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Performance Evaluation of Developed Automated Drip Irrigation System

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ABSTRACT

The recent irrigation techniques introduce automated irrigation using sophisticated equipments to supply water and nutrients to plants as soon as they need it. Research in the developed countries is progressing towards real time irrigation, decision support system and expert systems. As the farm holdings are not large enough in India and also high cost of automation cannot be realized in India, in view of high cost of automated systems and to apply simple electronic circuit principles an attempt has been made to develop a low cost automatic irrigation based on soil moisture. The experimental site was divided into five sub plots with 3 × 20 m size to conduct experiments with brinjal and tomato crops. The yield response of brinjal and tomato crops with plant to plant spacing of 40 cm for different row to row spacings (50 cm row to row spacing and 30×70 cm paired row spacing) and irrigation application methods (flood irrigarion, time based automated drip irrigation, soil moisture sensor based automated drip irrigation) was evaluated. The uniformity coefficient, horizontal wetting pattern, depth of penetration of drip system was observed to be 98.2%, 34.5 cm, 40 cm respectively. Overall yield response was observed to be best in soil moisture sensor based irrigation with paired row spacing as 8.06 t/ha, 6.52 t/ha for brinjal and tomato crops respectively.

Key words : Automatic irrigation, Decision support system, Electronic circuit,Soil moisture sensor.

Water and nutrients are two important inputs to agriculture which are determining the whole gamut of agricultural productivity and production in India in addition to the soil and seeds. In the changing climate scenario, the water resource has become very scarce and also being unscientifically used in the farming fields. India, consuming almost 80% of its total water resources for agriculture sector, needs to reduce the consumption of water and nutrients to substantial levels using advanced scientific methods of irrigation like drip and sprinkler irrigation systems and real time sensor based scheduling with electronic gadgets or sensors to enhance water use efficiency (WUE) and fertilizer use efficiency in India.

Research in water management in the developed countries is progressing towards real time irrigation, decision support systems and expert systems. As the farm holdings are not large enough in India and also high cost of automation cannot be realized in India, low cost automatic irrigation is suitable to farmers, if developed and can be made as a technology, farmers can feel comfortable in view of the frequent power cuts and less power available in his farm. To apply simple electronic circuit principles in irrigation an attempt has been made to develop low cost automatic irrigation based on soil moisture.

The automation of the irrigation process is important for three main reasons: scarcity of water, timely irrigation and maximum crop profit. Automatic irrigation systems presently available are costly and are not adopted by most of the Indian farmers. Therefore, appropriate low cost technology has to be developed to facilitate high water use efficiency.

The main components of the auto irrigation system are a soil moisture sensor, control circuitry, gate valve, auto pumping unit, timer and power supply. The auto irrigation system developed monitors soil water stress at the root zone continuously and controls irrigation as per present values of soil water tension and duration of irrigation.

In the light of the above discussion, it is proposed to develop and evaluate the performance and popularization of such automation sensors for drip irrigation systems for various crops to demonstrate to the farming communities and other line department personnel.

MATERIALS AND METHODS

The experimental field with an area of 600 sq m was selected at field irrigation laboratory, Department of Soil and Water Engineering, College of Agricultural Engineering, Bapatla. Geographically the experimental site is located at latitude of 15^0 54| N and longitude of 80^0 30| E with an altitude of 4.5 m above mean sea level. The field was divided into five sub plots with 3 × 20 m size to conduct experiments under drip irrigation with brinjal and tomato crops. Each sub plot is allocated to grow crops with plant to plant spacing of 40 cm to conduct the following scheme of experiments.

Treatment 1 – crop at 50 cm row to row spacing with flood irrigation.

Treatment 2 – crop at 50 cm row to row spacing with automated drip irrigation system.

Treatment 3 – crop at 30×70 cm paired row spacing with automated drip irrigation system.

Treatment 4 – crop at 50 cm row to row spacing with soil moisture sensor based automated drip irrigation system.

Treatment 5 – crop at 30×70 cm paired row spacing with soil moisture sensor based automated drip irrigation system.

The crop duration was for 130 and 135 days for brinjal and tomato crops respectively and the water was applied as per the crop water requirement. The fertilizers and pesticides were applied to enhance the fertility status of soil and protect the crop from diseases and insects. At every 15 days interval during the crop growth, initial observations on plant height were made from each plot. Finally, yield response for the treatments, root depth & distribution and wetting pattern were recorded in all 5 treatments and analyzed the collected data.

The harvest of brinjal and tomato was carried out from Febraury 2nd to March 30th, 2014. The crop yields were harvested at an interval of 4-5 days. The weight of the produce was recorded in each picking for each plot and the total yield for each plot was calculated. Completely randomized block design (CRBD) was used for statistical

Table 1. Amount of water collected in catch cans at each dripper of 3 laterals.

Dripper	Amount of water (ml)	Amount of water (ml)	Amount of water (ml)
1.	360	355	350
2.	360	355	340
3.	355	350	350
4.	350	340	340
5.	355	350	345
6.	355	355	350
7.	350	345	340
8.	345	340	340
9.	345	340	330
Average	352.7	347.7	342.7

Table 2. Computation of uniformity coefficient.

Frequency (1)	Observation (2)	Application * Frequency (3)	Numerical deviation(4)	Frequency * Numerical deviation(1)* (4) X
2	360	720	12.3	24.6
6	355	2130	7.3	43.8
7	350	2450	2.3	16.1
4	345	1380	2.7	10.8
7	340	2380	7.7	53.9
1	330	330	17.7	17.7
	Total	9390		166.9

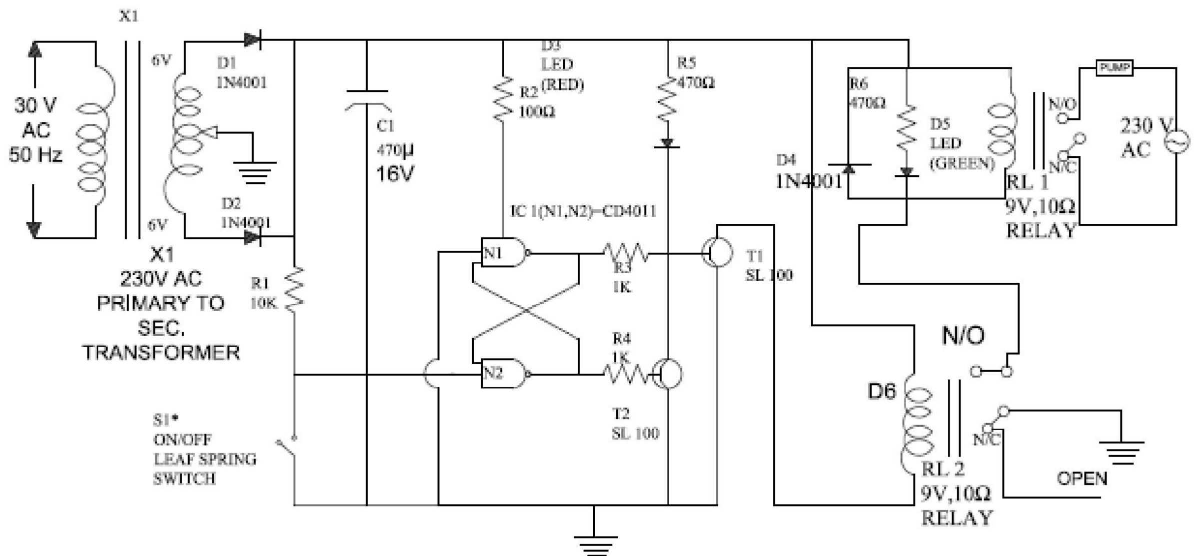


Fig. 1 Circuit diagram of soil moisture sensor

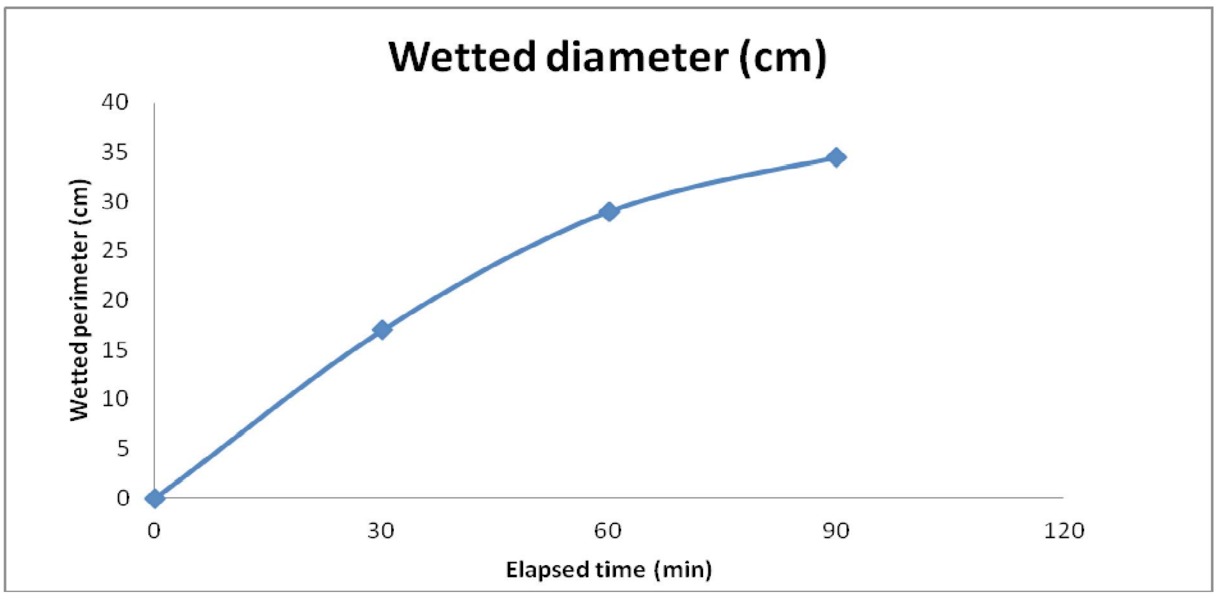
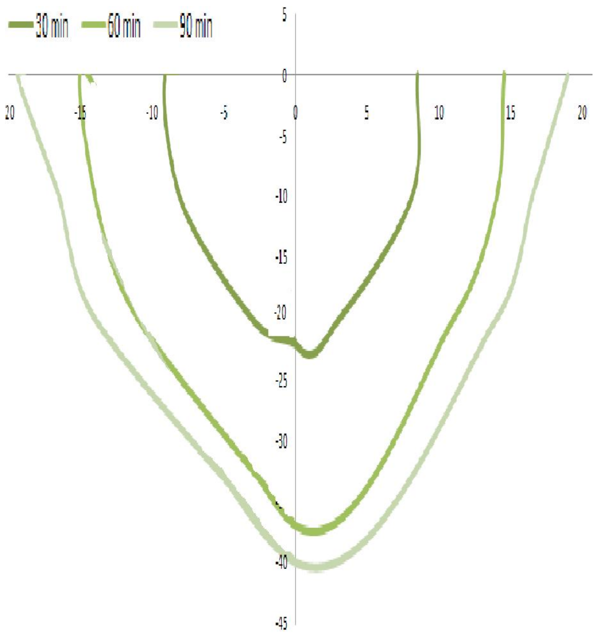


Fig.2. Moisture front advance in horizontal direction under point source of Application.

analysis of the yield data. For studying the effect of plant spacing and method of irrigation applied on root distribution, trench was made around the selected plants in each plot after the final harvest. After removing the root system from the soil, it was carefully arranged on a graph paper and root distribution was measured.

Wetting pattern in different treatments under automated drip irrigation was recorded on time basis for 90 minutes with an interval of 30 min. The x_1, x_2 and y as directions *i.e*, right side of the plant, left side of the plant and root zone of the plant respectively.

Uniformity coefficient of the drip irrigation system was tested by placing the collecting cans randomly under the drippers and operated for 10 min and collected water was measured with the measuring jar. To characterise the uniformity of



Y axis - Depth of penetration
X axis – horizontal spread

Fig.3. Moisture front advance in vertical direction under point source of Application.

distribution, commonly used. Christiansen's coefficient of uniformity is calculated with the following equation.

$$Cu = 100\left(1 - \frac{\Sigma X}{mn}\right) \quad \text{............ (1)}$$

Where,

Cu = coefficient of uniformity,

ΣX = absolute value of the deviation of the individual observation of discharge from the mean value m

n = total number of observations.

RESULTS AND DISCUSSION

Development of low cost soil moisture sensor

Low cost soil moisture sensor was working using the following circuit design. The sensor works mainly on the principle of electrical conductivity.

The circuit is prepared by using a transformer, diode, capacitor, integrated circuit, resistor, transistor, electromagnetic relay etc. The transformer acts as step down transformer reducing AC 230 V to AC 6V. Diode is a valve for current allowing it to go in only one direction. Capacitors are used to store energy by producing a charge imbalance. Integrated circuit CD4011 is the most commonly used complementary metal oxide Semiconductor (CMOS) chip. The working voltage range of the IC is 5V to 16V.Each output can deliver output current of about 10mA at 12V but this range can reduce as the power supply voltage reduces. An electromagnetic relay is used which allows a relatively small electrical voltage or current to control a larger voltage or current. The circuit diagram is drawn on a board and the circuit components are fixed on the board by soldering using solder iron and soldering lead. A plastic box is used for covering the circuit board. Two aluminum strings are used as probes and the probes are placed at effective root zone depth of crops at a distance of wetted diameter of dripper.

Wetting pattern

The surface wetted perimeter and depth of percolation of water were recorded in all the four treatments during the process of application of water. The observations were shown in Fig.2 & Fig.3. The wetted circle diameter increased gradually from 17 cm after application of water in the first 30 min to 34.5 cm at the end of irrigation i.e. after 90 minutes.

From the above Fig.3 it is evident that the depth of percolation increased gradually from 23 cm after 60min to 40 cm after 90 min.

Uniformity coefficient

The uniformity coefficient was measured by collecting discharge at each dripper by using catch cans.

The uniformity coefficient was calculated by using Equation 1

m = sum of all observations/ no of observations

= 9390/27

= 347.7

Coefficient of uniformity $Cu = 100\left(1 - \frac{\Sigma X}{mn}\right)$

=100(1 166.9/9390) = 98.2%

Yield attributes

The total yield of brinjal in 6 pickings from February 12th to 6th March with 3-4 days interval is presented in Table 4.5. The yield in the plot by Soil moisture sensor based automatic drip irrigation with

Table 3. Total yield of brinjal under different irrigation application methods.

Method of irrigation application	Yield/Plot of 60 sq. m area (kg)	Yield (kg/ha)	Yield (t/ha)
Flood irrigation	44.22	7373.30	7.37
Time based automatic Drip irrigation	44.00	7333.33	7.33
Time based automatic Drip irrigation with paired row spacing	47.76	7690.00	7.69
Soil moisture sensor based automatic drip irrigation	42.45	7075.00	7.07
Soil moisture sensor based automatic drip irrigation with paired row spacing	48.37	8061.66	8.06

Table 4. Total yield of tomato under different irrigation application methods.

Method of irrigation application	Yield/Plot of 60 sq. m area (kg)	Yield (kg/ha)	Yield (t/ha)
Flood irrigation	36.61	6102.16	6.10
Time based automatic Drip irrigation	36.20	6034.83	6.03
Time based automatic Drip irrigation with paired row spacing	38.10	6351.16	6.35
Soil moisture sensor based automatic drip irrigation	36.42	6070.16	6.07
Soil moisture sensor based automatic drip irrigation with paired row spacing	39.13	6522.33	6.52

Table 5. ANOVA test for yield response of brinjal crop.

Source	df	SS	MSS	F calculated	F tabulated
Treatments	4	6.600	1.650	3.566	3.06
Error	15	6.940	0.462		
Total	19	13.541			

Table 6. ANOVA test for yield response of Tomato crop.

Source	df	SS	MSS	F calculated	F tabulated
Treatments	4	1.612	0.403	33.962	3.06
Error	15	0.178	0.011		
Total	19	1.790			

paired row spacing was observed to be higher as 8.06 t/ha compared to the yield obtained in other methods of irrigation application. The total yield of tomato in 6 pickings from February 22nd to 16th March with 3-4 days interval is presented in Table 4.6. The yield in the plot by Soil moisture sensor based automatic drip irrigation with paired row spacing was observed to be higher as 6.52 t/ha compared to the yield obtained in other methods of irrigation application.

This higher yield can be attributed due to maintenance of field capacity level moisture in root zone depth. The root development was observed to be higher in sensor based irrigation.

The yield data was analysed using the standard procedure of completely randomized block design. An analysis of variance was carried out at 5% probability level. The yield response was observed for each treatment plots of brinjal and tomato. The observations were statistically analyzed for its variance and presented in Table 5. and Table 6. respectively for brinjal and tomato crops.

Since F calculated e” F tabulated the null hypothesis is rejected that means there is a significant difference in brinjal yield response in all treatments with coefficient of variance (CV %) of 6%.

Since F calculated e” F tabulated the null hypothesis is rejected that means there is a significant difference in tomato yield response in all treatments with coefficient of variance (CV %) of 1.16%.

The analysis of variance inferred that there is a significant difference in yield response at all treatment plots of brinjal and tomoto.

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