INNOVATIVE ENERGY TECHNOLOGY SYSTEMS AND ENVIRONMENTAL CONCERNS: A SUSTAINABLE APPROACH
ISBN: 978-93-84144-81-4

Performance of a Developed Low Cost Microcontroller based Automated Drip Irrigation System in Kinnow Crop

Manish Debnath[1] and Neelam Patel[2]

[1]Ph.D. scholar, (Soil and Water Conservation Engg.)
Indian Agricultural Research Institute, New Delhi–12
[2](Soil and water conservation Engg.) Water Technology Centre
Indian Agricultural Research Institute, New Delhi–12

Abstract

Irrigation scheduling plays a vital role to achieve better plant growth and higher crop yield. Horticultural crops require a large amount of water to fulfill their evapo-transpiration needs. In India, the irrigation scheduling is done following conventional method, which is least efficient, time consuming and also wastes a huge amount of water. Drip irrigation is one of the best options for enhancing crop yield per unit of water applied. Drip irrigation, associated with automatic irrigation scheduling technique, can save time, human labor and also minimize the wastage of water. An automated drip irrigation system based on leaf-air temperature differential using LM35 IC as leaf and air temperature sensor was developed in laboratory and tested for Kinnow crop. The developed sensor circuit was integrated with the drip head works for irrigation automation. The soil moisture content, leaf-air temperature differential, crop canopy diameter, leaf area index were monitored during the study period. The system maintained the soil moisture content nearer to the field capacity (30.02%) based on temperature differential values fed into the microcontroller unit. The amount of water applied by the developed system was 0.128 m^3 water per plant per month which was 8 % less than the water applied by the controlled condition based on the crop water requirement (0.139 m^3per plant per month).

Keywords: Drip irrigation, sensor circuit, leaf-air temperature differential

1. Introduction

In India, farmers have been irrigating crops at regular intervals using irrigation techniques with manual control and individual's visual judgment. Irrigation with drip system is economical and efficient. In the conventional drip irrigation system, it is needed to keep watch on irrigation time table, which is different for different crops. The recent irrigation techniques include automated irrigation using sophisticated equipment to supply water to the plant on the basis of their demand. Irrigation automation unit can be based on soil moisture, climatic or plant parameters. Plant canopy temperature is a good indicator of plant water stress [1]. The plant canopy and ambient air temperature difference is a good indicator of the water status of a plant [2]. The leaf-air temperature differential based irrigation scheduling is the concept of irrigating the crop whenever a predetermined leaf-air temperature differential reaches a given value. Thermocouple, thermistor and infrared sensors were used by various researchers for plant canopy temperature measurement or for leaf-air temperature differential measurements for irrigation scheduling [3,4,5]. Microcontroller based irrigation scheduling [6] can be done using low cost sensors. Commercially available sensors for leaf-air temperature measurements are costly and require calibrations before their use in the field. A low cost, LM35 IC based sensor circuits was designed and developed using low cost locally available components and integrated with drip irrigation headwork to irrigate the crop automatically. The developed sensor does not require any calibration for temperature readings as the output of the sensor is in degree centigrade. The main aim of this study was to evaluate performance of developed automated system in kinnow crop in which it is difficult to measure soil moisture because of their deep and elaborate root system.

The core zone identified for the production of Kinnow by the Department of Horticulture is Maharashtra, NEH, Darjeeling, Punjab and Rajasthan. Rajasthan holds third place in Citrus Fruits, mandarian (Oranges) production, fourth in sweet Oranges (Mosambi). The quality and yield of citrus depends on precisely and accurate supply of water and nutrients. Precise application of water and nutrients are possible through drip systems. Most of the crops are irrigated through conventional irrigation methods. Kinnow is one of the important horticultural crops in India therefore developed automatic irrigation system was evaluated in the kinnow crop for its performance.

2. Materials and methods

2.1. Location of experimental field

The experiment was conducted at the Precision Farming Development Centre, Water Technology Centre, Indian Agricultural Research Institute (IARI), Pusa, New Delhi, India, which is located within 28°37'22" N and 28°39'00" N latitude and 77°8'45" E and 77°10'24" E longitude covering an area of about 475 ha at an average elevation of 230 m above mean sea level. The soil of the experimental area was deep, well-drained sandy loam soil comprising with 63.66 % sand, 21.16 % silt and 15.16 % clay. The bulk density of soil was 1.58 g cm^{-3}, field capacity 30.02 % and saturated hydraulic conductivity of 1.19 cm h^{-1}, respectively. The pH and EC of soil was 9.17 and 0.138 dS m^{-1}, respectively.

2.2. Design of field experiments

The designed and developed sensor system was installed in the field and integrated with drip irrigation head works. This system was operated by electrical powered pump. A field plot of 30m x 70 m containing 4 rows of plants was used for testing the developed system. Each row was having 12 plants at a plant to plant and row to row spacing of 5m X 5m. Plants were having average canopy diameter of 3.20 m. Two rows of plants, 24 in numbers were given controlled irrigation meeting 100 % crop water requirement and two rows of plants were irrigated through the developed automated system based on leaf-air temperature differential value to meet the 100 % crop water requirement. Sensor circuit was installed in the shaded side of the plant (during the noon time). One of the two LM35 sensors of the developed sensor circuit was attached to the lower side of the leaf by means of a plastic clip and another one was hanged freely in the air nearer to the sensor attached to the leaf. Two access tubes per plant at a distance of 80 cm and 160 cm from the plant stem were installed up to 100 cm soil depth to measure the soil moisture using Frequency Domain Reflectometer (FDR). An infrared sensor was used to measure the leaf-air temperature reading to compare the readings measured by the developed sensor.

ISBN: 978-93-84144-81-4

2.3. Leaf-air temperature differential measurement by IR sensor

Plant canopies emit long-wave infrared radiation as a function of their temperature. The Infra red Thermometer (IRT) senses this radiation and converts it into an electrical signal, which is displayed as temperature. In the field, an IR sensor (Everest Interscience INC, Model No: 6110-4ZL) was used to measure the air-leaf temperature differential.

2.4. Plant canopy diameter

To check the plant growth during the experimental period irrigated using developed automated system, plant canopy diameter was measured using a measuring tape of 1.5 m length. Kinnow plants having equal canopy diameter were chosen in the field randomly. Plants selected for mounting the sensor and system having average canopy diameter of 3.20 m.

2.5. Leaf Area Index measurement

Leaf Area Index (LAI) is a dimensionless quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area in broad leaf canopies .

$$LAI = \frac{Leaf\ area\ (m^2)}{Ground\ area\ (m^2)}$$

In the field the Leaf Area Index was measured by using the instrument LAI-2000 Plant Canopy Analyzer. The LAI-2000 calculates LAI and other attributes from radiation measurements made with a "fish-eye" optical sensor (148° field-of-view). After collecting above-canopy and below-canopy measurements, the control unit performs all calculations and the results are available for immediate on-site inspection. The Leaf Area Index of the experimental crop, i.e., Kinnow was measured during the testing period of the developed automated system.

2.6. Soil moisture measurement

Soil moisture was measured by using FDR. The working principle of FDR is that a high frequency series of pulses is sent down the wave guides rather than a single pulse. The electronics of system measure the shift in frequency rather than the change in time. Two access tubes made of PVC were installed up to a depth of 1.0 m in experimental field for each plant to measure the soil moisture contents (volumetric basic). Daily measurements of soil moisture were taken in the root zone of plants during the experimental period.

2.7. Estimation of water requirement of crop under control irrigation

Water requirement of crops defines quantity of water needed to meet the water losses through evapo-transpiration of a disease-free crop under non restricting soil conditions, including soil, water and fertility and achieving the full potential under a given soil environment in a given time. Water requirement of the Kinnow crop was calculated on the basis of reference crop evapo-transpiration (ET_0) on the daily basis and a weekly irrigation was scheduled in conventional drip system. The crop-evapotranspiration (ET_c) was estimated by multiplying reference evapo-transpiration (ET_0) with crop coefficient (K_c) for different months i.e. $ET_{c=}ET_0$ x K_C.

The water requirement of the Kinnow crop was then calculated as

$$WR = \frac{\mathrm{ETc}*\mathrm{AC}*Kc}{E}$$

ISBN: 978-93-84144-81-4

Where,

WR=Water Requirement of crop, m^3 /day/plant

ET_c=Crop evapo-transpiration, m/day

A_C =Plant canopy area, m^2

E=Efficiency of the irrigation system, in fraction (0.90 for drip)

K_p=Pan coefficient in fraction (0.7)

3. Results and discussions

3.1 Soil moisture content variation for scheduling using temperature sensor

The developed LM35 sensor based automated system integrated with drip irrigation head works was tested in the 5 years old matured Kinnow plants. Fig. 1 shows the soil moisture status under automation based on leaf-air temperature differential. Fig. 1 shows the daily soil moisture content variation from 28 to 30 % for a 10 days period. The system was able to irrigate crop as per leaf-air temperature differential conditions. The system irrigated the crop on every fourth day i.e., after every three days interval from the previous irrigation. For the 10 days period the system irrigated the field on day 1, 5 and 9 as shown by the red bars in the Fig. 1. After 24 hours of irrigation the soil moisture content reaches nearer to the field capacity, then decreased down in next two days. There was no rainfall during the experimental period. The system maintained the soil moisture content nearer to the field capacity throughout the experimental period.

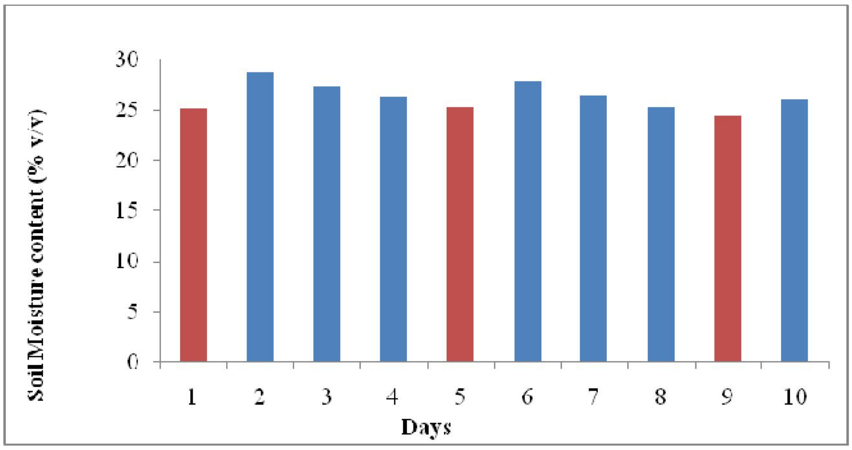

Fig. 1: Soil moisture status under automation based on leaf-air temperature differential.

Fig. 2 shows the soil moisture content variation under irrigation applied by using developed automated system for different leaf-air temperature differential values. Leaf-air differential temperature was measured by using developed sensor and by IR sensor. Temperature differential measured by the infrared sensor was slightly higher than the developed sensor. The infrared sensor measures only surface temperature of the body under the study, also its functioning gets affected by the viewing angle, wind velocity, solar radiation which may lead to a higher reading then measured by the developed contact type sensor. The soil moisture content was maintained near to field capacity by the developed system in the plant root zone.

ISBN: 978-93-84144-81-4

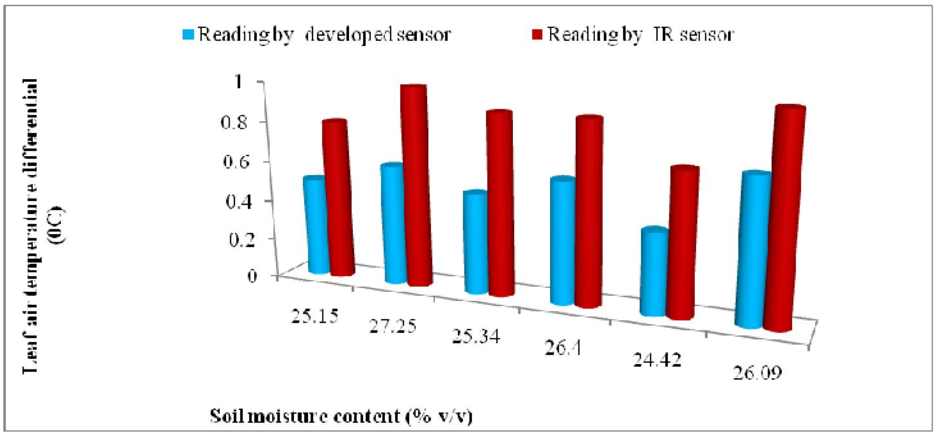

Fig. 2: Soil moisture content variation with leaf-air temperature difference.

3.2. Crop canopy diameter, Leaf Area Index and the amount of water applied under the developed automated system and the conventional drip irrigation system

The reference evapo-transpiration (ET_0) and the average crop coefficient (Kc) during the experimental period were taken as 8.87 mm/day and 0.65, respectively. Table 1 shows the values of average crop canopy diameter, Leaf Area Index and water applied under the conventional irrigation system and under the developed automated system. The average crop canopy diameter and leaf area index values for the plants irrigated under the developed automated system were found to be nearly equal to that of plants irrigated under conventional irrigation condition. The amount of water applied for the plants irrigated using conventional system i.e. irrigation based on 100 % of crop water requirement was found to be more than that of the water applied by the developed system using leaf temperature sensor. It was observed that without affecting the plant growth, amount of irrigation water can be saved in sensor based automatic drip system.

Table 1: Average crop canopy diameter, Leaf Area Index and water applied under the conventional drip system and the developed automated system

Parameters	Plants irrigated using developed automated drip system	Plants irrigated using conventional drip system
LAI	1.55	1.57
Canopy diameter (cm)	160	162
Water applied (m^3/plant/month)	0.128	0.139

4. Conclusions

The developed automated system was evaluated and tested successfully in Kinnow crop. The system maintained the soil moisture content near to the field capacity throughout the experimental period based on the leaf-air temperature differential conditions. The average amount of water applied by the developed system was slightly less (8 %) than the water applied by the controlled condition i.e., based on 100 % of crop water requirement. The developed system can be used by the farmers for commercial cultivation of horticultural crops for savings of labor and water.

ISBN: 978-93-84144-81-4

5. Acknowledgements

Authors would to thank Ministry of Water Resources for providing the financial support to conduct this research through research project entitled “Development of an Indigenous Automated Micro Irrigation System”

References

[1] Jacson, R.D., Idso, S.B., Reginato, R.J., and Pinter Jr. P.J., “ Canopy temperature as a crop water stress indicator”, *Water Resour. Res.*, 17, 1981, pp. 1133-1138.

[2] Bhosale, A.M., Jadhav, A.S., and Bote, N.L Varsheya, M.C. “Canopy temperature as an indicator for scheduling irrigation for wheat “ , *J. Maharashtra Agric. Univ.* 21, 1, 1996. pp. 106-109.

[3] Ahmed, M., Misra, R.D. (Eds.), Manual on Irrigation Agronomy, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 1990, pp. 121-122, 272-282

[4] Fisher,. D. K. and Kebede, H., “A low-cost microcontroller-based system to monitor crop temperature and water status” , *Computers and Electronics in Agriculture* 74 , 2010 pp. 168–173.

[5] Abraham,N., Hema, P.S., Saritha, E.K. and Subramannian, S., “Irrigation automationbased on soil electrical conductivity and leaf temperature”, *Agricultural Water Management* , 45, 2000, pp. 145-157.

[6] Swamy, D.K., Rajesh, G., Pooja, M.J. K., and Rama Krishna, A. “Microcontroller Based Drip Irrigation System”, *International Journal of Emerging Science and Engineering (IJESE)*, 1,6, April 25 2013, ISSN: 2319–6378.