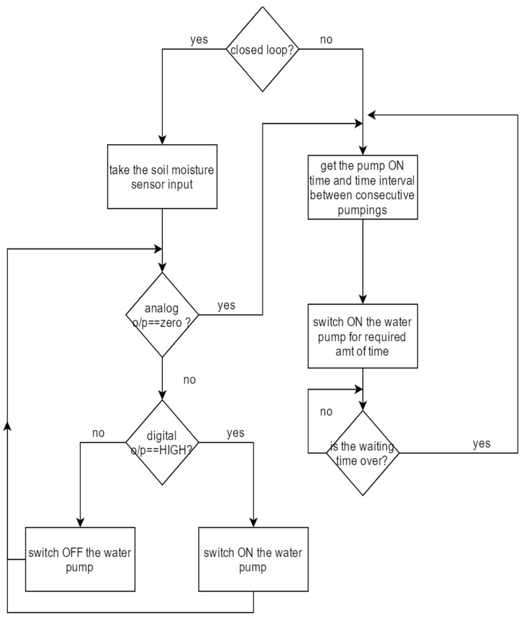

Fig. 2: Soil moisture monitoring and control.

This part is carried out as a subroutine. In the actual program, once the pump status is changed or when the program is in the waiting period it will carry out the fertilizer delivery part and again return to this subroutine.

b. Fertilizer mixing and delivery

Three water soluble fertilizers N, P and K are stored in the 3 tanks with high concentrations. The concentrations of the three fertilizer solutions and the amount of each constituents needed in the final mixture delivered to the plants are given as input to the system. By considering the flow rate of the pumps used, the system calculates the time it should pump solution from three tanks into the mixing tank.

Time (seconds) = (quantity needed (Kg)) ÷ (conc(Kg/Litre) ×

flow rate (Litre/second))

Then the three pumps are switched on for the calculated amount of time and during this time the outlet pump of the mixing tank will be switched off and the moisture content in the soil will be monitored and controlled without any interruption. Once the mixing has been done the system has to deliver it to the field. The system will check if the water pump is switched on and if it is on then it will calculate the amount of time required to pump the mixed fertilizer solution in the mixing tank. This time is calculated by considering the time for which N, P and K pumps were switched on and also by considering the time for which the mixing tank outlet pump has been operated after the last mixing cycle. Consider Tn, Tp and T_k as the times for which N, P and K pumps have been turned on. Also consider Tx as the time for which the outlet pump was activated after the last mixing cycle. Let Tnew be the required time to pump the remaining mixture, T_{prev} be the time required to pump out the remaining mixture before the last mixing cycle and k be the ratio of flow rate between the NPK pumps and the mixing tank outlet pump.

$$T_{new} = k(T_n + T_p + T_k) - T_x + T_{prev}$$

Thus the program calculates the time required to pump out the mixture. This time helps the system in deciding if the mixing tank is empty. In case it is empty, the outlet pump will not be activated. Therefore for the mixing tank outlet pump to be activated two conditions should be satisfied i.e. the water pump should be active and the mixing tank should contain the fertilizer mixture and not be empty.

Another input that will be given to the system is the time interval between two mixing processes. This interval can be in days. Considering this time, the system will wait before starting another mixture process. While waiting, the system will also keep monitoring and maintaining the moisture level in soil. In this interval, the system also makes sure that the fertilizer mixture remaining in the mixing tank is being delivered when the crops are being watered. Fig. 3. Show the flow chart for fertilizer mixing and delivery.

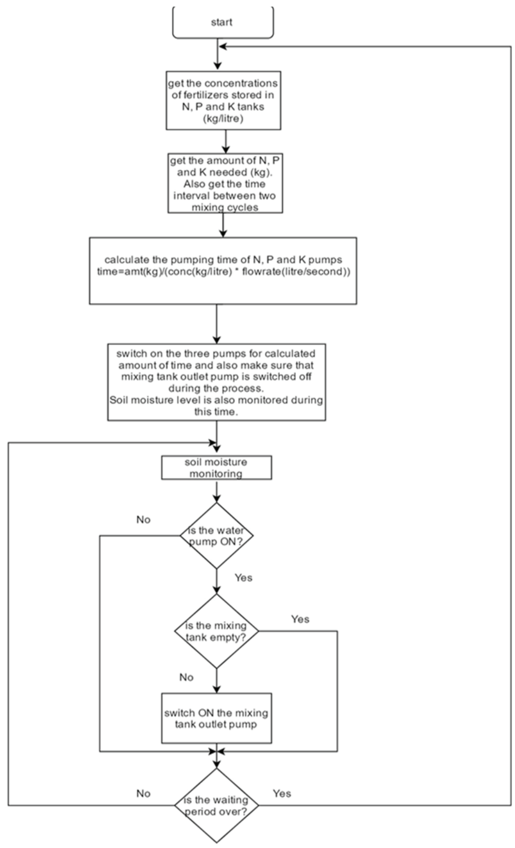

Fig. 3: Fertiliser mixing and delivery process

III. Prototype Components

a. relay module connections and specifications

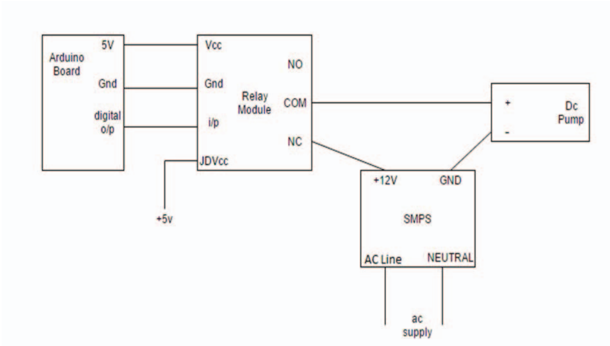

Fig. 4: Relay module connections

As shown in Fig. 4. the supply for relay module LED is given from 5V in the arduino board and the supply for electromagnetic driver circuit is given from external source to isolate the arduino from the driver circuit thereby protecting the arduino board from high currents. The digital o/p that will be used to operate the relay and control the pump is given to the relay input terminal. The electromagnet in the relay will be excited when the input is switched off because the LED is connected between 5V and the arduino output. Therefore when the arduino output is low the LED glows.

Since the pump should be switched on when the arduino output is high, the normally closed terminal is used in connecting the pump. The relay is connected in series with the power supply and the pump through its NC (normally closed) and COM(common) terminals. The surface viewer is a three dimensional curve that denotes mapping. The specifications of the relay module are:

- Working voltage = 5V
- Maximum Output parameters are:

AC 250V and 10A

DC 30V and 10A

b. Switching mode power supply (SMPS) specifications and connections.

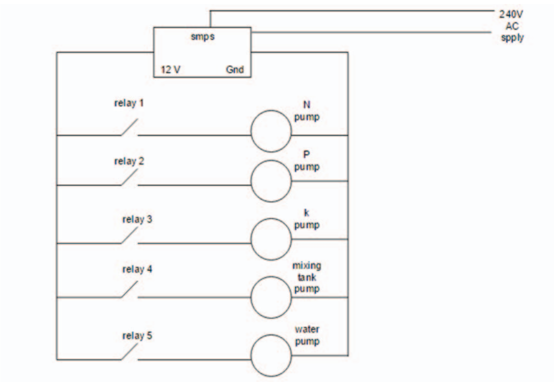

Fig. 5: SMPS connections to pumps.

Switching mode power supply (SMPS) is used as the power source for pumps in the prototype made. As shown in Fig. 5. The SMPS is connected to the AC power supply for input. It then steps it down, converts and regulates it to 12 V DC output. The 5 pumps are connected to the SMPS in parallel and relay switches are in series between SMPS and its corresponding pump.

Specifications of SMPS unit used in the prototype are:

Input voltage = 240 V AC

Output voltage = 12 V DC

Output current = 2

c. DC pump specifications.

A self-priming diaphragm pump is used to pump the liquids in the prototype. Its specifications are as follows:

- Rated Voltage: DC 9 V to 12V (1 amps)
- Load current: 0.7A (Max)
- Flow: 1.5 Litre/min
- Max Lift: 3m
- Max Suction: 2m
- Max Water Temp: 70 °C
- Pump Size: 90mm * 40mm * 35mm approximately
- Input/output tube diameter: outer 8.5mm, inner 6mm approximately
- Max Current: Up to 2 Amps while starting up.

d. Wi-Fi module (ESP8266) connections and configurations:

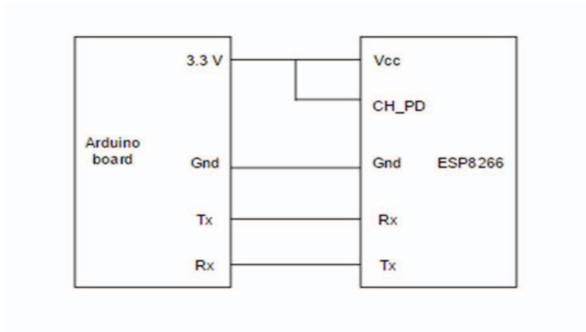

Fig. 6: ESP8266 connections.

As shown in Fig. 6. ESP8266 Wi-Fi module should be powered by a 3.3 V voltage source and can't tolerate 5 V supply. The 3.3 V in the arduino board is given to Vcc of the module. CH_PD is the chip enable pin. It should high for normal operation therefore it is also connected to 3.3 V from the ardiuno board. Two pins of arduino have been configured for serial communication with ESP8266. These are the Tx and Rx pins and are connected to Rx and Tx pins of ESP8266 respectively. This establishes serial communication between the Wi-Fi module and the arduino enabling them to transmit data between them.

The following steps have been followed to configure ESP8266:

1. Upload a bare minimum code to arduino and then connect the ESP8266 to ardiuno. The default serial communication pins of arduino should be used.
2. Open the serial monitor in Arduino IDE software. ESP8266 comes with a default baud rate of 115200.

Therefore change the baud rate settings of serial monitor to 115200 and also choose 'both NL&CR' in the serial monitor settings.

3. Type the command 'AT'. The ESP8266 will respond with 'OK' ensuring that the module is working properly.
4. The operating mode of ESP8266 should be both station mode and access point mode.
5. It can act as a client station that can access internet by connecting to router or it can also serve as an access point for other devices. This can be done by typing the AT command 'AT + CWMODE = 3' in the serial monitor.
6. Then the multiple connection mode should be enabled by typing the command 'AT + CIPMUX = 1' in the serial monitor.
7. The baud rate of ESP8266 should be changed from default value of 115200 to 19200. This is done by typing the command 'AT + UART_DEF = 19200, 8, 1, 0, 0'.
8. Restart the ESP8266 and check whether the necessary changes have been properly carried out by changing the serial monitor baud rate to 19200 and giving the following AT commands

   'AT' expected response is 'OK'.

   'AT + CWMODE?' expected response should be '3'.

   'AT + CIPMUX?' and the response should be '1'.
9. The ESP8266 can be connected to an access point by giving the SSID and password of the access point in the AT command 'AT+CWJAP = 'SSID', 'password' '. The arduino can be programmed in such a way that every time the arduino is started, it will make the ESP8266 connect to the access point with a given SSID and password. Hence there is no need to use a computer and serial monitor of arduino IDE software to make the ESP8266 connect to an access point. The access point's SSID and password should be specified in the code uploaded to arduino.
10. The baud rate for communicating with ESP8266 should also be specified in the code. The Tx and Rx pins for establishing serial communication with ESP266 should also be define in the arduino program.

As shown in Fig. 7. The soil moisture sensor probe has two terminals (+ve and – ve) terminals that are given to the signal conditioning circuit. The 5 V supply for the sensor is given from arduino. The analog output of the sensor module ranging from 0 to 5v is given to the analog I/O terminal of arduino.

e. *Interfacing Soil moisture sensor module with Arduino and characterization:*

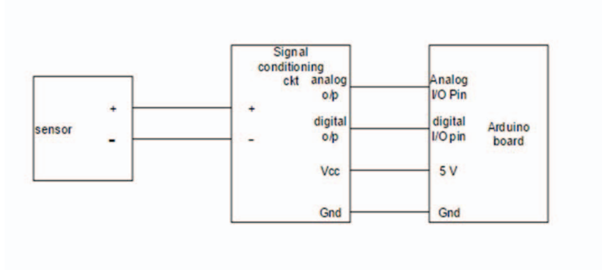

Fig. 7: Soil moisture sensor connections.

The digital output is given to digital I/O terminal of arduino. The threshold for digital sensor output can be adjusted by the potentiometer in the sensor module.

The specifications of soil moisture sensor are:

Operating voltage : 3.3V to 5V

LM393 comparator chip

Both analog and digital output

Characterization of the soil moisture sensor:

The soil moisture probe is placed in a fixed volume of soil and the moisture content is varied by adding measured volume of water to it. The analog outputs are recorded for different moisture contents and a graph has been plotted. The output analog voltage decreases as the moisture content in the soil increases. The sensor characteristics is shown in Fig. 8.

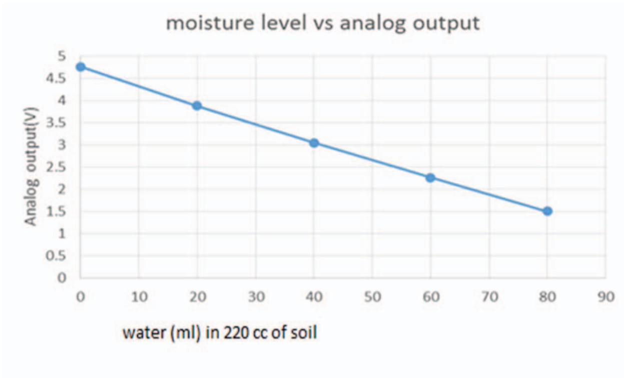

Fig. 8: Sensor characteristics.

f. *User interface.*

A mobile application called Blynk is used as the interface. Blynk is a mobile application platform to control arduino over internet. The user can input various parameters such as NPK required, concentrations of the fertilizers used, see the status of moisture content in the soil, give start/stop commands and select the mode of watering by using the Blynk application. Each project done using Blynk app will be given a unique identification number. The data entered by the user in the application will be transmitted to Blynk server. From the server, the data will be sent to the hardware that is connected to internet. The correct hardware is identified by using the identification number given. Blynk libraries are used in the program uploaded to arduino. These libraries enable the Arduino – ESP8266 combination to access the Blynk server and receive or send data to the server. The unique identification number should also be included in the code uploaded to arduino.

IV. PROTOTYPE

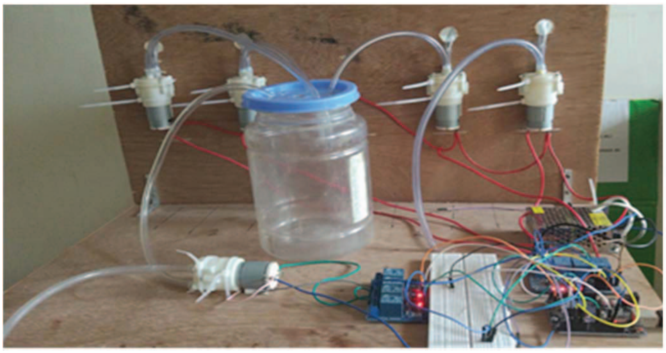

Fig. 9: Prototype

After the system has been designed a prototype as shown in Fig. 9, has been made to represent the functionalities of automated fertigation system. The prototype has been made with an Arduino as the controller, diaphragm pumps to pump the liquids, ESP8266 as the Wi-Fi module to connect the Arduino to internet and with Blynk mobile application platform to provide user interface.

1. The prototype has been tested and the functions successfully carried out by the prototype are:
2. It can prepare the NPK fertilizer mixture with the required quantity of NPK nutrients by pumping the different fertilizers for different amount of time into a mixing tank with a flow rate of approximately 1.5 litre/minute.
3. It can pump out the mixed fertilizer solution only when the water is also pumped.
4. It also keeps track of how much solution is remaining in mixing tank and activates the mixing tank outlet pump only if the mixing tank is not empty.
5. It can maintain the moisture level in the soil by taking the input from a soil moisture sensor.
6. It can also check if the soil moisture sensor is working and if the sensor is not working, the timed water supply method is followed.
7. It can connect to internet for taking input parameters and commands from user.

The fertigation system connects to the Blynk server with a ping time of 11ms. This can be seen in the serial monitor of Arduino IDE software when computer is connected to arduino through USB. The mobile application developed for fertigation system in shown in Fig. 10.

Fig. 10: User interface mobile application.

V. CONCLUSION

India's economy still mainly depends upon agriculture. Most of our population lives in the rural areas, where they are not exposed to technology and automation to a great extent. With the help of automation the agriculture output can be increased. The aim of this project was to mix the fertilizers in the required ratio for the crops and feed it through the irrigation lines and also maintains the soil moisture content at optimum levels, thereby helping the farmers to increase their yield with less budget as costs on workforce will be cut down with the help of this project. Hence this project aids the farmers to a great extent.

REFERENCES

[1] Baljit Kaur and Dilip Kumar, "Development of automated nutrients Composition control fertigation system"-, International journal of computer science, engineering and application, Vol.3, No.3, June 2013.

[2] Kapil Saroch, S.K. Sandal and N. Datt , "Studies on effect of irrigation interval and fertigation frequencies on crop growth, water use and productivity of summer brinjal"-. Himachal journal of agriculture reseaerch, Vol 42, No.1, June 2016.

[3] Papadopoulos, I. 1993. "Agricultural and environmental aspects of fertigation-chemigation in protected agriculture under Mediterranean and arid climates". p. 103- 133. In Proc. on "Environmentally Sound Water Management of Protected Agriculture". Bari Italy.

[4] I. Papadopoulos, C. Metochis and N. Seraphides., " Fertigation recipes for selected crops in the Mediterranean region"-, Agricultural Research Institute, Cyprus.

[5] D. Savvas, G. Manos, "Automated Composition Control of Nutrient Solution in Closed Soiless Culture Systems", Journal of Agriculture Engineering Research, Vol 73, No. 1. May 1999, pg. 29-33.

[6] Antonio Jose, Sergio Zolnier, Daniela de, "Development and evaluation of an automated sytem for fertigation control in soilless tomato production", Computers and Electronics in Agriculture, Vol 103, No. 1, April 2014, Pg. 17-25