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Performance Evaluation of Developed Low Cost Microcontroller Based Automated Drip Irrigation System

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ABSTRACT

Efficient irrigation management is necessary in many irrigation methods as to allocate the more budget in agricultural water use. India being an agricultural country needs some innovation techniques in the agricultural field. This can be achieved through modern technologies which assist computing, communication and control within devices. 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. In view of above issues, an attempt has been made to develop a low cost microcontroller used in automated drip irrigation system based on soil moisture. The microcontroller based soil moisture sensor is designed using keil µvision 3 software for maximum of four sensors present in each field and controls the irrigation water supply in the field to be using solenoid valve. Soil moisture sensor was calibrated to switch off the motor when soil moisture reaches to field capacity and switch on the motor when soil moisture reaches to 70% of field capacity. The experimental site was divided into three plots with 12 m × 35 m size to conduct experiments with sweet corn (*zea mays*) crop. The yield response of sweet corn crop with plant to plant spacing of 20 cm for different row to row spacings (75 cm row to row spacing and 40 cm×110 cm paired row spacing) and irrigation application methods (flood irrigation, single row drip and paired row drip method) was evaluated. The crop water requirement, emission uniformity, cob characteristics and wetting pattern using surfer software was observed. Overall yield response was observed to be best in microcontroller based soil moisture sensor with single row drip spacing as 7.93 t ha^{-1} and water saving was observed as 36% when compared to flood Evapotranspiration method. Water use efficiency for sweet corn crop is highest in single row drip method as 23.88 kg/ha-mm followed by paired row drip and flood method as 19.51 and 14.29 kg/ha-mm respectively. Water use efficiency for sweet corn crop is highest in single row drip method as 23.88 kg/ha-mm followed by paired row drip and flood method as 19.51 and 14.29 kg/ha-mm respectively.

Key words : Automatic drip irrigation, Keil µ vision 3, Microcontroller, Soil moisture sensor.

In India, 60-70% economy depends on agriculture, where it is the time to increase the production for the growing population. Today a major challenge is to allocate the water budget in agricultural and industrial use. The irrigation sector, which currently consumes over 80 % of the available water in India, continues to be the major water consuming sector due to the intensification of agriculture. India has to increase use of land, conserve water and other natural resources to meet the demands with the increasing population. One of the main reasons for the low coverage of irrigation is the predominant use of flood (conventional) method of irrigation, where water use efficiency is very low. Suitable methods which are both eco and farmer friendly have to be developed.

A variety of automated drip irrigation methods have been proposed, but most of them have been found very expensive and complicated to use. In future, each and every farmer, whether poor or uneducated, might be wake up in need of such a system and therefore the proposed applications targeting an automatic irrigation system with minimum cost and time and through human computer interaction.

Automated irrigation is getting popular in India due to acute labour shortage condition and scarcity of water. Some remote rural areas in the country are totally depended on the rain. They don't have the irrigation equipment to irrigate their farm. Those who can afford such irrigation techniques are not having sufficient time to maintain all the fields. Automation in irrigation management refers to those innovations which partially or fully replace manual intervention from watering operations. Automatic drip irrigation system allows farmers to apply the right amount of water at the right time, regardless of the availability of labour in the field is not mandatory to turn valves on and off.

In the light of the above discussion, it is proposed to develop and evaluate the performance of microcontroller based low cost automated drip irrigation for various crops to an ultimate result of more crop per drop.

MATERIAL AND METHODS

Study area

The experimental field with an area of 1330 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 a latitude of 15^0 54.833^1 N and longitude of 80^0 29.834^1 E with an altitude of 6 m above the mean sea level. The field was divided into three plots with 12 m × 35 m size to conduct experiments with sweet corn crop.

PLOT I:

The first plot is paired row, the plant to plant spacing is 0.2 m, paired row spacing of 0.4m×1.1m. Between dripper to plant is 0.2 m on both sides of the lateral and lateral spacing is 1.5 m with recommended dose of fertilizer application manually.

PLOT II:

The second plot is single row, the plant to plant spacing is 0.2 m, and row to row spacing is 0.75 m with recommended dose of fertilizer application manually.

PLOT III:

The third plot is flood, the plant to plant spacing is 0.2 m, and row to row spacing is 0.75m with recommended dose of fertilizer application manually.

Methodology

The crop duration was 90 days (Jan 25th to Apr 24th) and the water was applied as per the crop water requirement for flood irrigation. Where as in drip method, water applied is based on the operation of automatic soil moisture sensor. When the soil is reached to field capacity the irrigation was automatically stopped and the system starts giving irrigation, when the soil moisture is reached to 70 % of field capacity. The fertilizers and pesticides were applied to enhance the fertility status of soil and protect the crop from diseases and insects. Finally, yield response for the treatments, plant height, root depth and cob characteristics were recorded in all three treatments.

The emitter coefficient of variation (C_v) is used as a measure of anticipated variations in discharge in a sample of new emitters. The value of C_v have been estimated from the measured discharges of a sample set of 32 emitters operated at a reference pressure head. The value of C_v can be computed as follows.

$$C_v = S/q \quad \ldots (1)$$

$$= \frac{\sqrt{q_1^2 + q_2^2 + \ldots q_n^2 + n(q)^2}}{q\sqrt{n-1}}$$

Where, Cv = emitter coefficient of manufacturing variation

S = standard deviation of the discharge rates of the sample.

q = average discharge rate of the emitters sampled.

$q_1, q_2 \ldots q_n$ = individual emitter discharge-rate values

n = number of emitters in sample.

The emission uniformity in point source and line source in drip irrigation systems is estimated by following equation.

$$EU = 100\left[1.0 - \frac{1.27\,C_V}{\sqrt{n}}\right]\frac{q_m}{q_a} \quad \text{----2}$$

EU = design emission uniformity, %

n = number of emitters per plant

C_v = the manufacturer's coefficient of variation

q_m = the minimum emitter discharge rate for a minimum pressure in the section (lph).

q_a = the average or design emitter discharge for the section (lph).

The harvest of sweet corn crop was carried out from April 20th to April 24th, 2015. The crop yields were harvested manually at an interval of 4-

Table 1. Average emitter discharge for sweet corn for four laterals.

S.No	Emitter discharge in 5 min			
	Lateral 1(ml)	Lateral 2 (ml)	Lateral 3(ml)	Lateral 4(ml)
1.	215	210	198	200
2.	215	200	200	198
3.	210	197	195	205
4.	215	210	205	198
5.	195	205	200	198
6.	205	200	202	202
7.	200	200	200	200
8.	195	198	205	198

Table 2. Actual water applied for sweet corn crop in different irrigation systems

S.No	Treatment	Water applied during sowing(mm)	Water applied during crop growth (mm)	Total water applied (mm)	% of water saving
1	Flood	50	470	520	-
2	Single row drip	50	282	332	36
3	Paired row drip	50	282	332	36

Table 3. Cob Characteristics for Different Irrigation Treatments.

Treatment	No. of kernel rows/cob	No. of kernels/cob	Cob diameter (cm)	Cob length (cm)	Individual fresh cob weight (g)
Flood irrigation	16	656.8	5.15	20.26	367.6
Single row drip	16.8	755.2	5.51	20.54	405.2
Paired row drip	14.8	558.8	3.824	18.8	226.6

Table 4. Yield of the sweet corn under the different irrigation systems.

S.No	Type of irrigation system	Plot size	Yield per plot (kg)	Yield (kg ha^{-1})	Yield (t ha^{-1})
1.	Flood	12m x35m	312	7429	7.43
2.	Single row drip	12m x35m	333	7929	7.93
3.	Paired row drip	12m x35m	272	6476	6.48

Table 5. Water use efficiency of the sweet corn under different levels of the irrigation.

S.No	Treatments	Yield (kg ha^{-1})	Water applied (mm)	Water use efficiency (kg/ha-mm)
1	Flood irrigation	7429	520	14.29
2	Single row drip	7929	332	23.88
3	Paired row drip	6476	332	19.51

5 days. The weight of the produce was recorded in each picking for each plot and the total yield for each plot was calculated.

Moisture distribution pattern in drip irrigation system was studied for different depths, after irrigation to get the variation in moisture distribution with variation in time. The soil moisture contour map was plotted using the computer software package “surfer” in windows version.

The water use efficiency is the ratio of total yield obtained to that of amount of water used. For calculating the water use efficiency, the yield obtained from each experimental site and the amount of water used for each treatment were recorded and calculated by using the following equation.

Water use efficiency = yield (kg ha.mm)kg ha^{-1}) / amount of water applied (mm) … (3)

RESULTS AND DISCUSSION

Emission uniformity of drip system

The emission uniformity was measured by collecting discharge at each dripper by using catch cans for 5 minutes time and presented in Table 1. Emission uniformity was found by using the Karmeli and Keller procedure and calculations were given below.

Standard deviation S = 5.80

Co-efficient of variation C_v = 0.028

Emission uniformity EU = 92.87 %.

Crop water requirement

The amount of water applied in flood irrigation system for sweet corn crop was based on CROPWAT data (470 mm) in addition to 50 mm water used at the time of sowing. Hence, totally 520 mm of water used in flood method. The amount of water applied measured regularly with the help of time-discharge relation and total water applied in different irrigation systems was presented in Table 3. The authenticity of automation unit was cross checked by collecting soil samples near the moisture sensors and found the moisture contents through gravimetric method for both the limits. The readings were found as the soil field capacity is 8.47 % and the sensor will off automatically at moisture content of 8.16 % and automatically on at moisture content of 5.8 %. It was observed that

Fig 1. Soil moisture distribution pattern at 30 min during irrigation

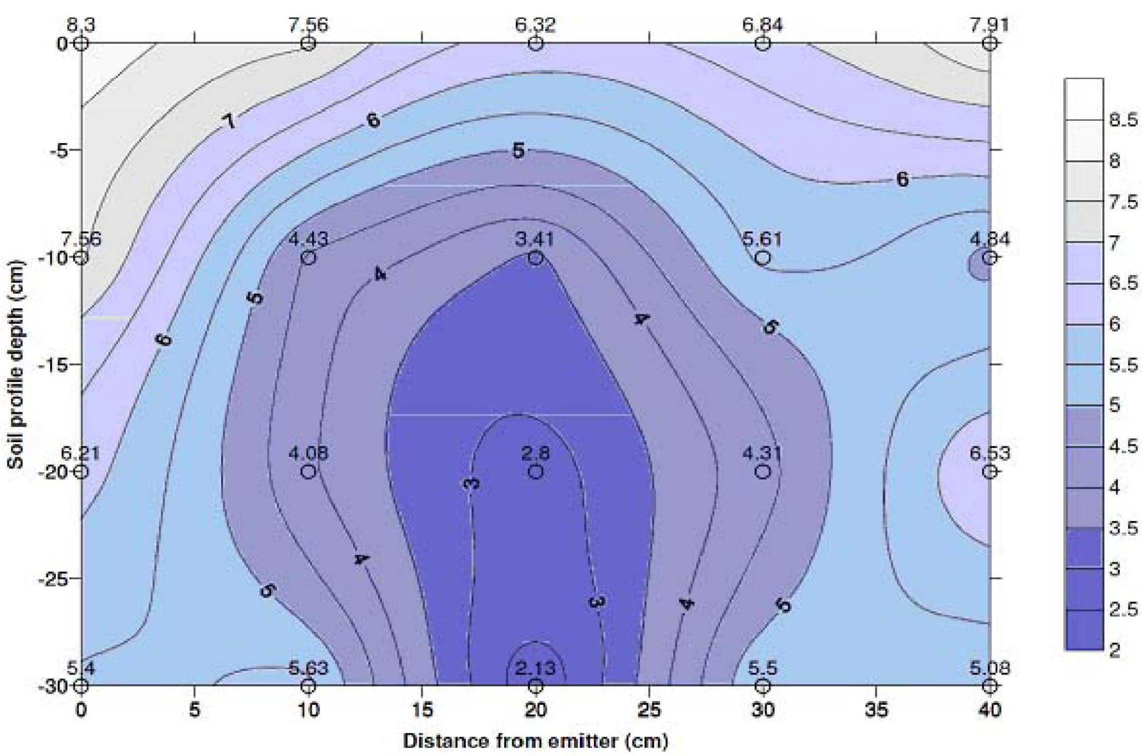
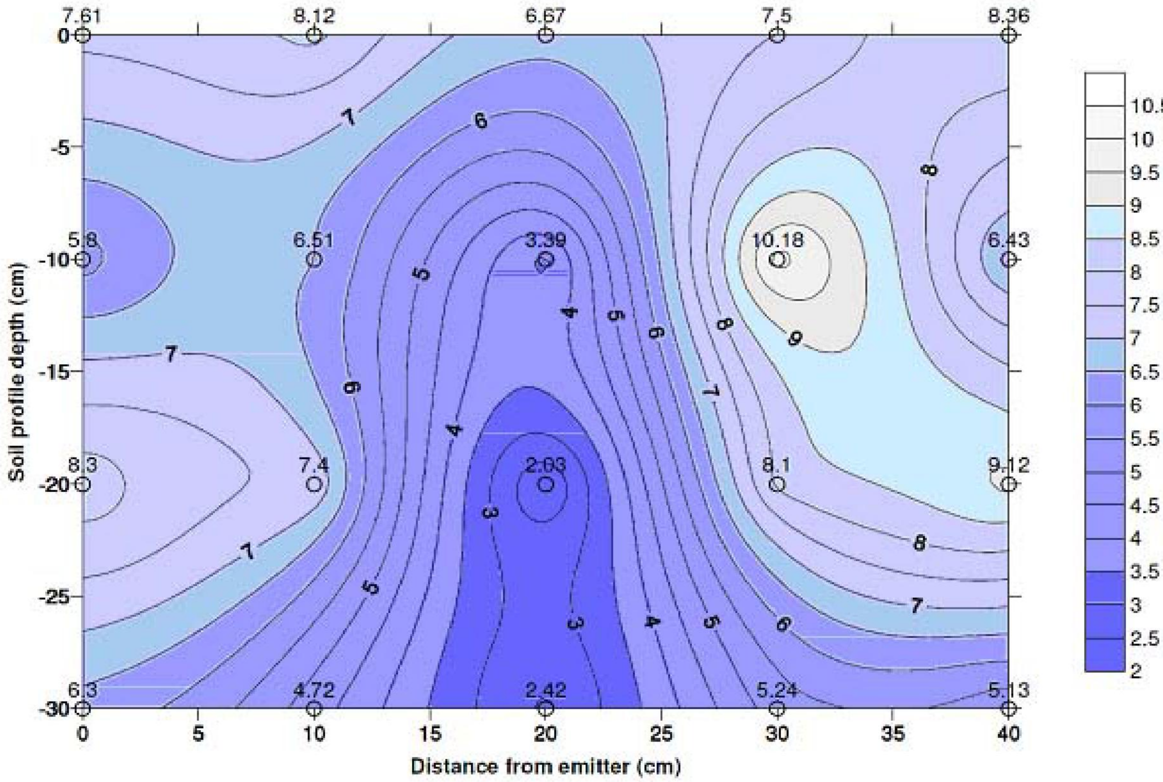


Fig 2. Soil moisture distribution pattern at 60 min during irrigation.



332 mm of water applied in drip instead of 520 mm in flood method for sweet corn and 36 % water saved in drip method.

Yield and its attributes

The height of sweet corn plant is measured by using scale from the selected 1m^2 for an interval of 15 days in all three treatments and average value from each plot is taken. It was observed that the plant height of sweet corn was varies in different treatment of irrigation. The plant height of single row drip system shows 2.51 m gives good result than paired row 2.04 m and flood (2.22 m). The height of the plant is more in single row because of efficient application of water to the plant at correct time based on soil moisture sensor.

It was also found that the plant root depth of sweet corn was varies in different treatments of irrigation. As compared the root depth, single row drip method having more root depth i.e. 28 cm as water is applied near by the plant based on soil moisture sensor and followed by flood irrigation having 24 cm and by next paired row drip having 22 cm.

To study the sweet corn cob characteristics, one m^2 area was selected in each treatment. The observed cob characteristics are no. of kernel, rows per cob, no. of kernels per cob, cob length and cob diameter and the fresh cob weight. The no. of cobs in 1 m^2 area is collected and average of those cobs is to be represented in Table 3.

The total yield of sweet corn for different experimental plots was calculated and presented in Table 4. The yield from the flood irrigation plot, single row drip plot, paired row drip plot was observed as 7.43 t ha^{-1}, 7.93 t ha^{-1}and 6.48 t ha^{-1}respectively. The yield of the single row drip plot was observed to be higher when compared to the yield obtained from the other experimental plots. The higher yield can be obtained due to the efficient application of water at right time near the root zone by low cost microcontroller based soil moisture sensor which is present in the field and supplies water automatically whenever there is need of water to the plant which helps for the favourable conditions for growth of the plant.

Soil moisture distribution pattern using surfer

Soil moisture distribution pattern for the 30 min, 60 min and 90 min during irrigation is shown in Fig. 1, 2 and 3. At 30 min during irrigation, amount of moisture content decreased as the distance from the plant increased due to lateral spacing and the moisture content near the plant was 8.3 per cent. The moisture content at 10 cm depth near the plant was 7.56 per cent. The moisture content reduced from 7.56 per cent to 5.4 per cent at a depth of 10 cm to 30 cm. The percentage decrease in moisture content near the plant was 34.9 per cent. At a distance of 10cm from the plant the moisture content increased from 4.43 to 5.63 per cent at a depth of 10 cm to 30 cm from surface. The percentage decrease in moisture content at a distance of 10, 20 and 30 cm from the plant are 25.5, 66.2 and 19.5 per cent

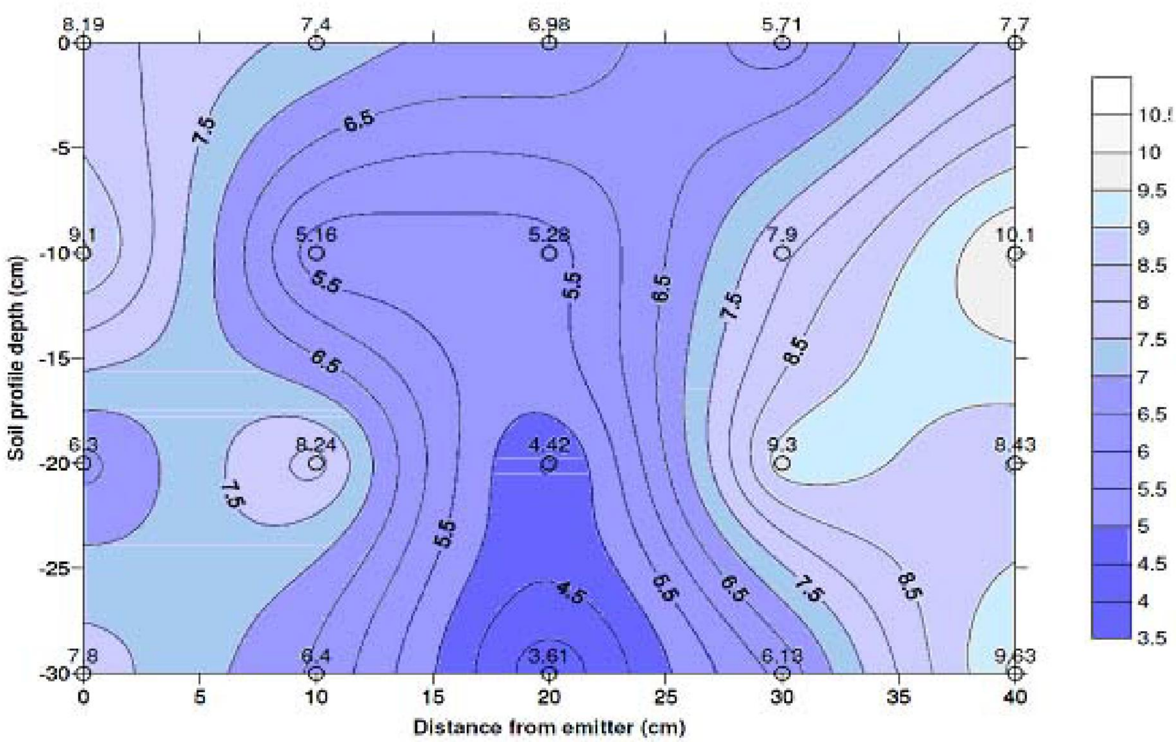
At 60 min during irrigation, the moisture content near the plant is 7.61 % and reduction in moisture content near the plant is 17.2 %. At a depth of 20 cm near the plant the moisture content is increased from 7.61 to 8.3 %. The percentage decrease in moisture content at a distance of 10, 20 and 30 cm from the plant are 41.8, 63.7 and 30.1 per cent.

At 90 min during irrigation, the moisture content near the plant is 8.19 % and reduction in moisture content near the plant is 4.76 %. At a distance of 30 cm and 40 cm from the plant the moisture content increased from 5.71 to 6.13 % and 7.7 to 9.63 % at a depth of 30 cm from the surface. The percentage decrease in moisture content at a distance of 10 cm and 20 cm from the plant is 13.5 and 48.2 per cent.

Water use efficiency

It was found that water use efficiency is highest in single row drip method as 23.88 kg/ha-mm followed by paired row drip and flood method as 19.51 and 14.29 kg/ha-mm respectively as shown in Table 5. In paired row drip system, more water use efficiency observed than flood due to 36% water saving even though yield is less compared to flood method.

Fig 3. Soil moisture distribution pattern 90 min during irrigation



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