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Solar Powered Automated Fertigation Control System for Terrace Farming Using Zigbee

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Abstract: Production of vegetables in terrace of the house has been experiencing accelerated growth,but watering and nutritioning plants is a serious task, scheduling the water requirement along the plant's life cycle is a challenging issue faced by us in this busy environment as the requirement varies with growth. So this system is developed to overcome the above difficulties. Automation in fertigation is done.Fertigation allows people to automatically deliver adequate nutrient quantity and concentration through drip irrigation to plant's active root area throughout the growing season. This system is developed using embedded system,which is powered using renewable solar power. This system has the advantage that it can be adapted to any climate and its low cost design with reduced manual operation.

Key words: Automation · Fertigation · Terrace Farming · Drip irrigation · Solar power · Sensors · Zigbee.

INTRODUCTION

Agriculture uses 85% of available fresh water resources worldwide and this percentage will continue to be dominant in water consumption because of population growth and increased food demand. There is an urgent need to create strategies based on science and technology for sustainable use of water, including technical, agronomic, managerial and institutional improvements.

There are many systems to achieve water savings in various crops, from basic ones to more technologically advanced ones. For instance, in one system plant water status was monitored and irrigation scheduled [1] based on canopy temperature distribution of the plant, which was acquired with thermal imaging. In addition, other systems have been developed to schedule irrigation of crops and optimize water use by means of a crop water stress index (CWSI).

The precise intelligent control of the irrigation andFertilization is the key technology of modern agriculture, which is widely used in the developed country. Unlike the traditional nutrient formula and fertilization management, the intelligent fertilizationuses [2] computer to make up nutrient automatically. China has brought in some intelligent control equipment for the irrigation and fertilization in recent years. However, it is mainly used in the minority of the greenhouses but not in public because of the high cost, planting climatic differences and the complicated manual.There are three typesof irrigation-surface irrigation,overhead irrigation and drip irrigation.

Motors used for irrigation uses either diesel generator or electricity, this is overcome by solar energy. Irrigation can also be done by the gravitational flow of water,but it cannot be controlled. Terrace farming which is also considered as agriculture has a trending growth,which can suffice the daily need of food for the family. In this two drip irrigation has the efficient water conservation and can be concentrated to the root.Hence it can be considered as the most water efficient method of irrigation, since evaporation and runoff are minimized thus this system [3] uses drip irrigation system which can be adapted for terrace farming which is done in pots.

Fertilizers injected through drip irrigation systems is a process called fertigation [4] are one type of micro irrigation system.Water soluble fertilizer can be also applied without any wastage by this drip irrigation system.Fertigation allows the delivery of water and nutrients to plants root area. Even this fertigation system has the constrain of excess concentration of fertilisers which is done by manual on/off water pump.

Automation in fertigation has been proposed by this system which allows automated [5] on/off of motor for correct nutrient-water mixing and flows it through drip irrigation system. Thus the water and fertilizers are spread

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throughout the plants which lead them for better growth. In environmental applications sensors are used to monitor a variety of environmental parameters. Similarly in agricultural field sensor networks are used to provide data for appropriate management such as monitoring of environmental conditions like weather, soil moisture content, soil temperature, soil fertility, mineral content, growth of crops. Thus the sensor networks plays a major role in the automated fertigation system.

This system is designed to monitor and control the fertigation using microcontroller, sensors and low cost zigbee module which is described in the following sections. This system is tested using sample pots ofTomato plants for our convenience and even can be used for chilly, bitter guard and other vegetable crops.

Problem Identification: Automation in the irrigation [6] system is existing in our country through which the water can be supplied to the field automatically when there is need of water in the field. But the supply of fertilizers are manually spread in landtill date.Also there is a difficulty in supplying correct water and fertilizers quantity and there is no way to measure the water content in the soil.

There is no method to determine the water and fertilizers quantity present in the tanks,user has no idea when the system stops, when the water and fertilizers gets completely drained in the tanks and alsothere is no way for system monitoring.

The major factor in the irrigation process is the time, the time at which the tanks should start supplying the water and fertilizers to the plants and the key in Fertigation is striking to correct balance for optimal plant life with optimal use of water. The existing system works under the electricity which at times the power may be off and the system might stop due to the electricity problem. It is a major problem when it comes to cultivation of crops.

Objective: Above problems was overcome with this system which uses moisture sensor to sense the water content in the soil and level sensor is used for accurate water-fertilizer mixing. Water is kept in a separate tank and fertilizers are kept in separate tank. Both are mixed in the mixing tank and sent through drip irrigation [7] pipes.

This system has user-friendly LCD interface that gives the water and fertilizers amount present in the respective tanks. So the user can fill the tank with fertilizers and when the water level reaches its minimum limit the water is filled in the tank by automatic turning on the underground water pump.

The use of solar power [8] for the system is another efficient way to reduce the usage of electricity. Solar panels were used which can power the system directly or energy can be stored in the batteries which can be utilized when needed.

To provide a necessary communication link between sensors and controller zigbee module is used in this system as they are low cost and does the job well. This system reduces time, conserves water, saves energy by using solar power, [9] avoids over fertilization. This system can be easily programmed to any climate change.

Proposed Method: This system is designed using the following hardware components namely:solar panel,charge controller,micro controller,water level sensors,solenoid valves, motor, tanks and zigbee module. The various blocks used in this system are given below,

The micro controller we use is the PIC micro controller which is low cost and more efficient. The controller is programmed in MP lab software using embedded c language,simulation isdone in Proteus software tool,then the hex file is created and dumped into the controller IC,finally the system is ready for hardware testing. The components and its features like power,current ratings are given in the table, the specification varies with the components used as the manufacturers have different specifications and those specifications are given below,

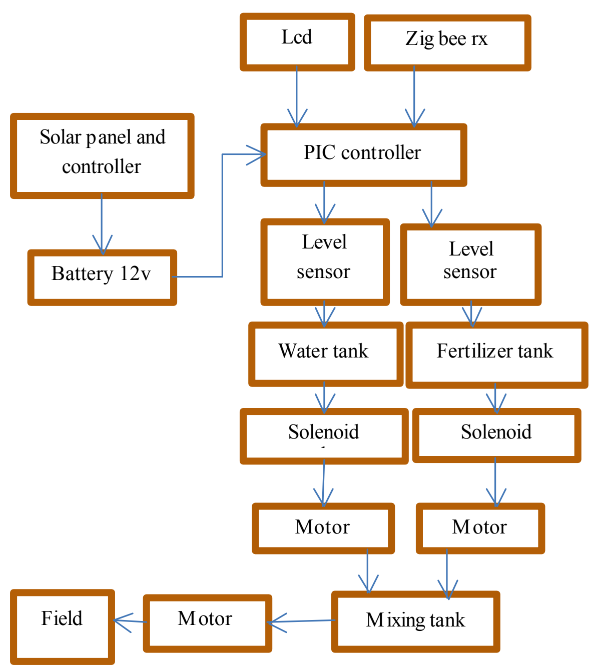

Fig. 1: Fertigation system block diagram

Component name	Features/Specification
Solar Panel	Output power:30W Output voltage:12 V
Charge Controller	Output current:6A Output voltage:12V
Tanks	30 L
Motors	Flow rate:160L/m Operating voltage:12V Power consumption:5W
Solenoid valves	3/4 Inch 12V
Battery	Output voltage:12v Output current:6AH
PIC controller	40 pin IC Operating speed: DC - 20MHz clock input 8 kBytes Flash Program Memory 368 Byte RAM Data Memory 256 Byte EEPROM Data Memory Two 8-bit timer/counter(TMR0, TMR2) One 16 bit timer/counter (TMR1) 10 Bit 2 Channel A/D converters
Capactive Water level sensor	Operating Voltage: 12 V Operating Temperature: -10 to 120°C Max Probe Length: 1.8 m
Moisture sensor	Operating voltage:3.3 V-5V
Zigbee module	Operating voltage:3.3V-5V Max data rate:250kbps Max range:120m 128-bit encryption

Fig. 2: Table showing specifications

Irrigation Schedule and Nutrient Volume Requirement: The system was developed using three cylindrical polyethylene tanks. The fertilizer and water was taken in the respective 30 litre tanks and another 30 litre tank was used for mixing.

The architecture by which the fertigation process is done is given below in Fig 3,

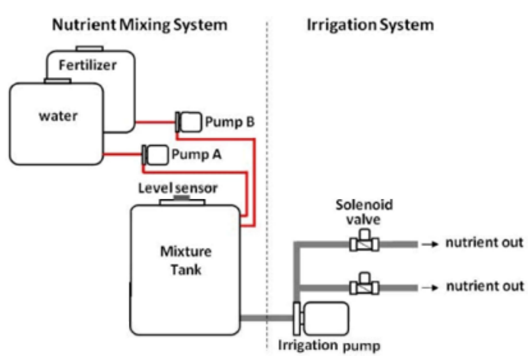

Fig. 3: Architecture of fertigation system

The pump A and pump B used are water pumps with a flowrate of 160 litre/hour rated at 12 V and irrigation pump (Fig. 5) also has a flow rate [10] of 160 litre/hour rated at 12 V.The irrigation pump can be changed according to the field size and overhead. This system is designed using flow rate of 160L as it was sufficient for terrace farming. A continuous capacitivewater level sensor (Fig 6) is used to monitor water and nutrients level in the tanks [11].

Fig. 4: Pump A, Pump B and Irrigation pump

Fig. 5: Continuous Water level Sensor and moisture sensor

Threeunits of 12 V solenoid valve (fig.7) used in this system to control water flow to the mixing tank and to control nutrient flow to the irrigation piping system the example of nutrient volume and schedule is shown in the Fig 7.

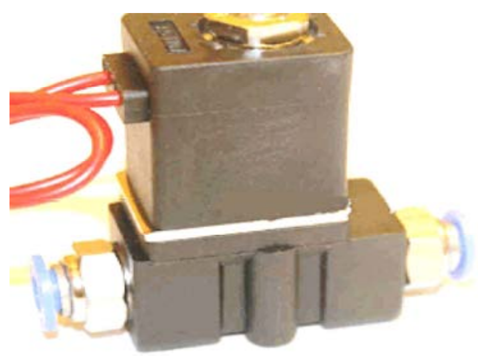

Fig. 6: Solenoid valve 12V

Age (Week)	Daily Nutrient Volume(ml)	Daily Irrigation Frequency	Time: Morning		Noon	Evening	
1	500	5*100 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
2	750	5*125 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
3	1000	5*200 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
4	1000	5*200 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
5	1500	5*300 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
6	1500	5*300 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
7	2000	5*400 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
8	2000	5*400 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
9	2000	5*400 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
10	2000	5*400 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m
11	2000	5*400 ml	8 a.m	10 a.m	12 p.m	2 p.m	5 p.m

Fig. 7: Table showing nutrient volume and schedule

Moisture sensor is used as a interrupt enabler that turns off the irrigation system when the moisture level is detected 100 percent. Zigbee module is used to provide wireless communication between moisture sensor and controller which is portable.

NUTRIENTS	N	P	K	Ca	Mg
UPTAKE,KG/Ha	85	19	190	43	11
RECOMMENDED,KG/Ha	87	35	122	61	14

Fig. 8: Table showing nutrient requirements for tomato

Fig. 9 shows the recommended nutrients quantity (N,P,K,Ca,Mg) required by tomato plant, this quantities are suggested by Hagin and Lowengart,1996. This requirement varies with the growth stage (days) of the tomato plant, this is shown in Fig. 6.

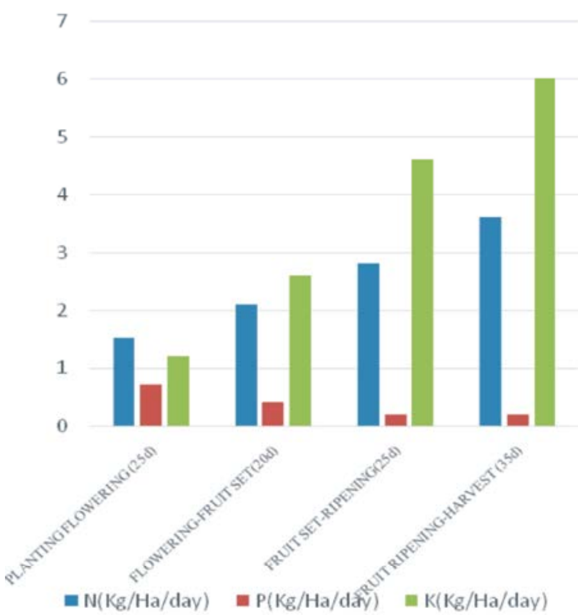

Fig. 9: Nutrient requirement along the growth stage of tomato

The total quantity of nutrients given as reference in the above fig is N: 450, P:65, K:710 kg/ha.

The uptake of nutrients by tomato is varied with time from the day of planting to the yield period with peak nutrients uptake. The growth stage varies from 150-180 days.

Proposed Algorithm: Soil moisture is sensed, if it is below 50% it turns ON the system only for irrigation and no fertilization is done.Fertilization is done only once a day based on the programmed data.

When the water and fertilizer level reaches the minimum value it will be displayed in the LCD display as critical low level with beep sound. So the user can identify it and the respective tanks can be filled with water and fertilizers.

The algorithm for the system is shown in flow chart below in Fig. 10.

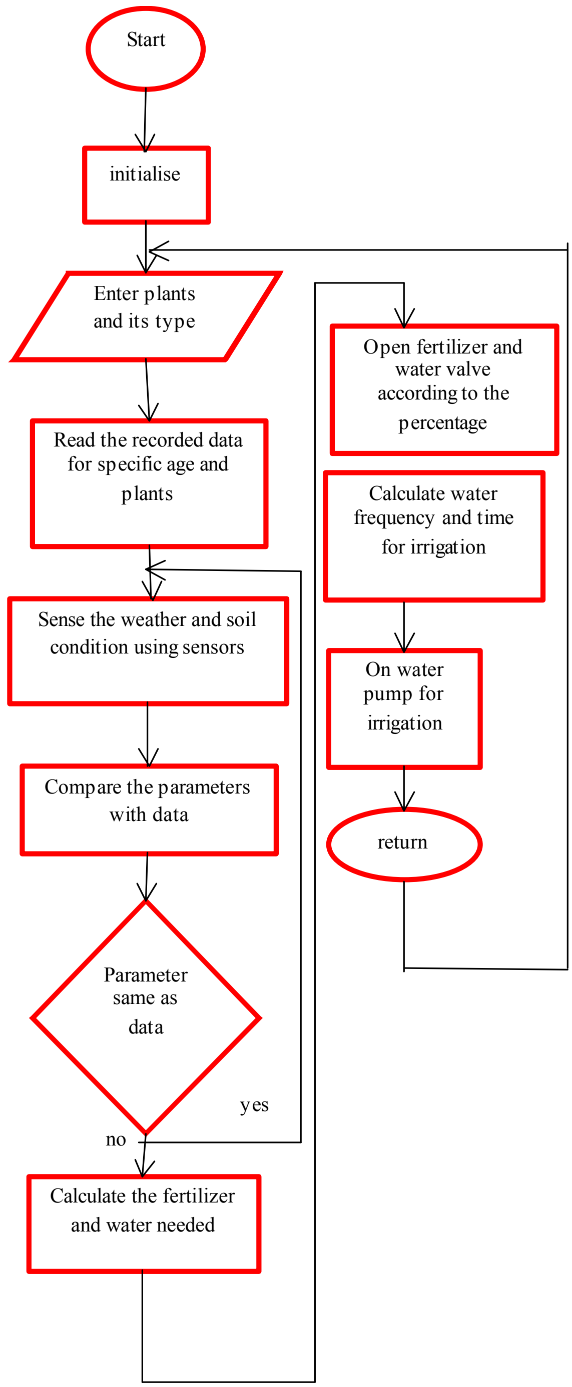

Fig. 10: Flowchart algorithm for fertigation system

Field Layout: The fieldlayout of terrace farming inthe system through which the irrigation pipes are connected to the plants are shown below in Fig. 11.

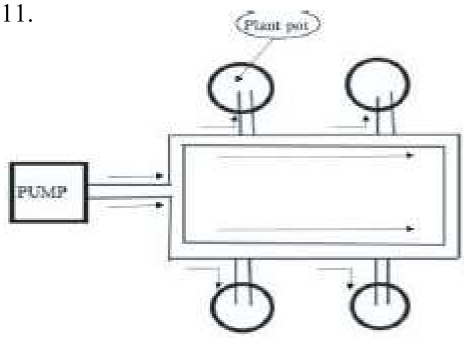

Fig. 11: Layout of piping connection

The irrigation is done by using drip irrigation tubes which has the advantage of flow rate control, as the terrace farming has different plants which needs different water requirement.

Some plants require different quantity of water and nutrient supply. Our system has various blocks in which the plants are separated according to the water and nutrient [12] supply needed for the plants.

The pipes are directly connected with the soil of the plants so that the water is directly injected to the root area of the plants which leads the growth of plants in an efficient manner.

RESULT

Above table and graphical comparison clearly shows that there is a significant difference in plant growth by manual fertilization and fertigation by drip system, there is a improved growth in plant length, girth, weight and total yield of tomato plant.

	Parameter				
Method	Plant height (cm)	No. of leaves/plant	Equilatoral diameter (cm)	Fruit yield (gm/plant)	Fruit yield (t/ha)
Manual Fertilization	45.4	6.26	5.9	18.78	31.38
Fertigation by drip system	47	6.4	6.33	21.43	35.8

Fig. 12: Table comparing results of tomato

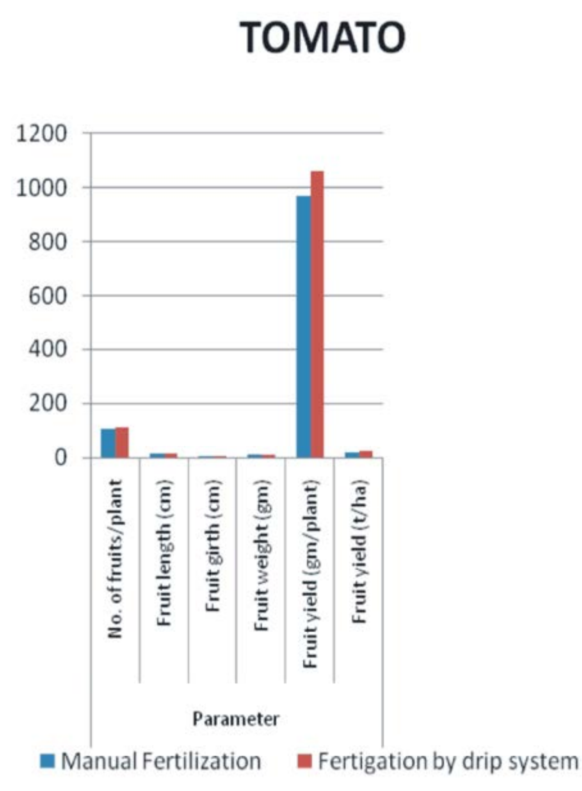

Fig. 13: graphical comparision of tomato growth

	Parameter					
Method	No. of fruits/plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight (gm)	Fruit yield (gm/plant)	Fruit yield (t/ha)
Manual Fertilization	106.58	14.68	4.35	9.088	968.53	20.86
Fertigation by drip system	112.1	15.52	4.9	9.468	1061.33	22.86

Fig.14: Table comparing results of brinjal

From table in Fig. 14 and graphical comparision in Fig. 15 there is a significant differnce between manual fertilization and fertigation by drip irrigation. Better growth in the devolpment of leaves, fruit yield in the brinjal plant is clearly visible from fertigation system.

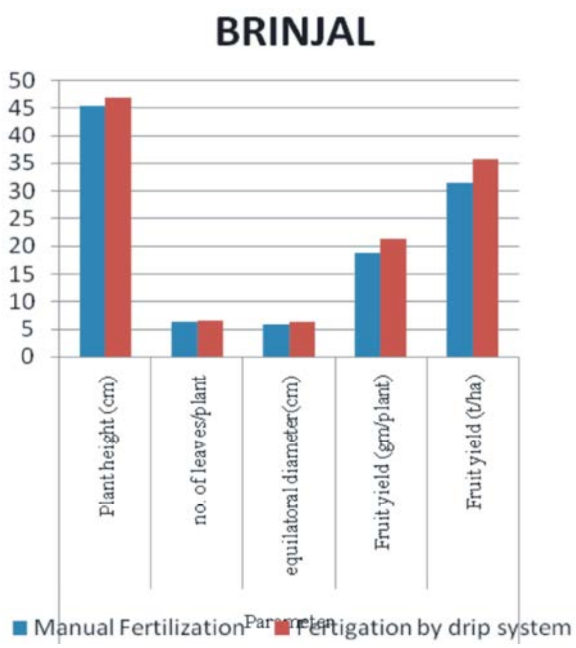

Fig. 15: Graphical comparison of brinjal growth

From this two reference it is clear that there is an increased plant growth and its total yield by this fertigation system when compared with manual fertilization system.

CONCLUSION

Evaluation of the developed system has established that system was able to maintain nutrients level and daily nutrient to each plants accordingly as it was programmed. Hopefully this system can be used as a prototype in our country to automatically control and monitor nutrients deliver system.

The automated fertigation system implemented was found to be feasible and cost effective for optimizing water resources for agricultural production. This system allows cultivation in places with water scarcity thereby improving sustainability.

The automated fertigation system developed proves that the use of water can be diminished for a given amount of fresh biomass production. The use of solar power in this fertigation system is pertinent and significantly important for organic crops and other agricultural products that are geographicallyisolated, where the investment in electric power supply would be expensive.

The fertigation system can be adjusted to a variety of specific crop needs and requires minimum maintenance. The modular configuration of the automated fertigation system allows it to be scaled up for larger greenhouses or evenopen fields.

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