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Logical Circuit for Fertigating *Cucumis sativus* L. in a Polyhouse

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ABSTRACT

Automated fertigation system is a highly advanced system for water and fertilizer administration in irrigated agriculture. It promises the application of water in right quantity along with right fertilizer at right time, thereby reducing fertilizer loss and cost of labour resulting in saving of money with the help of an automated mechanism. The present study was undertaken to develop a timer based automated fertigation system using an FIP and to evaluate the performance of the system. Field evaluation of the developed automated fertigation system was carried out by growing salad cucumber variety 'Saniya' in grow bags inside a poly house located at Agricultural Research Station, Anakkayam, Malappuram, Kerala. Comparative evaluation was carried out between biometric observations and yield parameters of the two sets of crop grown inside the polyhouse, one fertigated automatically with the developed system and the other one fertigated using venturi injector. The crop growth parameters like height of the plant, days to first flowering, days to 50 percentage flowering, days to initial budding, days to first harvest and leaf area index and yield parameters viz. size of the fruit, number of fruits harvested per plant and average yield were recorded during the study. Data collected was subjected to statistical scrutiny viz., ANOVA (Analysis of Variance) and Student-t test. Values of all these parameters were found to be better for the crops grown with automated fertigation system compared to venture injector. The developed system operates using solar panel generating a power of 250 W on an average along with a battery, which makes the system operations possible up to 4.4 days, during periods without sunshine. Hence it can be concluded that the developed automated fertigation system can ensure better yield for salad cucumber variety 'Saniya' grown inside the polyhouse.

Keywords: *Biometric observations, Cucumber, FIP, Irrigation, Solar, Timer, Yield parameters.*

INTRODUCTION

The adoption of fertigation by farmers largely depends on the benefits derived from it and fertigation is in its introductory stage in Kerala. Its success in terms of improved production depends upon how efficiently plants take up the nutrients. Proper scheduling and intervals are also needed to provide nutrients at a time when plants require them.

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The adoption of fertigation worldwide has shown favourable results in terms of fertilizer use efficiencies and quality of produce besides the environmental advantages. The choice of selecting various water soluble fertilizers are enormous and therefore, selection of chemicals should be based on the property of avoiding corrosion, softening of plastic pipe network, safety in field use and solubility in water.

Automated fertigation system is a highly advanced system of drip automation for water and fertilizer administration in agriculture. It promises the application of water in right quantity with right fertilizer at right time, without manual endeavours and labour. Thus, labour cost could be reduced with the help of an automated mechanism. Using an automated fertigation system can help producers to make correct choices that can essentially affect water and fertilizer utilization and can decrease fertilizer lose. Some automated systems are capable of integrating irrigation scheduling with nutrient dosing activities while other systems only manage the nutrient dosing equipment.

The present study was undertaken to develop an automated fertigation unit and to evaluate the performance of the system in the field. The developed system is powered completely by solar energy and its effectiveness is also tested to control the fertilizer mixing process and injection of nutrient solutions at various growth stages of the crop.

MATERIALS AND METHODS

The system was made by developing logical circuits between various components as shown in Figure 1. The major and auxiliary components used for the development of the system are listed below.

A. Major components

A.1 Fertilizer tank

Three fertilizer tanks are used to store concentrated fertilizer solutions individually. Each Fertilizer tank is having 40 l capacity and fertilizers are filled manually to these tanks. Water is filled for making solution through solenoid valves by a push button switch which is in turn controlled by level sensors. Solenoid valves of a particular tank will activate only when the tank is empty and it will deactivate if the tank is full and it will allow filling again only after the tank is empty.

A.2 Mixing tank

All the fertilizers which are pumped individually from each fertilizer tanks reach the mixing tank, from where it gets mixed up together thoroughly. The tank is having 10 l capacity. And this mixed solution is then injected into the drip line with the help of an injection pump which is controlled by timer and level sensors.

A.3 Fertilizer pumps

Three fertilizer pumps are used to pump fertilizer from each fertilizer tank to mixing tank. Each pump will work sequentially with the impulse from the timer. The pumps must be calibrated before setting the timer. The pumps works with 12 V DC instead of 24V AC from the timer, so it is connected through a 12V relay. If the tank is empty, the fertilizer pumps will be deactivated even if the timer sends signal to the pump.

A.4 Fertilizer Injection Pump

Fertilizer injector pump is used to inject fertilizer into the drip line. FIP with an injection rate of 10 l/h is used in this design. It works with 230 V.

A.5 Level controller

Level controllers are a set of relays controlled by level sensors / float switch; these controllers control the function of fertilizer pump, bubbler, water filling solenoid valves and fertilizer injector pump.

A.6 Timer

Timer is the major controlling device in this design and is used to control the working of fertilizer pumps, fertilizer injection pumps and the drip valve according to the preset timings. It works with 24 V AC, which can control any device that works with 24 V AC like solenoid valves. It has 2 input slots 1 common slot and 8 control slots.

1. Slot 1 or timer station T1 used to control fertilizer pump1 and bubbler 1
2. Slot 2 or timer station T2 used to control fertilizer pump 2 and bubbler 2

3. Slot 3 or timer station T3 used to control fertilizer pump 3 and bubbler 3
4. Slot 4 or timer station T4 used to control fertilizer injector pump
5. Slot 5 or timer station T5 used to control drip valve
6. Slot 6-8 or timer station T6-T8 are optional control slots for installing additional instruments like mist, side curtain.

B. Auxillary components

B.1 Transformers

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction

i. 12-0 V, 2A transformer

This transformer is used to supply power to the fertilizer pumps.

ii. 12-0-12 V, 3A transformer

Two transformers of this specification were used. One of them was used to supply power to the 8-station timer while the other supplied power to the relay boards and solenoid valves.

B.2 Relay board (4 – channel)

Four 4-Channel relay boards are used for controlling pumps, bubblers and level sensors inside the tanks and FIP. These 4-channel relay boards work in 12 V and senses voltage within a range of 3.3 V to 5 V.

B.3 Voltage regulator

Voltage regulator regulates the power supply from 12 V DC to 3.3 V DC, 5 V DC and 12 V DC.

B.4 Relay (12V 7A)

Four 12V 7A relays are used for controlling four 4-Channel relay boards that control pumps and bubbler. Other than this, eight relays of same specification are used for the working of fertilizer level indicators.

B.5 Push button switch

Push button switches are used for activating the solenoid valves for filling of fertilizer tanks with water. These are three in number.

B.6 Rectifiers

Rectifiers are used to convert AC to DC.

B.7 Solenoid valves

A solenoid valve is a valve which helps to operate a valve automatically. Solenoids operate use an electromagnetic solenoid coil to change the state of a valve from open to closed, or vice-versa. If the solenoid valve is in normally closed condition, when the coil is energized, the valve gets lifted open by the electromagnetic force produced by the coil. It requires pressurized water.

Solenoid valves of the following specifications were used:

i. 2” Solenoid valve

2” Solenoid valves are used to switch ON and OFF drip.

ii. 1” Solenoid valve

1” Solenoid valve is used to fill water in the fertilizer tanks.

B.8 Float switch

Float switches are used inside each tank to sense whether the tank is empty or full and send the signal to level indicator, fertilizer pump controlling relay, bubbler relay and push button switch. When the tank is full, the level indicator shows green signal, it cuts the power supply to the respective tank filling pushbutton switch and the power supply switch will be engaged only after tank is emptied. When the tank is empty, the power is supplied to the relay board connected to the red light in the level indicator.

B.9 Bubblers

Bubblers are used to agitate the fertilizer inside each tank with water to make thorough fertilizer solution before every pumping into the mixing tank and it is controlled by the timer through bubbler relay. The bubbler is working with 230 V AC instead of 24 V AC from the timer so it is also connected through a 12 V relay.

B.10 Level indicators

Level indicators are used to indicate the fertilizer level in each tank. It indicates whether the tank is empty or full. These are eight in number, 2 each for three fertilizer tanks and one mixing tank.

B.11 Solar panel

Solar panel with specification of 16 V 300 W was used in the design to supply an uninterrupted power supply to all the control units particularly the timer.

B.12 Battery

A 150 AH 12 V battery is used for storing the solar power.

B.13 Solar power generator

Solar power generator is used to convert the solar power to 230 V, 550 W.

B.14 Wooden casing

Other than fertilizer and mixing tanks, timer and level indicators all other components of the logical control circuit which control the working of the system is enclosed in a wooden casing of size 70x70x28 cm fitted with an exhaust fan to reduce the heat inside the casing

Calibration of fertilizer pumps

In laboratory, three fertilizer pumps were calibrated to find out how much amount of water it pumps out in a minute for which the pump was placed in a container with water and was allowed to pump to a height equal to the height of mixing tank for 1 minute and the amount of water coming out through pump outlet was collected and measured using a measuring cylinder,. This was done three times and the average value was noted. Calibration was done to decide how much time the pump should work so as to apply required amount of fertilizer for the plants. And this time is then set in the timer station T1, T2 and T3 for the working of fertilizer pumps. Process of calibration was done two times during the crop season as the pumping rate may vary with time due fertilizer deposition.

Fertilizer scheduling

The fertilizer recommendation for the crop for an area of 1 ha was obtained from package of practices (POP) published by KAU from which the fertilizer requirement for the required number of plants was calculated considering the recommended spacing. The total fertilizer required for the crop was provided in uneven splits in such a way that, fertigation was carried out once in three days and a break was provided in this schedule after four dozes of fertilizer application to avoid the salt injury to the crop due to fertigation. The total amount of water required for each fertilizer to achieve the desired concentration was also calculated. The total amount of fertilizer and water as per the calculations is initially filled in the tank (float switches are adjusted inside the tanks according to the amount of water initially present in each tank) and is pumped according to the schedule. The schedule was prepared for 90 days interval.

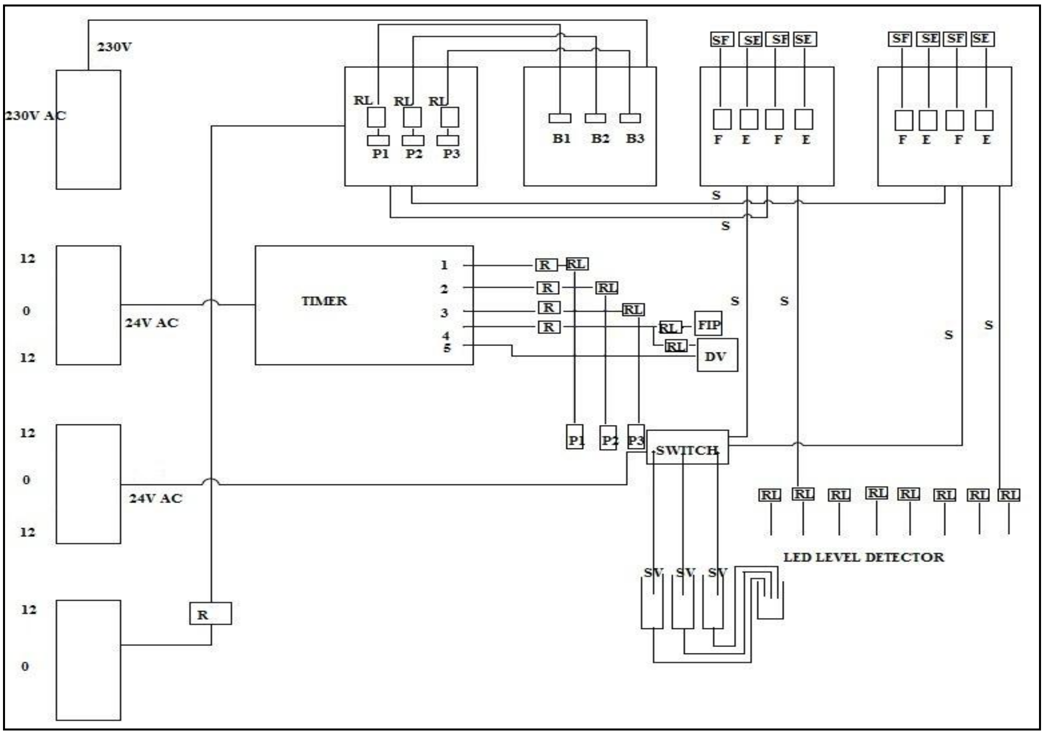

Figure. 1 Logical circuits in the system

RL - Relay;B1,B2,B3 - Bubbler 1,2and 3;F and E – Full and empty; SF and SE – Full and empty signal; R- Rectifiers; FIP- Fertilizer Injection pump;S- Signal; DV-Drip valve; P1,P2 and P3 – Fertilizer pumps

During of operations

As the amount of fertilizer added during different splits and the requirement of different fertilizer differed, the time of pumping of each pump for achieving the required amount of fertilizer was calculated considering the amount of fertilizer pumped in unit time by each pump. This time of pumping thus calculated is being set in the timer stations T1, T2 and T3. As the crop growth progresses the nutrient requirement of the crop differs so the timer has to be reset accordingly. Timings of the stations T4 which controlled the fertilizer injection pump and T5 which controlled the drip valve was set to work for duration of ten minutes throughout the crop season.

Working of the system

In this design, timer station T1 becomes ON according to the pre-set timings and if tank1 is not empty, fertilizer pump P1 and bubbler B1 get activated through two 12 V relays respectively. If the tank is empty T1 goes to OFF condition or else, P1 and B1 get activated. Sequentially when timer station T2 becomes ON according to the pre-set timings, it is checked whether the tank is empty. If it is empty T2 goes to OFF condition or else fertilizer pump P2 and bubbler B2 get activated through relays. Similarly, when T3 is ON according to pre-set timings, P3 and B3 get activated through relay when tank is not empty and if it is empty, it turns OFF. When timer station T4 becomes ON according to pre-set timings, level in the mixing tank is checked, and if it is empty, it turns OFF. But if the tank is not empty, fertilizer injection pump along with drip valve get activated through relays. When timer station T5 becomes ON according to pre-set timings, drip valve turns ON. The conditions whether the tanks are empty or not empty are decided by the level sensors / float switch (which will be indicated by level indicators).

RESULTS AND DISCUSSION

Comparative evaluation was carried out between biometric observations and yield parameters of the two sets of crop grown inside the polyhouse, one fertigated automatically with the developed system and the other one fertigated using venturi injector at various stages of plant growth. It is indicated as T_1 and T_2 respectively. The readings were taken once in a week from both the plots.

Biometric observations

i. Height of the plant

Drip fertigation can enable the application of soluble fertilizers and other chemicals along with irrigation water in the vicinity of the root zone (Patel & Rajput, 2011; Narda & Chawla, 2002). The application of water and nutrients in small doses at frequent intervals in the crop root zone ensures their optimum utilization and higher growth (Jayakumar et al., 2014). The results showed that at the final stages, plant height was significant between the individual treatments i.e., T_1 outperformed T_2. This indicated the superiority of the automated drip fertigation T_1 than the other. It registered the maximum plant height of 273.0 cm at the 4^{th} observation, followed by T_2 with 242.8 cm. The concentration and availability of various nutrients in the soil for plant uptake depends on the soil solution phase which is mainly determined by soil moisture availability.

ii. Flowering parameters

Earliest flowering was obtained in the treatment T_1 (21 days), whereas in the treatment T_2, it was late by 3 days. The optimum levels of nutrient status in the media aided early flowering and the increase in number of pistillate flowers might be due to the vigorous vine growth and more number of branches resulting in increased metabolic activity in cucumber (Bishop et al., 1969). Similar is the case in 50 per cent flowering, first fruit and first harvest for T_1 and which was followed by T_2.

iii. Leaf Area Index

The results indicate that at all the stages; the values of T_1 were numerically higher, when compared to T_2. This indicated that uniform application of fertilizer through drip fertigation could give maximum leaf growth for cucumber. The vegetative growth of the plant is directly related to the nitrogen applied (Klein et al., 1989). Moreover according to studies conducted by Baruah and Mohan (1991), potassium application is important in leaf growth and development. Nitrogen, phosphorus and potassium are three necessary nutrients which affect the plant growth and thus the uniform and frequent application of fertilizer through developed automated drip fertigation system might have result in the better leaf area index.

Yield parameters

i. Number of fruits per plant

The results showed that T_1 recorded the higher number of fruits per plant than T_2 statistically significant. It registered the maximum number of 29.12 fruits per plant and this was followed by T_2 with 10.50 fruits. The increase in number of fruits of T_1 might be due to the increased vegetative growth of the plants grown under the developed system leading to enhanced nutrient uptake and better water utilization which results in increased rate of photosynthesis and translocation of nutrients into the reproductive part or the produce compared to the conventional method of fertilizer application. The present findings are in accordance with the results of (Sharma et al., 2011). According to Ramnivas et al. (2012), interaction of irrigation and fertigation might have resulted to maximum fruit weight.

ii. Size of the fruit

The results showed that the automated drip fertigation system in polyhouse T_1 recorded the higher fruit weight than the other two treatments. It registered the maximum fruit weight of 246.4 g and this was followed by T_2 with 212.9 g.

T_1 registered the maximum fruit length of 21.35 cm and it was followed by T_2 with 20.70 cm. The increase in length of the fruit might be due to regular water and nutrient supply through drip fertigation, crop plants can complete all metabolic process at appropriate time. The adequate moisture and moisture supply also helps in keeping various enzyme systems active. Therefore, quality of the produce is better in drip fertigated crops as compared to control.

The results showed that the T_1 recorded the higher equatorial circumference than the other two treatments. It registered the maximum equatorial circumference of 16.25 cm and this was followed by T_2 with 12.75 cm. This is because of the increase in crop growth due to the interaction effect between irrigation and fertigation levels. 100 percentage applications of the scheduled nutrients to the root zone had also contributed to the fruit diameter (Ramnivas et al., 2012). These findings are in agreement with the report of Singh and Singh (2005) that the trickle irrigation with 100% recommended nitrogen fertilizer gave the maximum fruit circumference, fruit length and fruit weight in papaya.

iii. Total yield

The results showed that the automated drip fertigation system in polyhouse (T_1) recorded the higher fruit yield of 23.86 t ha^{-1} and this was statistically significant over T_2 with 7.71 t ha^{-1}. This might be due to the combined effect of cultivars, wider spacing, poly house cultivation and timely and uniformly availability of all the nutrients through the developed automated fertigation system. The present results are in agreement with the findings of Arora et al. (2006) in greenhouse grown tomato; Ban et al. (2006) in melons.

Automated drip fertigation of cucumber adequately sustain favorable vegetative and reproductive growth as compare to conventional method of fertilizer application.

Solar power performance

The solar panel could produce a voltage level of 16 V and 13.6 V during sunny and cloudy days respectively. Average power generated by solar panel was around 250 W. Energy consumption for the system on an average was only 33.72 W-h. The battery can hold up to 1800 watt, hence the system can operate up to 53 hours equivalent to 4.4 days (as the system works only during day time) without sunshine.

CONCLUSION

Thus it can be concluded that the developed system for automatic fertigation ensured better yield and was found economically feasible for cucumber variety ‘Saniya’ grown inside the polyhouse. Moreover, being fully operated with solar power, the system can be installed at remote and rural locations to achieve reductions in cost of production and produce better yield.

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