EVALUATION OF AUTOMATED DRIP IRRIGATION SYSTEM USING LOW COST SOIL MOISTURE SENSOR

M. Tech. (Agril. Engg.) Thesis

by

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EVALUATION OF AUTOMATED DRIP IRRIGATION SYSTEM USING LOW COST SOIL MOISTURE SENSOR

Thesis

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by

Jeet Raj

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CERTIFICATE -I

This is to certify that the thesis entitled "**Evaluation of automated drip irrigation system using low cost soil moisture sensor**" submitted in partial fulfillment of the requirements for the degree of **Master of Technology in Agricultural Engineering** of the Indira Gandhi Krishi Viswavidyalaya, Raipur, is a record of the bonafide research work carried out by **Jeet Raj** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigations have been duly acknowledged.

Chairman

Date: 28/7/18

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member	(Er. Prafull Katre)	

CERTIFICATE -II

This is to certify that the thesis entitled "**Evaluation of automated drip irrigation system using low cost soil moisture sensor**" submitted by **Jeet Raj** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirement for the degree of **Master of Technology in Agricultural Engineering** in the Department of Soil and Water Engineering has been approved by the external examiner and Student's Advisory Committee after oral examination.

Signature External Examiner

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Place: Raipur

Jeet Raj
(Jeet Raj)

Date: 28/07/18

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Symbols	Description
^oC	Degree Celsius
cm	Centimeter
E_a	Application Efficiency
EC	Electrical Conductivity
E_d	Distribution Efficiency
et al.	and others
etc.	et cetera
EU_f	Emission Uniformity
FC	Field capacity
g	gram
g ha^{-1}	gram per hectare
hr	Hour
ha	Hectare
h	Hour
i.e.	that is
km	Kilogram
km ha^{-1}	Kilogram per hectare
km cm^{-1}	Kilogram per square centimeter
km ha^{-1} mm^{-1}	Kilogram per hectare per millimeter
km	Kilometer
Km h^{-1}	kilometer per hour
m^3s^{-1}	Cubic meter per second
kW	Kilowatt
l	Litre
l h^{-1}	litre per hour
m	Metre
mm	millimetre
msl	Mean Sea Level
pH	Potential of Hydrogen
q ha^{-1}	Quintal per Hectare
q ha^{-1} cm^{-1}	Quintal per Hectare per Centimeter
Q_{var}	Emitter Flow Variation
RH	Relative Humidity
T_{max}	Maximum Temperature
T_{min}	Minimum Temperature
µ	micron

LIST OF ABBREVIATIONS

Abbreviations	Description
Avg.	Average
B/C	Benefit Cost Ratio
C.G.	Chhattisgarh
Dia.	Diameter
DAT	Days after Transplanting
DI	Drip Irrigation
Ep	Evaporation
IGKV	Indira Gandhi Krishi Vishwavidyalaya
IW	Irrigation Water
M.C.	Moisture Content
No.	Number
Sig.	Significant
S.No.	Serial Number
SVCAET & RS	Swami Vivekananda College of Agricultural Engineering and Technology & Research Station
w.r.t	With respect to
WUE	Water Use Efficiency

THESIS ABSTRACT

Title of the thesis	:	Evaluation of automated drip irrigation system using low cost soil moisture sensor
Full Name of the Student	:	Jeet Raj
Major Subject	:	Soil and Water Engineering
Name and Address of the Major Advisor	:	Dr. Dhiraj Khalkho Scientist Department of Soil and Water Engineering, Faculty of Agricultural Engineering, IGKV, Raipur
Degree to be Awarded	:	M.Tech

Signature of Major Advisor

Signature of Student

Date: 5|09|2018

Signature of head of the Department

ABSTRACT

Land and water resources are the basic needs of agriculture and for the economic development of any country. The demand for these resources will continue to grow due to ever increasing population. The world population is increasing faster than the food supply. India has only 2.4% of land mass and 4% fresh water resources of the world. Agriculture uses about 70 to 80% of total available water. Drip irrigation method distributes water to the field using the pipe network and transforms it from the pipe network to the plant by emitters. In spite of the advantages of drip irrigation methods, the traditional network in drip irrigation method has many problems. Gravity fed drip irrigation with Soil moisture sensor system is the best available approach for efficient utilization of soil moisture and for producing higher yield to fulfill the ever growing food demand in the country.

The present study was conducted on "Evaluation of Low Cost Soil Moisture Sensor Based Automated Drip Irrigation System" at the experimental field of Department of Soil and Water Engineering, SVCAET & RS, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The aim of the experiment was to integrate and set up a low cost sensor system for monitoring of soil moisture content along with calibration and validation the sensor system in conjunction with the low cost gravity operated drip irrigation system.

Laboratory tests of the soil samples revealed its texture as clay loam. Field capacity (27 %) and Bulk density (1.34 g cc^{-1}) was obtained. Alfa-mart sensor, TDR and gravimetric method were used to measure soil moisture content. Soil moisture sensor system was calibrated between VMC of 80-50% for field capacity of the soil by using Gravimetric method.

Gravity fed drip irrigation system 750 litres overhead (total height 3.55 m) tank was used for irrigation. The experiment constituted two treatments Conventional drip irrigation (Control) and Sensor based drip irrigation. As Control irrigation water is provided based on farmer practice and Sensor based treatment water was provided according to field moisture content. For Control irrigation and Sensor based drip irrigation 2 and 10 lines of laterals were used respectively. Wetting patterns was measured at 0.25 kg cm^{-2} operating pressure. Wetted width and depth of soil after 15, 30, 60 and 90, minutes of water application were recorded. The maximum horizontal wetting front advance was observed to be 4.2, 8.2, 11.2 and 16.4 cm respectively and maximum vertical wetting front advance were recorded as 8.4, 12.4, 20.1 and 22.3 cm respectively from emitters with discharge of 1.3 l h^{-1} at 0.25 kg cm^{-2}.

Drip irrigation discharge of 1.03 l h^{-1} inline emitter was measured at different locations in the field at 10 min interval of different operating head to evaluate out the hydraulic performance of drip irrigation system based on, emission uniformity, emitter flow variation, uniformity coefficient and irrigation efficiencies. Based on the experimental record Emission uniformity (98.80%), Uniformity coefficient (97.94%), Distribution efficiency (97.04%) and Application efficiency (95.62 %) were found maximum at operating head 3.35 m to 3.36 m. The growth characters was progressively increased and influenced by different irrigation treatments. In Control irrigation maximum plant height was 98.30 cm, number of branch per plant was 3.50, number of fruit per plant was 15.12, avg. weight of fruit 10.10 gram, avg. length of fruit was 9.30 cm, yield per plant was 209 gram and water use efficiency was 27.68 kg ha^{-1} mm^{-1} was obtained. In Sensor based treatment maximum plant height was 115.90 cm, number of branch per plant was 4.90, number of fruit per plant was 15.81, avg. weight of fruit 13.40 gram, avg. length of fruit was 11.20 cm, and yield per plant was 234 gram was obtained.

Water use efficiency was found maximum (46.76 kg ha^{-1} mm^{-1}) under sensor based treatment. After calculating total volume of water 4850 m^3 used by Control irrigation and 3116.0 m^3 for the production of okra in one ha area. So Sensor based treatment safe 1734 m^3 of water in one ha area.

शोध सारांश

शोध का शीर्षक	:	कम लागत वाली मिट्टी नमी सेंसर आधारित स्वचालित ड्रिप सिंचाई प्रणाली का मूल्यांकन
विद्यार्थी का पूरा नाम	:	जीत राज
मुख्य विषय	:	मृदा एवं जल अभियांत्रिकी
मुख्य सलाहकार का नाम व पता	:	डॉ. धीरज खलखो वैज्ञानिक मृदा एवं जल अभियांत्रिकी इं. गां. कृ. वि., रायपुर
सम्मानित किये जाने वाली उपाधि	:	एम. टेक (कृषि अभियांत्रिकी) मृदा एवं जल अभियांत्रिकी

Jeet Raj

मुख्य सलाहकार के हस्ताक्षर

विद्यार्थी के हस्ताक्षर

विभागाध्यक्ष के हस्ताक्षर

दिनांकः 28/07/2018

सारांश

भूमि और जल संसाधन कृषि की बुनियादी जरूरतों और किसी भी देश के आर्थिक विकास के लिए महत्वपूर्ण हैं। इन संसाधनों की मांग लगातार बढ़ती आबादी के कारण बढ़ती रहेगी। खाद्य आपूर्ति की तुलना में विश्व जनसंख्या तेजी से बढ़ रही है। भारत में केवल 2.4% भूमि द्रव्यमान और दुनिया का 3% ताजा जल संसाधन है। कृषि कुल उपलब्ध पानी के 70% से 80% का उपयोग करता है। ड्रिप सिंचाई विधि में पाइप नेटवर्क का उपयोग करके खेत में पानी का वितरण किया जाता हैं और इसे पाइप नेटवर्क से उत्सर्जक द्वारा पौधों को दिया जाता हैं। ड्रिप सिंचाई पद्धतियों के फायदे के बावजूद, ड्रिप सिंचाई विधि में पारंपरिक नेटवर्क में कई समस्याएं हैं। गुरुत्वाकर्षण विधि एवं मृदा नमी संवेदक प्रणाली के साथ ड्रिप सिचाई पद्धति का उपयोग नमी के संरक्षण के लिए उपयुक्त दृष्टिकोण हैं एवं यह देश में खाद्य मांग को पूरा करने के लिए अधिक उपज के उत्पादन में सहायक हैं।

मृदा और जल इंजीनियरिंग विभाग, एस. वी. सी. ए. ई. टी. और आर. एस., कृषि अभियांत्रिकी संकाय, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर, छत्तीसगढ़ में ''कम लागत वाली मृदा नमी सेंसर आधारित स्वचालित ड्रिप सिंचाई प्रणाली का मूल्यांकन'' पर एक प्रयोग आयोजित किया गया था। प्रयोग का उद्देश्य मृदा की नमी की निगरानी के लिए कम लागत संवेदक प्रणाली को एकीकृत करना और स्थापित करना, कम लागत वाले गुरुत्वाकर्षण संचालित सिंचाई प्रणाली और प्रदर्शन के साथ संवेदक प्रणाली को कैलिब्रेट और मान्य करने के लिए मिट्टी की नमी का उपयोग करके ड्रिप सिंचाई प्रणाली का मूल्यांकन करना था ।

मृदा के नमूनों के प्रयोगशाला परीक्षणों से मृदा का क्ले लोम होना ज्ञात हुआ। फील्ड कैपेसिटी (27%) और बल्क डेंसिटी (1.34 ग्राम सीसी^{1}) प्राप्त किया गया। अल्फा–मार्ट सेंसर, टीडीआर और

गुरुत्वाकर्षण विधि का उपयोग मृदा नमी को मापने के लिए किया गया। मृदा नमी सेंसर प्रणाली को गुरुत्वाकर्षण विधि का उपयोग करके मिट्टी की क्षेत्र क्षमता में कैलिब्रेटेड किया गया।

गुरुत्वाकर्षण आधारित ड्रिप सिंचाई प्रणाली में 750 ली. ओवरहेड (कुल ऊंचाई 3.55 मीटर) टैंक सिंचाई के लिए इस्तेमाल किया गया। प्रयोग में दो उपचार नियंत्रण सिंचाई और सेंसर आधारित उपचार गठित किये गए। नियंत्रण सिंचाई में पानी किसान अभ्यास के आधार पर प्रदान किया गया और सेंसर आधारित उपचार में मृदा की नमी के अनुसार प्रदान किया गया। नियंत्रण सिंचाई में 2 पार्श्व और सेंसर आधारित उपचार में 10 पार्श्व का उपयोग किया गया। वेटिंग पैटर्न को 0.25 किलो/सेमी^{2} अपरेटिंग दबाव पर मापा गया। 15, 30, 60 और 90 के बाद मिट्टी की गीली चौड़ाई और गहराई, पानी के कुछ मिनट दर्ज किए गए। अधिकतम क्षैतिज गीला मोर्चा फ्रंट अग्रिम 4.2, 8.2, 11.2 और 16.2 से.मी. क्रमशः देखा गया और अधिकतम ऊर्ध्वाधर गीले मोर्चा फ्रंट अग्रिम को क्रमशः 8.4, 12.4, 20.1 और 22.3 से.मी. के रूप में दर्ज किया गया, जो 1.03 ली/घंटा के निर्वहन के साथ 0.25 किलो/सेमी^{2} अपरेटिंग दबाव पर मापा गया।

1.03 ली/घंटा इनलाइन एमिटर के ड्रिप सिंचाई डिस्चार्ज को विभिन्न अपरेटिंग हेड के 10 मिनट अंतराल पर क्षेत्र में विभिन्न स्थानों पर मापा गया ताकि उत्सर्जन एकरूपता, उत्सर्जन प्रवाह भिन्नता, एकरूपता गुणांक के आधार पर ड्रिप सिंचाई प्रणाली के हाइड्रोलिक प्रदर्शन की जांच हो सके। सिंचाई क्षमताएं प्रयोगात्मक रिकॉर्ड उत्सर्जन एकरूपता (98.80%), एकरूपता गुणांक (97.94%), वितरण दक्षता (97.04%) और आवेदन दक्षता (95.62%) अपरेटिंग हेड 3.35 मीटर से 3.36 मीटर पर अधिकतम पाए गए। विकास के पात्र क्रमशः विभिन्न सिंचाई उपचारों से प्रभावित हुए एवं उनमे वृद्धि दर्ज की गयी। नियंत्रण सिंचाई में पौधे की अधिकतम ऊंचाई 98.30 से.मी. थी, प्रति पौधे शाखा की औसत संख्या 3.50 थी, प्रति पौधे में फल की औसत संख्या 15.12 थी। फल का औसत वजन 10.10 ग्राम, फल की लंबाई 9.30 सेमी, प्रति पौधे उपज 209 ग्राम/से.मी. और पानी की उपयोग दक्षता 27.68 किग्रा/हेक्टेयर/मिमी प्राप्त की गई थी। सेंसर आधारित उपचार में अधिकतम पौधों की ऊंचाई 115.90 से.मी. थी, प्रति पौधे शाखा की संख्या 4.90 थी, प्रति पौधे फल की औसत संख्या 15.81 थी, । फल का औसत वजन 13.40 ग्राम, फल की लंबाई 11.20 से.मी. थी, और प्रति पौधे उपज 234 ग्राम प्राप्त की गई।

सेंसर आधारित उपचार के तहत जल उपयोग दक्षता अधिकतम (46.76 किग्रा/हेक्टेयर/मिमी) पाया गया। उच्च क्षेत्र में भिंडी के उत्पादन के लिए गणना करने के दौरान नियंत्रण सिंचाई द्वारा उपयोग किए जाने वाले पानी की कुल मात्रा 3116 मी^{3} और सेंसर आधारित उपचार द्वारा उपयोग किए जाने वाले पानी की कुल मात्रा 4850 मी^{3} दर्ज की गयी। इस आधार पर सेंसर आधारित उपचार नें एक हैक्टर क्षेत्र में 1734 मी^{3} पानी सुरक्षित किया।

CHAPTER I
INTRODUCTION

Agriculture has been an indispensable to the subsistence of the people of India in general and farmers in particular. It has naturally remained the basis of Indian economy since time immemorial and agriculture has played a dominant role in the country's economy from the very beginning. About 65% of the Indian population either directly or indirectly employed in agriculture sector. The well-being and progress of the nation is closely connected with agriculture. Therefore, farming and agriculture profession deserve to be highly respected for the prosperity of the nation.

Land and water resources are the basic needs of agriculture and for the economic development of any country. The demand for these resources will continue to grow due to ever increasing population. The world population is increasing faster than the food supply. India has only 2.4% of land mass and 4% fresh water resources of the world. Agriculture uses about 70 to 80% of total available water. Water is recognized as a vital resource both for livelihood, food security and environmental sustainability. If sufficient water resources are available, it is possible to increase the intensity of cultivation up to 300% or more and large extent of areas of waste/fallow lands can be brought under cultivation, which will solve the problem of food shortages for the increasing population.

Water is one of the primary inputs in agricultural production. Water for agricultural use is becoming scare, both in quantity and quality, not only in the traditionally prone arid and semi-arid zones, but also in regions where rainfall is abundant. Agriculture represent the major user worldwide, and a general perception that agricultural water use is often wasteful and has less value than other uses is widespread. Arid and semi-arid regions are predominantly dependent on artificial irrigation. An artificial process of watering to field is known as Irrigation. In India, mostly farmer depends on monsoon for the requirement of water for farming that depend on nature and now system of nature is changed due to pollution or global warming that's why there is need of developing automatic and efficient method of irrigation. Near about 50% of total cultivated area in India is under irrigation and remaining depends upon rain or there is no advanced method of irrigation are followed by farmers while irrigating through ancient way requires a lot water that is not present in efficient amount now (less than 2.5% water is usable while 71% of total surface is covered with water). When farmer do watering to the field, they don't know for how much time they keep motor on or they don't have any data of soil moisture or don't have any idea that for how much time let the water flow in the field.

Water in these regions is the most limiting factor requiring its optimal use. Irrigation water is supplied to the plants/crops to replenish root-zone moisture storage when natural rainfall is poorly or inadequately distributed. However, it is nearly impossible and economically unfeasible for traditional flood irrigation methods to apply the same amount of water to all plants within a field, which results in reduced crop yields (Wu, 1987; Bhatnagar and Srivastava, 2003). Moreover, the traditional flood irrigation methods waste huge amount of water as deep percolation. When irrigation supplies are in small quantity, the more efficient use of the available water becomes compulsory. The efficient utilization of irrigation water is possible by the adoption of high efficient irrigation system, such as, drip irrigation systems. The growth of drip irrigation has really gained momentum in recent years. From a mere 1500 ha in 1985, the area under drip irrigation has grown to 3, 55,400 ha in 2001 and at present five lakh ha against the estimated potential area of 27 M ha.

The ever increasing demand for irrigation water, everywhere, has now focused national attention and public interest on utilization of existing water supplies, integrated irrigation water conservation and management policy and practices. Micro irrigation system delivers water to the crop using network of various kinds of filtration systems, sub mains and laterals with emission points (drippers) spaced along the lateral length. Each emitter supplies a small, precisely controlled, uniform quantity of water, nutrients directly into the root zone of the plant. Water and nutrients enter the soil from emitters, moving into the root zone of the plant through the combined force of gravity and capillary. With this, the plant's intake of moisture and nutrient is replenished almost immediately, ensuring that plant never suffers from water stress, thus enhancing and improving quantity to achieve high yield. Micro irrigation systems such as system that drip saves 27 to 42 per cent of water. Helps to increase water use efficiency by reducing soil evaporation and drainage losses.

Drip irrigation is an irrigation method that allows precisely controlled application of water and fertilizer by allowing water to drip slowly near the plant roots through a network of valves, pipes, tubing, and emitters. The component of drip irrigation includes pump, mains, sub main pipe, lateral and emitters along with filters. The dripper is an important component of a trickle irrigation system through which water is delivered to the plant in the field. Emitters are classified as online and inline drippers based on their arrangement on lateral. These are also categorized as pressure compensating (PC) and non-pressure compensating. The lateral can be a small plastic tube combined with emitters. The laterals are designed for distributing water into the field with an acceptable degree of uniformity. The sub-main acts as a control system, which can adjust water pressure in order to deliver the required amount of flow into each lateral. The main line serves as a conveyance system for delivering the total amount of water for the drip irrigation system. Evaluation of hydraulics of drip irrigation system helps in improving the design of irrigation system and better control of irrigation water. Its field application efficiency can be as high as 90% compared to 60–80% for sprinkler and 50–60% for surface irrigation. Drip is a better system of irrigation than furrow method for okra and gives improved fruit yield by 36 per cent (Gorantiwar *et al*., 1991).

There is a great need to modernize agricultural practices for better water productivity and resource conservation. Presently, farmers irrigate their lands at regular intervals through manual control. This process consumes more water and at times crops get damaged. The use of automatic micro-controller based irrigation system can resolve this problem as irrigation will take place only when there is an intense requirement for irrigation water. The use of automated irrigation system can provide water on a real time basis at the root zone based on the availability of soil water at the crop root zone which also leads to saving of water (Migliaccio *et al.* 2015, Ojha *et al.* 2015, Soulis *et al*. 2015, Cristi *et al.* 2016).

Sensor based irrigation system has been demonstrated to address the challenges of higher productivity with greater resource-use efficiency by applying water as per the temporal and in-season variability. The soil moisture sensor based irrigation system facilitates aggregation of data on soil and plant conditions and in conjunction with decision support advisories and control systems, applies real time irrigation based on crop need.

Irrigation scheduling can be done using a combination of soil, plant, and climate data (Deb et al., 2013). Non-destructive continuous soil water monitoring using time domain reflectometry (TDR) or capacitance-based sensors and evapotranspiration (ET) estimates (Sammis et al., 2012) are used to schedule irrigation. These methods can optimize irrigation scheduling of crops and prevent water wastage and groundwater contamination due to nutrient leaching.

As the population expected to grow 9.1 billion by 2050. World need to meet the demand of agricultural food products. Climatic change provides a major challenge in agriculture sector which reduces the total yield by 15-30%. The practical solution is obtained by using water irrigation methods coupled with advance technologies. Many agricultural activities can be highly enhanced by using digital technologies. One of these activities was the regulation of the quantity of water in cultivated fields, a process which is directly interwoven with the sustainability and the productivity of crops, since insufficient or excessive irrigation may not only be obstructive, but also destructive. The purpose of this project was to develop an integrated system for automated irrigation with help of soil moisture sensors. At its core, the proposed system aims at efficiently managing water supply in cultivated fields in an automated way. The system takes moisture content of the field and calculates the quantity of water that is needed for irrigation. Combination of drip irrigation and soil moisture sensor is relatively a new concept in Chhattisgarh.

The present study was framed with the objective to incorporate electronic and digital technology couple to water saving irrigation technique i.e. drip irrigation system with the below mentioned objectives at the Dept. of Soil and Water Engineering, Faculty of agricultural engineering, IGKV Raipur.

Objectives:

1. To integrate and setting up of low cost sensor system for monitoring of soil moisture content.
2. To calibrate and validate the sensor system in conjunction with the low cost gravity operated irrigation system.
3. Performance Evaluation of drip irrigation system using soil moisture sensor.

CHAPTER - II
REVIEW OF LITERATURE

The chapter deals with the review of literature related to the present study. The review pertaining to research work conducted on soil moisture based irrigation scheduling, advance in drip irrigation system, soil moisture sensor based irrigation system are presented in this chapter.

The first experiments on drip irrigation possibly were started in Germany around 1860's as sub-surface irrigation system. The drip system was developed for field crops in Israel in the early 1960's and in Australia and North America in the late 1960's. The area under drip irrigation system in the USA was about 1 M ha, followed by India, Spain and Israel. In India, there has been a tremendous growth in the area under drip irrigation during the last two decades. At present, around 3.5 lakh ha area was under drip irrigation through the efforts of the Central and State Governments of India, while it was only 40 ha in 1960's.

2.1 Soil Moisture based Irrigation Scheduling

Arbat *et al.* (2009) was studied the ornamental plant production in Girona (Spain) represents an important economic sector, being with 1200 hectares one of the first production zones in Southern Europe. Most of this area was irrigated using blocked-end wide furrows, adapted to the mechanization of the ornamental plant production, which exhibit singularities compared with the traditional cultures. On the other hand, in this area there was strong competition for the water use between the different economic sectors which was pushing agriculture to increase water use efficiency and productivity. Motivated by the lack of technical information about irrigation performance and water productivity in ornamental plant production a two years study (2006 and 2007) in a representative commercial field of 'Prunus ceracifera' Nigra was carried out. The irrigation performance evaluated from the field measurements during the different irrigation events in 4 different furrows exhibited a high value of the mean distribution uniformity (87.9%) and application efficiency (93.4%). The drainage below 60 cm depth, calculated from the continuous measurements of the soil water contents using Richards' equation, was minimal along the furrows, except at its end. The cumulated irrigation doses were 4946 m^3/ha on year 2006 and 3827 m^3/ha on 2007 and the water productivity was of 14.92 $/ha, considerably larger than the obtained with traditional crops as corn or fruit trees.

Saha *et al.* (2011) Alfalfa was the largest consumer of water among all crops in California. It was generally flood-irrigated, so any system that decreases runoff can improve irrigation efficiency and conserve water. To more accurately manage the water flow at the tail (bottom) end of the field in surface irrigated alfalfa crops, we developed a system that consists of wetting-front sensors, a cellular communication system and a water advance model. This system detects the wetting front, determines its advance rate and generates a cell-phone alert to the irrigator when the water supply needs to be cut off, so that tail water drainage was minimized. To test its feasibility, we conducted field tests during the 2008 and 2009 alfalfa growing seasons. The field experiments successfully validated the methodology, producing zero tail water drainage.

The model-based cut off irrigation system developed in this study can minimize drainage water loss from surface-irrigated alfalfa fields and substantially improve water management. It was successfully demonstrated to dozens of farmers at the Alfalfa Field Day sponsored by UC Cooperative Extension on May 19, 2010, at the UC Davis Agronomy Field Headquarters. Our sensor and cellular communication–based cut off irrigation system was still under development and was not currently being used in California alfalfa fields; it may be commercially available by early 2012. The wetting-front sensors are inexpensive, about $25 per unit. The central module costs about $500 and the modem about $200, for a total of between $800 and $1,000. Moreover, the wireless system can easily be moved from one location to another, reducing the initial investment necessary to implement the system. With the typical five irrigations per alfalfa season, water savings could be about 35,000 to 60,000 liters per acre. Although the experimental system described eliminates guesswork and minimizes tail water drainage, a simpler system, with one sensor per check, may be attractive to some growers as a starting point. This system would alert the irrigator when the wetting front arrives at the single sensor. However, the efficacy of the system in minimizing tail water runoff would entirely depend on the irrigator's judgment on placement of the sensor within the check.

Nallani *et al.* (2015) was studied Indian agriculturewasdependent on the monsoons which was not a reliable source of water, so there was a need for an automatic irrigation system in the country which can provide water to the farms according to their moisture and soil types. The objective of this paper was to develop a low cost power effective sensor based automatic irrigation system whichwasintegrated to the microcontroller unit. The sensors used in this paper are soil temperature sensor and humidity sensor SHT1X. These sensors are interfaced to the Wireless Sensing Unit (WSU) and the entire unit was placed under the soil. It will transmit the sensor value to Wireless Interface Unit (WIU). The main motive of using WIU was to receive the sensed value from WSU and to activate the solenoid valve as well as to send a message to the mobile and also sends an email to the account of the user located in the remote area if the received valuewasgreater than the threshold. The SMS and email are sent using GPRS module interfaced with the wireless interface unit. The irrigation system was tested under various temperatures and different levels of humidity for several plants in all conditions. The soil moisture sensor limits the water content in a particular area. The throughput obtained in wet and normal conditions are proved to be intuitive. Developing country like India sending SMS and email to authorize person was understandable.

Nagarajan and minu (2017) was studied in a developing country like India, there was an exponential rise in population nutrition requirement. To meet up with both the ends, the agricultural techniques should be perfected for optimal yield and quality. Irrigation and soil property monitoring system using sensors can be automated and operated wirelessly to achieve optimal water supply control and surveillance. The objective of this paper was to automate the whole wireless sensor network (WSN) system with a control over water pumps and dripper valves. The humidity, temperature and pH sensor's precepts provide a feedback, to control the water content of the soil. The system has an low-cost and energy reliable ZigBee for sensor data transformation, high-range GPRS system for data storing and analysis, and the whole system was powered by Solar panels which makes it self-sustainable. Customizable options for different crop with different requirements make it a versatile WSN system for automated irrigation based water management.

Jorden (2017) has configured his system to run for 2 hours after the sensor registers that water has reached that point. To minimise runoff and to allow the automatic changeover of sets buried advance sensors have been installed towards the bottom end of each block. These sensors are located between 100-150 m up from the tail drain, approximately 20 drills across from the edge of the block and are connected to radios on the bottom headland (each radio was connected to 2 sensors). This farm was representative of a typical BRIA farm. There are no pumps with all the water being delivered under gravity from the Sun Water channel. There was also no tail water recycling and one of the challenges was to manage the system to ensure effective irrigation while minimising runoff. A pressure transducer was installed in the first cylinder from the channel outlet. This transducer provides a fail-safe by notifying Russell when the water pressure gets too high (valves haven’t opened) or drops too low (channel grate was blocked; a valve has remained open when it should have closed; fluming has blown off). The sensors were originally placed closer to the end but have now been positioned so that water reaches the end of the block, while minimising the volume that runs off. Now a suitable point has been identified they will be trenched in as a permanent installation at a depth sufficient to avoid damage from in-field cultivation. The trenching requirement and long cabling runs for these sensors increases the costs compared to the other sites where the advance sensors are placed in drains close to the radio. Five irrigation sets have been automated. Each cylinder has only one outlet which means each radio controls just one actuator. This increases the cost of the overall system. If there were two outlets per cylinder, each radio could control two actuators which would reduce the cost. Russell now has enough confidence in the system to use it to automatically switch sets. As one set completes, the valve for the next set opens; when it was fully open the first valve closes. The automation was also saving him considerable time and fuel because he doesn't have to physically visit the farm to check how the irrigation was progressing.

2.2 Advance in Drip Irrigation System

Punamhoro *et al.* (2003) studied the performance of bhendi under different irrigation methods *viz.*, drip irrigation with bucket kit and drum kit, micro sprinkler, overhead sprinkler irrigation, flood irrigation, check basin irrigation and furrow irrigation. The results of the study revealed that highest WUE of 2.52 q ha^{-1} cm^{-1} was recorded in drip irrigation with bucket kit, while the lowest WUE of 1.06 q ha^{-1} cm^{-1} was noticed with flood irrigation.

Mohammed *et al*. (2013) evaluated the Hydraulic Performance of Drip Irrigation System with Multi Cases. The research studies the improvement of emission uniformity of emitters by using new system layouts instead of the traditional system. The first proposed system layout concluded to improve the hydraulic performance by improving the pressure of distribution in the system by connecting the ends of the laterals together in the subunit. For further improvement, a carrier (close pipe convey the water) near the source to the lateral ends has been added to the looped network to represent the second proposed system (looped with carrier network).

Rekha *et al*. (2005) conducted a field study on a sandy loam soil at Rajendranagar, Hyderabad to investigate the influence of trickle fertigation on yield and resource use efficiency of bhendi during the summer seasons of 2003 and 2004. The experiment consisted of 12 treatments: three drip irrigation (0.5, 0.75 and 1.0 Epan) + three fertigation rates (60, 90 and 120 N kg ha-1), furrow irrigation + 120 kg N ha-1, family drip system + 120 kg N ha-1 and a control (drip at 1.0 Epan + 0 kg N ha-1) and was laid out in a randomized block design with three replications. Results show that yield and water use efficiency differed significantly among the treatments. Consistently high yields (4188 and 4153 kg ha-1 in 2003 and 2004 respectively) and water use efficiency (8.23 and 8.10 kg ha-1 mm-1) were noted when the crop was drip irrigated at 1.0 Epan and fertigated with 120 kg N ha^{-1}. Higher agronomic use efficiency and agronomic use efficiency for the extra nitrogen applied were, however, observed for fertigation at 60 kg N ha-1. Furrow irrigated crop showed 54% and 57% lower yield than drip irrigated at 1.0 Epan and fertigated with 120 kg N ha-1 during 2003 and 2004 respectively.

Sahu and Rao (2005) prepared irrigation schedule using ET values and Soil Characteristic data. The hydraulic performance of the system was evaluated by measuring discharge variation among the different emitters, estimating friction head losses in different components. The correlation was developed between average discharge of emitters and pressure head. The coefficient of uniformity (CU) and emission uniformity coefficient (EU) were also estimated. The CU was found to be excellent (>95 percent) and EU was also found to be reasonably good (>90 percent).

Elmaloglou and Diamantopoulos (2007) carried out a wetting front advance patterns and water losses by deep percolation under the root zone as influenced by pulsed drip irrigation. The influence of the before mentioned factors on the wetting front advance and on the water losses by deep percolation under the root zone was studied for surface trickle irrigation. For this purpose a cylindrical flow model incorporating evaporation from the soil surface and water extraction by roots was used. The results show that, for both types of soils used in this study and for the two discharge rates, the vertical component of the wetting front was greater for the pulse than for the continuous irrigation for a time equal to irrigation duration. However, this difference was practically eliminated for a longer time.

Kumar and Singh (2007) conducted a study to evaluate the hydraulic performance of drip irrigation system with four emission devices viz dripper, micro-tube, drip-in and drip tape. The different hydraulic measures viz uniformity coefficient, emission uniformity, coefficient of variation and coefficient of manufacturing variation at different spacing and at different operating pressure head were determined by measuring discharge of different emission devices. At a particular spacing, the uniformity coefficient and emission uniformity increased while coefficient of variation decreased as the operating pressure head increased for all emission devices. The coefficient of manufacturing variation was lowest for micro-tubes and highest for drip tape. The suitability/unsuitability of different emission devices was discussed. The micro-tube was not suitable for close spacing. Computer software for hydraulic performance evaluation of drip irrigation system was also developed.

Safi *et al.* (2007) conducted an experiment at the research station of Tabriz University to evaluate discharge variation among emitters and uniformity after 3 years of operation at different pressures, as well as to determine the optimum length for irrigation tapes. Four hydraulic pressures, 50, 90, 150, and 200 kPa, 4 irrigation tapes 34 m long (used tape) installed at a depth of 10 cm, and 5 new irrigation tapes (unused) 34, 50, 80, 100, and 120 m long comprised the experimental treatments. The used tapes were chosen from a subsurface irrigation system that operated for 3 years for onion irrigation. The new tapes (unused) were the same as the used ones and were laid on the soil surface during the experiment. Emitter discharge and pressure were measured every 2 m along both the used and unused tapes at the above mentioned operating pressures, and data were analyzed to compute several uniformity criteria using traditional and ASAE EP458 methods. In both used and unused tapes, emitter performance at 150 kPa was better than at 50, 90, and 200 kPa. The maximum uniformity coefficient (UC) values of the unused and used tapes 34 m long were 96.9% and 91.8%, respectively. Considering the variation in UC with tape length and an engineering approach toward the performance of the system for used tape, the 80-m length was determined as a suitable length for irrigation tape. The result indicated that both traditional and ASAE methods are suitable for the evaluation of subsurface drip irrigation systems. The ASAE method, however, showed slightly lower uniformity in both unused and used tapes (1.6% and 3.65%, respectively).

Bhanu and Mahavishnan **(**2008) reviewed on drip fertigation in vegetable crops with Lady's Finger Emphasis on (*Abelmoschus esculentus* (L.) Moench) and observed that water and fertilizer are the two important inputs for agricultural production and are interrelated their effect on plant growth and yield. Since, water and fertilizer are costly inputs; every effort must be made to enhance water and fertilizer use efficiency by reducing their wastage. In recent years, fertigation – a technique of application of both water and fertilizers via an irrigation system was shown to be very effective in achieving higher water and fertilizer use efficiency. In this method both water and fertilizer are delivered precisely in the crop root zone as per the crop needs and according to crop developmental phase. Increased growth and yield with drip irrigation has been reported in several crops and the increase in yield ranged between 7-112% depending on the crops varieties and method of irrigation compared. The water and fertilizer saving through drip fertigation have been reported to be 40-70 and 30-50 per cent, respectively.

Gaur *et al.* (2008) conducted an experiment to study the flow phenomena under drip irrigation in sandy soil, using 4 lh^{-1} drippers for two hours duration. The average horizontal advance of 11.2, 14.37, 17.25, 18.25 and 21.25 cm was observed at the end of elapsed time of 15, 30, 60, 90 and 120 minute. The vertical water font advance at a distance of 7.5, 15.0, 21.0 cm from emitter after the end of 15, 30, 60, 90 and 120 minute elapsed time by cutting vertical cross section of the soil along with the Y axis up to a depth of 50 cm. Based on the results obtained it may be concluded that a 4 l h^{-1} dripper may be used in the crops of 45×45 cm^2 crop geometry having water requirement less than 8 lit/day/plant.

Hezarjaribi *et al.* (2008) conducted an experiment by collecting discharge rates at 4 different pressure levels of 50, 100, 150 and 200 kPa to assess the hydraulic performances of various kinds of emitters (including Mono-tandem, Hydrogol, In line-168, Matic, Katif 4 and Katif 8), calculate the coefficient of manufacturing variation, emitter discharge coefficient and emitter discharge exponent, in order to establish the emitter´s flow rate sensitivity to pressure and comparing the results to the manufactures´ specifications. Results indicated that design should be based on reliable test data, not on manufacturer´s supplied data. Mono-tandem, In-line 168 and Hydrogol, were classified as NPC and Matic, Katif 4 and Katif were classified as PC as expected. Except Matic, discharge of emitter was uniformly distributed at all operating pressure.

Chavan *et al.* (2009) conducted a field experiment to evaluate the performance of manually operated drip irrigation system for different types of emitters. For the experiment three different types of emitter's *viz*. 2 l h^{-1}, 4 l h^{-1} and 8 l h^{-1} were fitted on three laterals each of 10 m length. The emitters and lateral spacing was 1 m. The system was operated at varying pressures between 0.4 to 1.4 kg cm^{-2} with an increment of 0.2 kg cm^{-2}. The emitter flow rate was measured in the catch cans. The field and absolute emission uniformity was above 90 %. The system performed better in the range of 0.6 to 1.0 kg cm^{-2} with highest emission uniformity. The overall quality of emitters was better for high nominal discharge rates. These hydraulic parameters of emitters evaluated can be used for the design, operation and selection of the irrigation system. The manually operated system thus can be used for small farms.

Singh *et al.* (2009) mentioned Soil moisture sensor as an instrument for making rapid measurements of the soil moisture content in the root zone. Soil moisture sensors were used for understanding of soil water dynamics, evaluation of agriculture water stress, and validation of soil moisture modeling. Studies have shown that electrical resistance measurements may be used to infer soil moisture content under special circumstances. To establish the efficacy in field, six soil moisture sensors were compared for their performance in producing soil moisture data in an irrigated hybrid mango and guava plantation in Vertisols. The sensors used were: MP406, TDR, Moisture Point, Neutron Probe, Tensiometer, and Watermark. All sensors showed correlations (r2 > 0.7) to the neutron probe except the Moisture Point sensor. The MP 406 and TDR estimates of soil water were equal and sometime slightly lower than the neutron probe. The Moisture Point estimates of soil water were substantially lower than the neutron probe, MP406, and TDR. It was found that MP406 and TDR give better response as compared to the other sensors in Vertisols.

Kumar *et al*. (2011) studied the Evaluation of Evapo-transpiration Models for Pea (*Pisum Sativum)* in Mid Hill Zone-India. Efficient irrigation water management requires a good quantification of evapo-transpiration. Lysimeter was used to measure actual crop water use and local weather data were used to determine the reference evapo-transpiration (ET_0). The K_c values determined over the growing seasons varied from 0.5 to 1.15 for pea. The development of regionally based and growth-stage-specific K_c helps in irrigation management and provides precise water applications for this region. Six climatological models were selected for estimating reference crop evapo-transpiration on a daily basis. Some of these methods are based on combination theory and others are empirical methods based primarily on solar radiation, temperature and relative humidity. According to results the crop coefficient vary among locations and even among years, depending on soil evaporation (rainfall, irrigation), vapour pressure deficit, solar radiation and reference evapo-transpiration (ET_0).

Odofin *et al*. (2011) determined crop evapotranspiration (ET_c) and crop coefficients (Kc) for irrigated bush okra (*Corchorus olitorius*) at Minna in a tropical sub-humid area of Nigeria between February and April of 2008 and 2009 replications. The soil moisture depletion method was used to determine ETc while potential evapotranspiration (PET) was calculated on a daily basis using Blaney-Morin-Nigeria (BMN) evapotranspiration model developed for Nigerian environmental conditions. Across varieties and cropping periods, average weekly ETc ranged from 2.0 to 6.8 mm/day while seasonal ETc ranged from 326 to 374 mm/day, with *Amugbadu* having significantly higher seasonal ETc (P-0.01) in each cropping period, presumably because of its spreading growth habit. Weekly Kc values rose from a minimum of 0.38 at the initial stage of crop growth to a peak value of 1.05 at the mid-season stage and dropped to 0.40 at the end of the late season stage.

Popale *et al*. (2011) evaluated the hydraulic performance of drip irrigation system with two emission devices *viz.*, online dripper (8 lph) and drip-in dripper (1.3lph) for varying pressure *viz.*, 0.75, 1 and 1.25 kg/cm^2. Experimental set up was installed for determination of uniformity coefficient, emission uniformity and coefficient of variation. The result revealed that different hydraulic measures such as uniformity coefficient, emission uniformity and coefficient of variation at different operating pressure for online drip irrigation at 0.75 kg/cm^2 was 97.05%, 95.75% and 2.94%, respectively, similarly for the operating pressure 1.00 kg/cm^2 it was 97.99%, 97.08% and 2.00% and for 1.25 kg/cm^2 it was 98.15%, 98.33% and 1.84% also for inline drip irrigation uniformity coefficient, emission uniformity and coefficient of variation for operating pressure 0.75 kg/cm2 was 97.25%, 98.72% and 2.74% and for pressure 1.00 kg/cm^2 it was 97.30%, 99.44% and

2.69%, respectively, and at kg/cm^2 it was 98.92%, 99.53% and 1.07 %, respectively. The above result shows that the uniformity coefficient and emission uniformity increased while coefficient of variation decreased as operating pressure increased for all emission devices.

Vivek *et al.* (2011) carried out the effect of different drip irrigation levels on growth and yield of bitter gourd in semiarid conditions of Raichur during *Rabi/*summer 2009-10. The different drip irrigation levels included T1 - 60 % ET, T2 - 80% ET, T3 – 100% ET, T4 - 120% ET and T5 - furrow irrigation (control). The data revealed that 100 per cent ET level with drip irrigation produced superior values for plant height, number of branches, days taken for initiation of male and female flowers, number of fruits per plant, average fruit weight, fruit length, fruit girth and yield per hectare. The yield and yield parameters on either side of 100 percent ET level and with furrow irrigation showed a decreasing pattern.

Ghobari and Marazky (2012) evaluated the wetting patterns around drip and subsurface irrigation systems (DI and SDI) respectively with three irrigation scheduling techniques. The drip and subsurface irrigation systems were used to irrigate a tomato crop. The wetting patterns for each irrigation system and each scheduling technique was evaluated below the soil surface at different distances and depths from the emitter 24 and 48 hr. after irrigation. The soil moisture distribution patterns showed that the vertical movement of soil moisture was higher than the horizontal movement under both DI and SI systems.

Mazahrih *et al.* (2012) determined the date palm actual evapo-transpiration (ET_c) and crop coefficient of Medjool cultivar (*Phoenix dactylifera*) under different water regimes (50, 75, 100 and 125% of ET_c) at the Central Jordan Valley during 2011 growing season using Randomized Complete Block Design (RCBD). Twelve years age old date trees with eight meter spacing between trees and rows were used. The experimental plot size contained 12 trees using full automated drip irrigation supplied with fertigation system. Water balance budget method using Neutron Probe technique was used to determine ET_c. The required climatic data for estimation of reference crop potential evapo-transpiration using Penman-Montieth method were collected from a nearby climatic station. The seasonal amounts of applied irrigation water per date palm tree were 27, 40, 53 and 67 m^3 for the irrigation treatments 50, 75, 100 and 125% ET_c respectively, while the precipitation during the growing season was 245 mm. The annual measured date palm tree ET_c values were 1327, 1639, 1828 and 1987 mm, for the studied irrigation treatments, respectively, while the estimated potential evapo-transpiration was 1920 mm with K_c ranged between 0.5 to 1.18 during the growing season. The Medjool crop yield were 33.46, 35.98, 37.8 and 42.49 kg per tree with water productivity of 1.25, 0.90, 0.71 and 0.64 kg m^3, for the 50, 75, 100 and 125% of ET_c, respectively, also the date palms yield and growth parameters were significantly affected by irrigation treatments and second degree polynomial relationship between the water applied and crop production was obtained also. The application of 50 and 75% of ET_c was significantly increased the soil salinity by 1.5 to 3.7 units at the end of the growing season, while no significant effect when applying 100 and 125% of ET_c.

Owusu-Sekyere *et al.* (2012) studied to determine the crop coefficient, water requirement and the effect of deficit irrigation on the development and yield of tomato under a rain shelter. Completely Randomized Design (CRD) was used with three replications. There were four (4) different water treatments, namely: 100% of water requirement (T_1), 90% of water requirement (T_2), 80% water requirement (T_3) and 70% water requirement (T_4). The seasonal water requirement of tomato was found to be 302.98 mm, while the Kc was also between 0.62-1.61. Generally, the parameters studied were in the order $T_1= T_2> T_3> T_4$. The utilization of NPK from the start to the end of the experiment was in the order: for Nitrogenwas$T_1> T_2> T_3> T_4$ and Phosphorus and Potassium were similar in the order $T_1> T_2> T_3= T_4$. This suggested that 10-15% reduction of ETc of tomato will have no significant difference in growth and development while reduction of above 20% will have a negative effect on growth of tomato.

Snyder *et al.* (2012) developed a weather generator application program “SIMETAW” to simulate weather data from climatic records and to estimate reference evapo-transpiration (ET_0) and crop evapo-transpiration (ET_c) with the generated simulation data or with observed data at University of California, Davis and the California Department of Water Resources have. A database of default soil depth and water holding characteristics, effective crop rooting depths, and crop coefficient (K_c) values to convert ET_0 to ET_c are input into the program. After calculating daily $ET_{c,}$ the input and derived data are used to determine effective rainfall and to generate hypothetical irrigation schedules to estimate the seasonal and annual evapo-transpiration of applied water (ET_{aw}), where ET_{aw}wasthe net amount of irrigation water needed to produce a crop.

Soomro *et al.* (2012) evaluated the performance of drip irrigation and discharge of emitters at Coastal area of Gadap Sindh at Coastal Agricultural Research Station of PARC, Karachi. In order to see the effects of marginal quality ground water in comparison to good quality water (tap water) on crop yield and water use efficiency. Okra was grown under drip system of irrigation during the year, 2011. Before crop sowing, drip irrigation system was installed to assess for its performance through Uniformity Co-efficient which ranged from 93 to 96% and indicated that the system was working satisfactorily. The quantity of tap and ground water applied through drip system to okra crop was of equal volume i.e., 6989.7 m^3/ha. However, higher crop yield and higher water use efficiency i.e., 18.93 t/ha and 2.7 kg/m^3 were recorded under T1 over T2 (yield 17.0 t/ha and water use efficiency 2.4 kg/m^3) respectively. The increase of yield and WUE in T1 over T2 was about 10% in each case. Thus, it was inferred that okra crop can be grown successfully on sandy loam using saline (Marginal quality) ground water for irrigation.

Kyada and Munjapara (2013) conducted an experiment to determine the pressure discharge relationships and wetting front movement for various emitter rating and durations. The pressure of 0.25, 0.5, 0.75, 1.0, and 1.25 kg cm^{-1} was set turn wise and the volume of water dripped out from the different drippers was collected separately from each of five drippers for one hr. and the discharge rates were calculated separately for all set pressures. The various forms of the mathematical models were fitted to these data of pressure-discharge and the best fitted model was proposed for the pressure discharge relationships for all the emitter ratings. The horizontal and vertical movements of the wetted bulb were found increased with time and also with emitting rates.

Mohammed *et al*. (2013) evaluated the Hydraulic Performance of Drip Irrigation System with Multi Cases. The research studies the improvement of emission uniformity of emitters by using new system layouts instead of the traditional system. The first proposed system layout concluded to improve the hydraulic performance by improving the pressure of distribution in the system by connecting the ends of the laterals together in the subunit. For further improvement, a carrier (close pipe convey the water) near the source to the lateral ends has been added to the looped network to represent the second proposed system (looped with carrier network).

Sharma (2013) carried out hydraulic performance of drip emitters under field condition. The study revealed that for better discharge of on-line emitters of 2, 4 and 8 lh^{-1} capacity, optimal pressure of 40, 70 and 100 kPa was required respectively to achieve uniformity coefficient of more than 90%. In 2, 4 and 8 l h^{-1} capacity emitters, emission uniformity was 86.73, 84.37 and 91.6 per cent respectively. Manufacturing coefficient of variation for different emitters having 2, 4 and 8 l h^{-1} capacity was 0.165, 0.171 and 0.101 respectively. For inline emitter of 1.3 l h^{-1} capacity, optimal pressure 100 kPa was required to achieve uniformity coefficient of 85% and emission uniformity of 85.81 per cent respectively. Manufacturing coefficient of variation for the 1.3 l h^{-1} capacity emitter was 0.128.

Kenjabaev *et al.* (2014) conducted a research to determine daily and growth-stage-specific K_c and ET_c values for cotton (Gossypium hirsutum L.), winter wheat (Triticum aestivum L.) and maize (Zea mays L.) for silage at fields in Fergana Valley (Uzbekistan). The soil water balance model - Budget with integration of the dual crop procedure of the FAO-56 was used to estimate the ET_c and separate it into evaporation (E_c) and transpiration (T_c) components. An empirical equation was developed to determine the daily K_c values based on the estimated E_c and T_c. The ET_c, K_c determination and comparison to existing FAO K_c values were performed based on 10, 5 and 6 study cases for cotton, wheat and maize, respectively. Mean seasonal amounts of crop water consumption in terms of ET_c were 560-50, 509-27 and 243-39 mm for cotton, wheat and maize, respectively. The growth-stage-specific K_c for cotton, wheat and maize was 0.15, 0.27 and 0.11 at initial; 1.15, 1.03 and 0.56 at mid and 0.45, 0.89 and 0.53 at late season stages. These values correspond to those reported by the FAO-56.

Siddapur *et al.* (2014) carried out an experiment to study the effect of surface irrigation and drip irrigation methods on Marigold flower from October 2012 to March 2013 at New Orchard of Main Agricultural Research Station, University of Agricultural Science, Raichur. The objective was to work out the different levels irrigation of marigold and to compare the performance of growth parameter, yield, quality parameters, irrigation efficiencies and economics of drip and furrow irrigation (60, 80, 100 and 120% ET). The water saved in drip irrigation over furrow irrigation was found to be 74.92%, 68.07%, 61.45% and 54.65% for 60%, 80%, 100% and 120% ET respectively. The response of Marigold to different drip irrigation levels in terms plant height, number of flower per plant, number of branches and were significantly superior in respect of 80 per cent followed by 100 per cent ET level. Marigold under different irrigation treatments except 60 per cent ET level performed very well in terms of average ten flower weight and diameter of flower. The highest yield of marigold flower 19.63 t ha-1was obtained in 80 per cent ET level which was closely followed by 100 per cent ET level (17.03 t ha^{-1}). The application and distribution efficiencies were found to be higher with drip irrigation treatments as compared to furrow irrigation. All the drip irrigation treatments recorded higher benefit: cost ratio (4.88 to 2.30). The furrow irrigation produced a benefit cost ratio of 1.73. The general trend considering the different parameters tested suggests that 80 per cent ET level can be used to achieve higher yield of Marigold in sandy loam soils, under Raichur (semi-arid conditions).

Sharma *et al.* (2016) Limited water supplies in arid regions put constraints on agriculture. In arid New Mexico, greenhouse chile pepper production has the potential for water and nutrient savings. Three water treatments were (1) control where water was applied near the surface using two drip emitters, (2) partial root zone drying vertical (PRDv) where subsurface irrigation was applied at 20 cm depth from soil surface, and (3) partial root zone drying compartment (PRDc) where roots were divided into two compartments and irrigation were switched between compartments after 15 days. Sensor-generated volumetric water contents were correlated with the gravimetrically determined, and the new calibration coefficients improved the precision of estimates. From 2011 onward, irrigation amounts were adjusted to minimize deep percolation, and about 30% less water was applied in 2014 as compared to the 2011 growing season but no significant differences were observed in transpiration rate and leaf temperature. The ratio of intercellular to ambient CO_2 concentrations (Ci/Ca) was significantly correlated to transpiration rate and vapour pressure deficit in 2014 ($P < 0.05$). ET_a obtained from water balance and reference ET (ET_r) from Penman-Monteith developed the Kc for drip-irrigated greenhouse chile peppers for three growing seasons. The maximum values of Kc were about 1.4 during 2013 and 1.2 during 2014. The 2011 growing season was shorter and the maximum Kc was closer to one. Crop coefficients for greenhouse grown chile peppers varied with growing seasons and irrigation treatment. Irrigation scheduling can be done based on the soil moisture or Kc for the known growing season. This study demonstrated the water saving potential of PRD.

Manisha *et al.* (2015) conducted a field experiment to analyse the hydraulic performance drip irrigation system on emitter discharge, coefficient of variation and emission uniformity. The objective of this study was to assess the hydraulic performance of drip irrigation system. A parameter which can be used for emitter flow variation caused by variation in manufacturing of the emitter was called the coefficient of manufacturing variation (C_v). The extent to which manufacturer was able to control variations depends not only upon manufacturing and materials quality control but also on emitter design. Emission uniformity of the system decides the uniformity distribution of discharge by each emitter or uniformity distribution of water to each crop. Result shows that the discharge flow rate of emitter was increased with increase in pressure and the coefficient of variation was increased when the pressure was decreased, thus the pressure directly affected the discharge rate of emitter. The average emission uniformity coefficient observed at

1.5, 1.2, 0.9 and 0.7 kg cm^{-2} pressure was 95.04, 95.95, 94.44 and 87.63 percent respectively for 4 l h^{-1}. It was clear that highest emission uniformity was obtained at 1.2 kg cm^{-2} operating pressure.

Shashi kant (2016) conducted an experiment in levelled field to evaluate the hydraulic parameters of drip irrigation system on emitter discharge, coefficient of variation and emission uniformity for 1.3 l h^{-1} inline emitters at 0.7, 0.9, 1.2 and 1.5 kg cm^{-2} pressures. The discharge rate increased as the pressure increases from 0.7 to 1.5 kg cm^{-2}. At minimum pressure of 0.7 kg cm^{-2}, the discharge obtained from 1.3 l h^{-1} drippers was found to be 0.8 l h^{-1} respectively. When pressure increased from 0.7 to 0.9 kg cm^{-2}, the discharge rate came up to 1.0 l h^{-1} respectively. When pressure increased from 0.9 to 1.2 kg cm^{-2} the discharge rate came up to 1.18 l h^{-1}, respectively. When pressure increased from 1.2 to 1.5 kg cm^{-2}, the discharge rate came up to 1.29 l h^{-1}. The coefficient of variation 0.1 was found maximum at 0.7 kg cm^{-2} operating pressure and minimum 0.03 at 1.5 $kgcm^{-2}$ operating pressure. Thus for a particular spacing, coefficient of variation decreases as the operating pressure was increased for all emission devices. Emission uniformity of the system decides the uniformity distribution of discharge by each emitter or uniformity distribution of water to each crop. The calculated emission uniformity data at different pressures 0.7 kg cm^{-2}, 0.9 kg cm^{-2}, 1.2 kg cm^{-2} and 1.5 kg cm^{-2}, respectively. The maximum average emission uniformity 95.75% was observed at operating pressure1.5 $kgcm^{-2}$ followed by 1.2 kg cm^{-2} (94.25%), 0.9 kg cm^{-2} (92.37%) and 0.7 kg cm^{-2} (86.02%), respectively. Thus for a particular spacing emission uniformity increases as the operating pressure increases for all emission devices.

2.3 Soil Moisture Sensor Based irrigation System.

Jackson (1982) reported that the ideal irrigation scheduling technique should use the plant as the indicator of the plant stress, since the plant response both the aerial and soil environments. The use of canopy temperature to detect water stress was based on the principle that water lost through transpiration cools the leaves below the temperature of the surrounding air under well-watered conditions.

Stafford (1988) conducted an experiment and reported two types of sensing systems that could be used to estimate soil water content: contact and non-contact. A non-contact sensor did not disturb the soil so that it could be used where root systems had been established and ideally it should have provided the information on the soil moisture profile. In contrast, a contact sensor physically disturbed the soil as the sensing element moved and hence was suitable for use in cultivated soil. Attempts to produce sensors of soil water content had mainly exploited the electromagnetic spectrum, although there are notable exceptions such as electrical resistance measurements.

Noble *et al.* (2000) evaluated different sensors for monitoring the soil moisture content based on electrical resistance variation with moisture content. The sensor with sand as porous medium was found to be the most efficient one for the study area. A low cost, commercially available button type thermistor was used as the leaf and air temperature sensors. The amount of water applied per day, leaf-air temperature and soil moisture content were monitored during the study period. The systems maintained the designed soil moisture content and air-leaf temperature differential through-out the study period.

Dukes (2003) conducted an experiment on automatic soil moisture based drip irrigation for tomato production. Automated irrigation system based on soil moisture sensors (tensiometers at 15 bar) performed best for tomato yield. Significant reduction in deep percolation and application of low volume high frequency saves water by automatically control with soil moisture sensors.

Singh *et al.* (2009) investigated simulation of soil wetting pattern with subsurface drip irrigation from line source. Experimentation included determination of maximum depths and widths of wetted zone after 0.5, 1, 2, 3, 5 and 7 h of water application under laterals, porous pipes, and drip tape placed at 0.05, 0.10 and 0.15 m depths below soil surface. Statistical analysis revealed that there was no significant difference between predicted and observed values of wetted width and depth. The effect of discharge, depths of placement of lateral and duration of water application on wetted width and depth were similar for predicted and observed values. Predictability of model was expressed in terms of model efficiency, which was estimated at 96.4 and 98.4%, respectively, for prediction of wetted width and depth. This shows that developed model can be used to simulate wetting pattern under SDI system with line source of water application.

Osroosh *et al.* (2013) Seven irrigation scheduling algorithms and an automatic control system along with a wireless network of soil, thermal and weather sensors were developed and assessed in Prosser, WA in the growing season of 2013. The system was comprised of six wireless sensor and valve actuating nodes installed across an apple orchard, a central base station made up of a transceiver connected to a laptop, and a graphical user interface (GUI). The irrigation algorithms/treatments included the time-temperature threshold (TTT), crop water stress index with dynamic threshold (CWSI), soil-based using granular matrix sensors (SOIL), weather-based using a temperature-only-based evapotranspiration (ET) model and soil water balance (WB), a combination of SOIL and WB (SL +WB), a conventional irrigation practice used in the region (CNTRL), and soil-based using a neutron probe (NP) as benchmark. Different treatments were compared based on the total irrigation water (It) applied during the season. They were also compared based on simplicity and expense for a grower to implement. Soil water content (θ_s) and stem water potential (ψ_{stem}) were monitored in a number of treatment plots. The total applied water for CNTRL was significantly higher than all other treatments ($p < 0.001$). The thermal-based TTT and CWSI treatments applied the same amount of water as NP and WB ($p < 0.001$). CWSI and TTT substantially reduced water applied (70%) while maintaining ψ_{stem} within the non-stressed range. In addition, hs in the treatment plots of TTT and CWSI did not exceed the maximum allowed deficit recommended for apple trees (MAD of 50%) showing a strong agreement with NP. The SOIL and SL +WB treatments resulted in tangible under-irrigation as leaf drop, decreased leaf turgidity, growth reduction and abnormally small fruits were seen. Among all the strategies, WB seemed to bear the characteristics of being economical, easy to implement and fairly accurate. Our preliminary results also support the use of wireless sensor network for automatic irrigation management of drip-irrigated apple trees.

Stefanos *et al.* (2013) Many agricultural activities can be highly enhanced by using digital technologies. One of these activities was the regulation of the quantity of water in cultivated fields, a process which was directly interwoven with the sustainability and the productivity of crops, since insufficient or excessive irrigation may not only be obstructive, but also destructive. This paper proposes a scheme based on the collaboration of an integrated system for automated irrigation management with an advanced novel routing protocol for Wireless Sensor Networks (WSNs), named ECHERP (Equalized Cluster Head Election Routing Protocol). At its core, the proposed system aims at efficiently managing water supply in cultivated fields in an automated way. The system takes into consideration the historical data and the change on the climate values to calculate the quantity of water that was needed for irrigation. In case that the change on the collected values was above a threshold more frequent data collection was proposed to minimize the necessary quantity of water. On the other hand, in case that the change of the values was below a present threshold then the time interval to collect data can increase to save sensor energy, leading to a prolonged sensor lifetime. The results show that network lifetime using ECHERP was improved up to 1825 min and if a roundwas110s the model provides energy efficiency using smaller water quantities.

Kumar *et al.* (2015) was studied soil moisture sensor based irrigation scheduling was relatively a new concept in India. A soil moisture sensor based wireless irrigation system was designed, developed and tested during the years 2013-15 in vegetable crops, i. e. okra**,** tomato, brinjal, broccoli, potato, and knol-khol on the research farm of the Precision Farming Development Centre, Water Technology Centre, Indian Agricultural Research Institute, New Delhi, India. A network of sensors was integrated with a wireless system having modified tensiometer, level sensor, controller, GSM receiver, transmitter, solenoid valve, water meter, and pump for automated irrigation scheduling. The sensor network, global system for mobile communication (GSM) and short message service (SMS) carried the data from the sensors to the user through a mobile set. This system allows the user to effectively monitor and control water application in the field via sensors and/or through a mobile phone set by sending a command in the form of message and obtaining the moisture status in the field.

Pandiyaraju *et al.* (2015) was studied Wireless Sensor Networks (WSNs) are widely used in agriculture applications, industrial automations, smart home applications, battlefield surveillances, landslides detection, forest fire detection systems, etc. Agriculture was the backbone for any country as its stability and economy are totally depend on agriculture. Most of the cultivation lands in our world are located in remote places, which are far away from the residential area, where frequent land observation was not possible. In conventional agriculture, farmers should physically visit their sites to observe the soil moisture, humidity, fertilizer contents to ensure the proper irrigation and crop management. This requires lot of human resources, time and money. In this paper, a novel Field Sensor Unit (FSU) and a Flying Agriculture Vehicle (FAV) are proposed to collect the agricultural field data like soil moisture, temperature, fertilizer contents from the field without manual intervention. The proposed FAV system significantly reduces the manual intervention, cost and field observation time.

Dhanekula *et al.* (2016) was studied an automatic irrigation system to provide water to the farms based on soil and temperature conditions. It can also control irrigation system through the web application and GSM by using Raspberry pi 2 and 8051 microcontroller. Number of sensor nodes will be placed on farm according to the area of the farm. Each sensor node contains temperature sensor, moisture sensor, water level sensor and motor. 8051 microcontroller makes the communication with all sensors placed in the farm and it can collect the parameters like moisture, temperature and water level. Raspberry pi 2 was used to control the web application and GSM modem. Raspberry pi 2 takes data from 8051 microcontroller continuously using a wireless communication device. In this paper Zig-Bee transceiver was used as a wireless device for transmitting and receiving data from both devices. A threshold value was given for each sensor, if any sensor crosses its threshold value a message will be send to the user and display in web applications. This system uses Raspberry pi 2 for achieving high speed of operation. In real time farms which are remote areas, this system uses 8051 controller for collecting data from sensors and transfer it to Raspberry pi 2 using wireless sensor device. This system controls the motor automatically when soil or temperature crosses its threshold and manually whenever user wants. This irrigation system works efficiently and speeds. This system sends message to the users whenever sensors exceed its threshold value. This system offers every user to understand the soil conditions and amenable manually.

Kumar *et al.* (2016) concluded that to manage the water resources efficiently, the focus has to be shifted towards agriculture because according to the Indian Agricultural Research Institute (IARI), Indian farm sector alone consumes 83% of all water use. The project aims to solve the water wastage problem in the country by using an automated irrigation system with the aid of a wireless sensor network. Wireless sensor network can be utilized to remotely monitor the parameters such as temperature, humidity, soil moisture, pH and productivity of plant growth on the greenhouse environment by matching the sensor devices with the wireless technologies. In existing system, automatic plant irrigation systems are based upon soil conditions, temperature conditions and humidity conditions. This project provides the practical solution for real time agriculture management system using wireless data flow control, remote monitoring along with automatic fertilizer and water irrigation for each node assigned and the data can be acquired using Lab-VIEW with respect to the user provided set values, equivalent control commands was transmitted form remote area unit to control area. After the control action the node unit keeps on monitoring the chamber the status was updated with the help of Lab-VIEW.

Kumar *et al.* (2016) developed an automation to supply water for home gardening and irrigation system in farm fields. It was done with the help of soil moisture sensor and temperature sensor which are fixed at root area of the plants. The values detected by these sensors are transmitted to base station. The key aim of base station was to collect data from field station and upload those values in internet by using Wi-Fi technology also notify user about any peculiar circumstances like low moisture and high temperature. This irrigation system has been approved under different climates with various levels of moisture contents especially the red chilly weeds.

Rajagopal *et al.* (2016) found that Wireless sensor Networks (WSNs) are widely utilized in motoring and collecting interests of environment information. Besides the challenging environmental conditions, India needs efficient and cost effective Wireless sensor and actuator Network (WSAN) to assist the farmers and improve the crop production. This paper surveyed varied international automated irrigation approach and compared it with the Indian scenarios to adopt the most effective irrigation technique. Existing approaches requires an efficient decision support system that can work well with Indian conditions.

Rani *et al*. (2016) found that the Automated irrigation and plant growth monitoring system was efficiently used to optimize the use of water resource for agriculture. The system consists of the distributed wireless sensor network of soil, moisture, temperature, colour sensors. Moisture and temperature sensors are placed in the root zone of the crops. The controller unit was used to control the irrigation motor thereby controlling the water flow to the field. The microcontroller of the controller unit was programmed with threshold values of the temperature and moisture content. Color sensor was placed height of the plant leaf, according to the leaf colour pesticides are automatically irrigated to the plants. High performance microcontroller PIC was used in the controller node. The Sensor nodes are power by the 9V battery which can be recharged with solar cell. GSM module used to send the information about the field. Due to the least cost and high performance, the system can be used even in areas of limited water supply and plant growth monitoring.

Reddy *et al.* (2016) carried out the study of an automatic irrigation system to provide water to the farms based on soil and temperature conditions using an android application, WSN and GPRS modules. Methods/statistical Analysis: An algorithm developed such that soil moisture sensor and temperature sensor values are continuously fed to Arduino UNO micro controller. The sensor information compared with the threshold values and based on that, decision will be taken to water the crops. The system equipped with the photovoltaic panels and dual communication established based on cellular internet interface for continuous inquiry of data by the user. We have also developed an android mobile application for intercepting the data generated. For that purpose, we can also employ a web site. Findings: Because of system's energy sovereignty, low cost and relatively more amounts of underground water saving, this system preferable at water scarcity locations like desert areas. Conclusion: This irrigation system has been working with high efficiency and top speed. This system sends message to the user whenever sensors exceed there threshold value, by this system every user can understand the soil conditions and controls the system too manually, if needed.

Sivamani *et al.* (2017) found that localization of Wireless Sensor Networks (WSN) becomes an elementary issue due to various inquisitive factors. Localization usually can be done by Fine-grained and Coarse grained localization algorithms. For Sensor network energy efficiency, scalability and robustness also the important factors during localization. In order to maintain the performance of the Network with the reduced number of Sensor Devices (SD) than in existing method, here we propose four Coarse grained algorithms. MATLAB® software gives detailed analysis and better solutions for the issues while clustering. In these algorithms the nodes are deployed in a random manner and then the clustering carried out. The Cluster Head (CH) formed by checking for the better stability performance of each node. With the help of CH, all the other nearby nodes will establish a reliable communication with the centralised sink. With the help of clustering process the dead nodes can also be found. The energy variations and dead nodes will be stored by the sink if necessary.

2.4 Critiques of Review

Indian agriculture is dependent on the monsoons which are not a reliable source of water, so judicious and timely utilization of available water and maximum utilization of soil moisture by minimizing water losses is the key to sustainable production and productivity. Drip is the widely adopted and one of the best water conserving technology available and use of automated drip system could be a blessing to the farmers for getting high yield from limited availability of irrigation water. The soil moisture based drip irrigation system is the need of the country to provide water to the farms according to their moisture and soil types. The objective of this research is to set up a low cost soil moisture sensor based automated drip irrigation system. Gravity with drip irrigation is best suited for irrigation method, and helps of soil moisture sensor will continuously monitor the moisture content and accordingly will function to irrigate the crop to its desired level. The system is continuously run the closed loop system functionally on the basis of moisture content and irrigation water requirement of the crop.

CHAPTER – III
MATERIALS AND METHODS

This chapter deals with a concise description of experimental materials used and the techniques employed during the course of investigation. The present investigation was conducted in summer season of 2018. The description of location of study area, experimental details, observation recorded and methods adopted throughout the course of investigation are presented under following heads:

3.1 Description of Study Area

3.1.1 Experimental site

Field experiment was carried out during the year 2018 in summer season at the experimental plot of Department of Soil and Water Engineering, SVCAET & RS, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) situated in the central part of Chhattisgarh at latitude 21^{O}14“9” N and longitude 81^{O}42“10” E and at an altitude of 302 meters above the mean sea level.

3.2 Agro-Climatic Conditions

Raipur comes under dry, sub-humid agro-climatic region. The source of rainfall is South-West monsoon. It receives an average annual rainfall of 1300-1400 mm, out of which 80-85 % is received from third week of June to mid-September and very little during October to February. May is the hottest and December is the coolest month of the year. The pattern of rainfall, particularly during June to September months has a great variation from year to year. The maximum temperature goes as high as 45 ^{O}C during summer and minimum as below as 6 ^{O}C during winter months. The atmospheric humidity is high from June to October and wind velocity is high from May to August with its peak in June-July months.

3.3 Weather during the Study Period

The weather data recorded during the period of investigation is given in Table 3.1. The maximum temperature during the experiment varied between 30.6 ^{o}C to 45.5 ^{o}C from 5 February 2018 to 10 May 2018 whereas, minimum temperature varied between 13.6 ^{o}C to 31 ^{o}C. The maximum rainfall during the period of experiment was 10 mm. The average maximum relative humidity for different months varied from 11 to 91 % while monthly average minimum relative humidity varied between 5 to 55 %. The average values of open pan evaporation ranged from 2.3 to 4.6 mm, whereas average sunshine values varied from 3.5 to 11.2 hours, maximum wind velocity during crop period was 9.8 km h^{-1} and minimum was recorded 1.2 km h^{-1}**.**

3.4 Treatment Details

3.4.1 Experiment field details

The experiment was laid out in the experimental plot of Dept. of soil and water engineering, SVCAET & RS, FAE, IGKV, Raipur, (C.G.). The layout of the experiment was shown in fig. 3.1. The experiment was conducted in the summer season of 2018. Two treatments Conventional Drip Irrigation (Control) and Sensor based Drip Irrigation System (Sensor based treatment) were laid down to evaluate the effect of different irrigation system through yield attributing characters of the crop. The sensor was placed at the depth of 15 cm. The length of wires of probe was taken as 18m, 15m, 12m, 10m and 4m. The gravity fed drip irrigation system was Control by the sensor system. The drip irrigation system consists of an overhead tank of 750 litre connected with the electrical pump controlled by the sensor system. The drip irrigation system consists of drip tubing of 20 m length which was placed at the 50 cm distance and having inline emitters at 30 cm distance. The morphological data were taken at every 5m distance on each lateral. During the treatment, the irrigation level was maintained in each lateral by using lateral valves and water pressure was maintained at 0.25 kg cm^{-2}. The experimental details were shown in table 3.2.

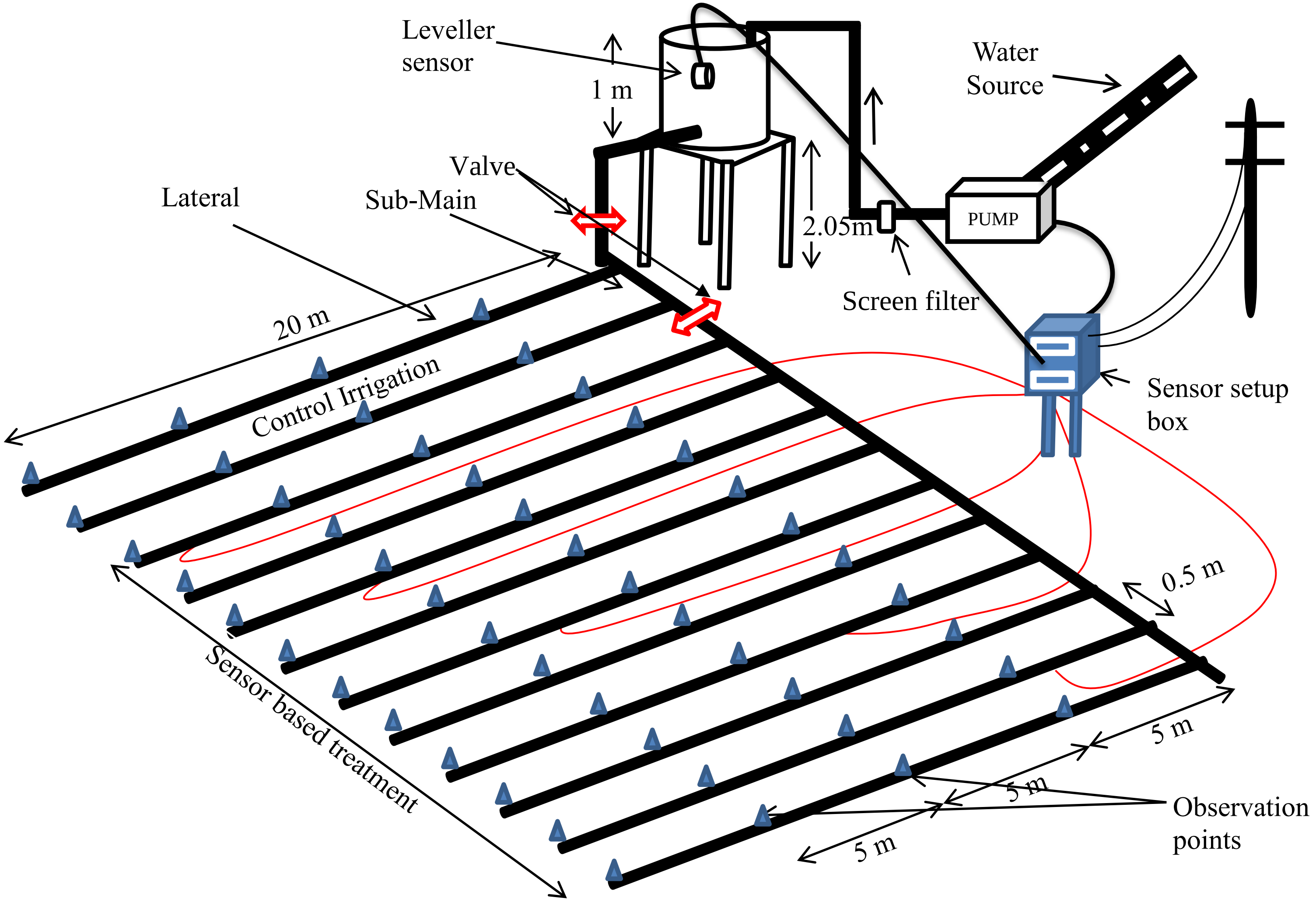

Fig. 3.1 layout of experiment field

3.4.2 Soil Sampling and Analysis

The soil of the experiment site was analysed in the laboratory of Department of Soil Science, IGKV, Raipur. A composite soil sample (aggregate from various parts of the field) was collected from 0-30 cm depth prior to planting during the study and analysed for particle size distribution, field capacity, bulk density, O, C, N, P, K, pH and EC. Details of soil physical and chemical properties of the experiment site are shown in Table 3.3.

Table 3.1 Weather data during the study period

Week	Month	Max. Temp. °C	Min. Temp. °C	RH-I	RH-II	Wind Speed kmph	EP mm	Rainfall mm	Sunshine hours
06	Feb	32.8	14.4	71	35	2.1	3.1	0	5.4
07		32.1	11.8	90	31	3.1	2.9	0	10.4
08		36.4	17	60	19	3.2	5.6	0	9.4
09	March	38.2	17.2	67	20	3.9	5.8	1.20	7.5
10		39.0	18.3	63	13	3.5	6.3	3.40	9.3
11		40.6	17	58	11	2.4	6.4	0	9.0
12		40.5	19	67	21	4.4	8.2	18.0	9.8
13		38	20.6	69	28	6.0	8.0	17	8.0
14	April	42.4	22.2	54	20	3.5	8.2	2	10.3
15		41.5	23.0	50	12.8	3.8	9.6	0	9.4
16		40.9	22.7	64	18	3.7	6.9	0	10.2
17		41.2	23.7	45	19	4.2	9.2	0	9.3
18	May	41.5	24.5	64	25	6.4	9.7	0.27	9.6
19		43.8	26.8	46	23	5.8	10.6	0.4	9.8

Table: 3.2 Experimental Details

Crop		Okra
Scientific name	:	*Abelmoschus esculentus L.*
Variety	:	Samrat
Experiment Gross area	:	120 m^2
Experiment Net area	:	72 m^2
Row to row spacing	:	50 cm
Plant to plant spacing	:	30 cm
Conventional drip irrigation (Control)	:	12 cm^2
Sensor based drip irrigation system	:	60 cm^2
Tank capacity	:	750 l
Tullu pump	:	0.5 hp (0.7lps)
Delivery head	:	4.05m

3.5 Sensor System

3.5.1 Soil moisture sensor

Alfa-mart sensor for 2-in-1 pH and moisture meter with easy to read scale was used in the present study. Using this scientifically calibrate measuring device we can have accurate soil moisture and pH level and can maintained the parameter at the right levels as shown in fig. 3.2. The sensor was found suitable for all types of soil. Simply insert probe of the meter into the soil, switch to the desired setting to measure and read the scale. No battery required, simple and convenient to use.

3.5.2 TDR (Time Domain Reflectrometry)

TDR (Time Domain Reflectrometry) technology delivers very accurate determination of soil moisture content. Data can be read from a handheld unit, logged or sent via a telemetry network to a PC for analysis. TDR technology is equivalently priced to good quality capacitance probes but is very much more accurate especially when used in "difficult" sediments such as heavy clays or those high in organic matter content. The soil moisture content is calculated inside the unit and the collected data can be read from the handheld unit. (As shown in fig 3.2).

Alfa-mart sensor

TDR

Fig. 3.2 Soil moisture sensors

3.5.3 Probe

Soil moisture probe measure the volumetric water content in soil. Soil moisture content is determined via its effect on dielectric constant by measuring the capacitance between two electrodes implanted in the soil (shown in fig 3.3). The dielectric constant is directly proportional to the moisture constant. Moisture content is influenced by soil type and soil temperature, some technical details are shown in Appendix C-2.

3.5.4 Analog input module AI561

The Analog Input Module AI561 was used as a remote expansion module at the following devices:

- S500 Bus Modules
- AC500 CPUs

- 4 configurable analog inputs (I0 to I3) in 1 group the inputs are not electrically isolated from each other.

Some time it is called PLC (Programmable logic controller). Electrical connection of Analog input module AI561 are shown in Appendix A.

Table 3.3 Soil Properties

	Particulars	Values	Method used
A.	Physical properties		
1.	Mechanical composition		
	Sand (%)	19.05	International Pipette method (Black,1995)
	Silt (%)	56.42	
	Clay (%)	44.75	
	Texture class	Clay loam	(Alfisols)
2.	Field capacity	27%	
3.	Permanent wilting point(cm m^{-1})	10.74	Pressure plate apparatus method
4.	Bulk density (g cm^{-3})	1.34	Soil core method
B.	Chemical properties		
1.	Organic carbon (%)	0.29	Walkley and Black's rapid titration method (Jackson, 1967)
2.	Available N (kg ha^{-1})	178.1	Alkaline permagnate method (Subbiah and Asija 1956)
3.	Available P (kg ha^{-1})	10.4	Olsen's method (Olsen's 1954)
4.	Available K (kg ha^{-1})	512.8	Flame photometric method
5.	pH	6.5	Glass electrode pH meter (Piper,1967)
6.	EC (ds/m at 25ºC)	0.08	Solubridge method (Black, 1965)

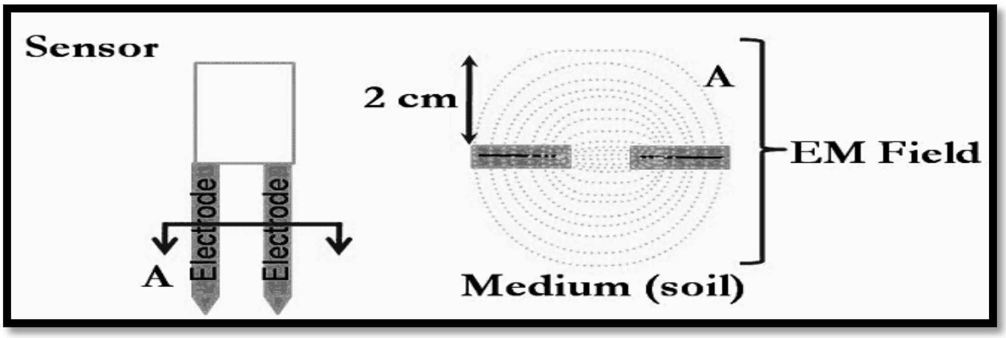

Fig.3.3. Soil moisture probe and its working

3.5.5 Displays

Single display 0.56" RED LED display was used to show output of sensor system. An LED display was a flat panel display, which uses an array of light-emitting diodes as pixels for a video display.

3.5.6 Terminal block

A terminal block is a screw-type electrical connector where the wires are clamped down to the metal part by a screw. It is a connector which allows more than one circuit to connect to another circuit. It often contains two long aluminium or copper strips that are designed to connect different components. These strips create a bus bar for power distribution that is sent to the connected components. A barrier strip is composed of several screw terminals shown in fig 3.4.

There are many applications that use terminal blocks & barrier strips. Screw-type terminals are often used in order to connect a chassis ground, like on a surge protector.

3.5.6.1 Main benefits

- High quality products: benefit from the best connection.
- Simplification and acceleration of flow: reliable expertise in delivery times.
- Perfect connection reliability in response to all connection challenges.

Terminal Box

Motor Starter

MCB

Relay Coil

Fig. 3.4 Component of sensor System

3.5.7 Miniature circuit breakers – MCBs

Miniature circuit breakers protect installations against overload and short-circuit, warranting reliability and safety for operations. System pro *M* compact S 200 series are current limiting overcurrent protective devices. They have two different tripping mechanisms, the delayed thermal tripping mechanism for overload protection and the magnetic tripping mechanism for short circuit protection. (fig.3.4)

3.5.7.1 Main benefits

- Extra-wide and complete range of MCBs to cover most applications and markets

- Certificates, documentation, training or background information to support customers due to their daily work
- Space and time saving and the unique bottom-fixing auxiliary contact
- Up to 6 kA breaking capacity

3.5.8 Motor starter

The MS132-32 manual motor starter. This device was used to manually switch ON and OFF motors and to protect them reliably and without the need for a fuse from short-circuits, overload and phase failures. The manual motor starter offers a rated service short-circuit breaking capacity I_{cs} = 25 kA at 400 VAC and the trip class 10. Further features are the build-in disconnects function, temperature compensation; trip-free mechanism and a rotary handle with a clear switch position indication other features. The manual motor starter is suitable for three- and single-phase applications. The handle is lockable to protect against unauthorized changes. Auxiliary contacts, signalling contacts, under voltage releases, shunt trips, 3-phase bus bars, power in-feed blocks are available as accessory shown in fig 3.4.

3.5.9 Control panels

The CP620 HMI control panels offer a wide range of features and functionalities for maximum operability. ABB Control Panels are distinguished by their robustness and easy usability, providing all the relevant information from production plants and machines at a single touch. The control panel series CP600 provides colour touch screens from 4.3” to 15”. A complete engineering software solution offers a great variety of HMI capabilities. A set of CP600 devices displays the visualization of the ABB PLC´s web server. The attractive, slim design with a built-in depth of 29 mm providing all connectors on one side for compact installation plus a front protection class of IP66 make the new portfolio best choice for versatile industrial applications. Standard landscape installation as well as portrait mounting underlines the flexibility of CP600-eCo for various demands.

3.5.10 Relay

The MG6 relay was used for applications where several independent circuits may be energized or de-energized upon the operation of a single primary relay contact or where the capacity of the primary relay contact is inadequate for the energy required. Numerical relays are based on the use of microprocessors. A big difference between conventional electromechanical and static relays is how the relays are wired. Electromechanical and static relays have fixed wiring and the setting is manual. Numeric relays, on the other hand, are programmable relays where the characteristics and behaviour can be programmed. Most numerical relays are also multifunctional.

3.6 Calibration of Soil Moisture Sensor

Firstly of all 100 gm sample of dry soil was taken and added 20 gm water (amount equal to field capacity) in it. After holding for one hour, the moisture content of the sample was measured with Alfa-mart and TDR-sensor. After that the moisture content was measured by gravimetric method. Sample was put in oven and set the temp. of oven is 105 ^{o}C for 24 h. The measured moisture content was 27% (VMC) which is equal to field capacity of soil.

Our sensor system was calibrated by using CoDeSys software. The probe was inserting on the same prepared sample. That time by using software moisture content was set between 0 to 100% by the scaling on the system. Same process was done with 10 different soil samples and validating the sensor system with the help of these reading.

3.7 Drip Irrigation System

The drip irrigation system design is an integration of the physical components such as emitters, valves, fittings, pipes and control equipment into a system arrangement to be able to meet the crop water requirements. Drip irrigation uses a pressurized network generally at lower operating pressures and rates of application. In the installed system water requirement and design intervals must first be evaluated. The emitters are then selected (according to their discharge, operating pressure, and spacing) and the duration of irrigation and number of applications per day are determined. Following this, the discharge head in the system are planned in accordance with the layout of the field and sequence of irrigation. Appropriate design of drip irrigation system is very essential to obtain proper performance and benefits. Each irrigation system should be designed taking into consideration of agro climatic factors, crop physiology, soil characteristics, water source and other engineering factors. The detail of the drip irrigation system used for experimentation is given table 3.4.

3.8 Hydraulic Calculation of Drip Irrigation System

3.8.1 Measurement of discharge from emitters

Drip irrigation system having a lateral size of 16 mm of 20 m length with 1.3 l h^{-1} emitters (inline) at 30 cm spacing (67 number of emitter per lateral) was used for the study of hydraulic performance. Twelve laterals from the sub main line were erected and 4 emitters in each lateral line were selected for obtaining the hydraulic information and they were placed in the distance of every 5 meter in the laterals. Irrigation water was supplied from over-head tank, 0.5 hp pump is used to fill the tank. The flow rate or discharge of emitter was collected directly in measuring cylinder (plate: 3.1). Discharge of emitters with respect to test time was converted into discharge per hour.

Table 3.4 Specification of drip irrigation system

(A) Control Head			
(1)	Pump	–	0.5 hp (0.7 lps)
(2)	Filter	–	Screen filter
(B) Distribution Network			
(1)	Type of main line	–	PVC
(2)	Size of main line	–	75 mm
(3)	Type of sub main line	–	PVC
(4)	Size of sub main line	–	63 mm
(5)	Type of lateral	–	LDPE
(6)	Size of lateral	–	16 mm
(7)	Spacing between lateral	–	50 cm
(8)	Length of lateral	–	20 m
(9)	Type of emitters	–	In line type
(10)	Discharge of emitter	–	0.8 l h^{-1}
(11)	Emitter spacing	–	30 cm
(12)	Operating pressure	–	0.25 kg cm^{-2}

3.8.2 Observations on wetted width and depth of soil

Observations on width and depth of wetted soil after 15, 30, 60, and 90 minutes of water application were recorded at operating pressure 0.25 kg cm^{-2} of 1.3 l h^{-1} inline emitter (plate:3.2). The water flow to first part of lateral (from the end cap side) was blocked after 15 minutes of water application and for second part it was blocked after 30 minutes of water application. The blocking of water flow was continued for next parts of lateral at 60, and 90 minutes duration of water application. The behaviour of depth and width of wetted soil volume with duration have been studied and presented in the results and discussion chapter.

3.8.3 Pressure measurement of different component of drip irrigation system

Maintaining the normal operating pressure in the system is essential to ensure uniformity of irrigation. Pressure gauge is provided at the filtration unit of drip system to indicate pressure of head control unit. Another pressure gauge is used for measuring the variation of pressure in different component of drip system. Pressure at the end of lateral is measured with the help of pressure gauge (plate: 3.4).

3.9 Performance Evaluation of Drip Irrigation System

Despite the success of drip irrigation system, there are several problems related to the optimal water application and fertilizer management. The theory behind drip irrigation system for conserving water and fertilizer is sound, but the implementation in the field is not always easy. Though the method has great potential for achieving high irrigation efficiency but due to improper design, poor management and maintenance, it can lead to low efficiency, result in non–uniform emitter discharge throughout the irrigated the field. To overcome these problems, the irrigators found it necessary to over irrigate the field. Over irrigation can leads to the wastage of water and nutrients, as well as there is a possibility of groundwater contaminations due to excessive leaching.

3.9.1 Coefficient of manufacturer's variation

Coefficient of variation defines as the ratio of the standard deviation of flow to the mean flow for a sample number of emitters. Coefficient of variation (C_v) is a statistical parameter expressed as:

$$C_v = \frac{S}{q_{avg}} \qquad \text{... (3.1)}$$

Plate 3.1 Measurements of Discharge and Pressure on lateral

Plate 3.2 Measurements of wetting patter of the soil.

Where, S is standard deviation of flow and q_{avg} is the mean flow for a sampled number of emitters of the same type tested at a fixed pressure.

A parameter which can be used as a measure of emitter flow variation caused by variation in manufacturing of the emitter is called the coefficient of manufacturing variation (C_V). Coefficient of variation measures the non-uniformity of the discharge in the emitters due to variation in manufacturing. Generally the most critical dimension of an emitter to maintain is the flow passage diameter (*d*) with the laminar and orifice emitter, the flow varies with d^2 but turbulent emitter flow varies with $d^{15/7}$ Consequently a 2% change in *d* results in a 4% change in flow in laminar and orifice emitters whereas a 6% change occurs in the turbulent emitter. As a result it would be expected that the manufacturing coefficient of variation would be the greatest for turbulent emitters detail is shown in table 3.5. The manufacturing coefficient of variation is determined from the flow rate measurement for several identical devices and is computed with following equation:

$$C_v = \frac{(q_1^2 + q_2^2 + q_3^2 + q_4^2 - n\,q_2^2)^{1/2}}{q_a\left(n-1\right)} \quad ..\ (3.2)$$

Where,

C_v = Coefficient of manufacture's variation

q_1, q_2, q_3, q_4 = discharges(lh^{-1})

n = number of emission devices tested

S = Standard deviation

q_a = average discharge of emitter

The table shows the ASAE interpretation of manufacturing coefficient of variation.

3.9.2 Methods of emission uniformity estimation

Emission Uniformity: Emission uniformity is the measure of the uniformity of emitters discharge from all the emitters of drip irrigation system and is the single most important parameter for evaluating system performance. Emission uniformity shows relationship between minimum and average emitter discharge.

Table 3.5: Recommended Classification of Manufacture's Coefficient of Variation

Emitter type	Cv range	Classification
Point	<0.05	Good
	0.005 to 0.10	Average
	0.10 to 0.15	Marginal
	>0.15	Unaccepted
Line source	<0.10	Good
	0.10 to 0.20	Average
	>0.20	Marginal

(Source: Design, installation and performance of trickle irrigation system, ASAE, Engineering Practice, 1985, ASAE EP 405)

The water application uniformity of emitters (except of pressure compensating type emitters) is influenced by the operating pressure, emitter spacing, land slope, size of the pipe line, emitter discharge rate, and emitter discharge variability. Emission uniformity is needed for calculating the gross depth of irrigation, irrigation interval and required system capacity. It depends upon water temperature and manufacturer's coefficient of variation of the system. The table 3.6 is showing the general rating of emission uniformity. The emitter uniformity during the field test was calculated using the following equation,

$$EU_f = \frac{q_m}{q_{avg}} \times 100$$

…(3.3)

Where,

EU_f = field test emission uniformity, percentage

q_m = is the minimum discharge rate computed from the minimum pressure in the system.

q_{avg} = average design emitter discharge rate in the system, l h^{-1}

Table 3.6: Recommended Classification of Emission Uniformity

EU_f Range	Rating
90% or greater	Excellent
80 to 90%	Good
70 to 80%	Fair
Less than 70%	Poor

3.9.3 Emitter flow variation (Wu and Gitlin, 1974)

It consists of finding the minimum and maximum pressure in the sub-units and calculating the emitter flow variation (Q_{var}) as follows.

Emitter flow variation (Q_{var}) was calculated as follows:

$$Q_{var} = 100(1 - \frac{Q_{min}}{Q_{max}}) \quad (3.4)$$

Where,

Q_{var} = emitter flow variation in percentage

Q_{min} = minimum emitter discharge rate in the system, lh^{-1}

Q_{max} = design emitter discharge rate, lh^{-1}

3.9.4 Uniformity coefficient (Us)

Statistical uniformity coefficient given by the equation (Bralts and Kesner, 1982)

$$U_S = 100(1- V_q) = 100\ (1- S_q / q_a) \quad (3.5)$$

Where,

V_q = coefficient of variation

S = is standard deviation of flow and

q_a = is the mean flow for a sampled number of emitters of the same type tested at a fixed pressure lh^{-1}

3.10 Drip irrigation efficiency

Irrigation efficiency (E_i) is the ratio usually expressed as percentage, of the volume of the irrigation water transpired by plants, plus that evaporated from the soil, plus that necessary to regulate the soil concentration in the soil solution, and that used by the plant in the building plant tissue to the total volume of water diverted, stored, or pumped for irrigation. There are two irrigation efficiency terms, namely distribution efficiency and application efficiency.

3.10.1 Application efficiency

The application efficiency is defined as the ratio of water required in the root zone to the total amount of water applied. It shows how well irrigation water is applied that is, what percentage of water applied is stored in the root zone as required and is available for plant use. The water required in the root zone is assumed to be applied at the minimum flow rate and over the total irrigation time. Therefore, application efficiency can be expressed as,

$$E_a = \frac{NTQ_{min}}{V_W} \times 100 \qquad \ldots(3.6)$$

Where,

E_a = application efficiency,%

N = total number of emitter

Q_{min}= minimum emitter flow rate, l h^{-1}

T = total irrigation time, h

V_w= total volume of water applied, l

Since, the mean emitter flow (Q_{avg}) is,

$$Q_{avg} = \frac{TV_w}{N} \qquad ..(3.7)$$

The application efficiency can also be expressed as,

$$E_a = \frac{Q_{min}}{Q_{avg}} \times 100 \qquad ..(3.8)$$

(Source: Mane, M.s., Ayare, B.L., Magar, S.S., “Principal of Drip Irrigation System”)

3.10.2 Distribution efficiency

The distribution efficiency determines how uniformly irrigation water can be distributed through a drip irrigation system into the field. It can be determined from the emitter flow variation along a lateral line (or sub main) in a drip irrigation system layout in the field and can be expressed by the equation.

$$E_d = \left(\frac{1-\Delta q_a}{q_m}\right) \times 100 \qquad \text{... (3.9)}$$

Where,

E_d=distribution efficiency %

q_m= minimum emitter flow rate, l h^{-1}

q_a =average absolute deviation of each emitter flow from the mean emitter flow

3.10.3 Water use efficiency

The amount of water applied (including rainfall) to the production of okra crop was calculated. Irrigation was applied every day in treatments of Control irrigation**,** and irrigation through sensor based treatment was applied according to moisture content. Water use efficiency (WUE) is the ratio between crop yield (kg/ha) and total amount of water used (m^3/ha) by the crop (including rainfall).

3.11 Field and seed bed preparation

The experimental field was prepared in the month of January, 2018 by Ploughing and was well pulverized with the help of Rotavator followed by seed bed preparation with the help of ridge former of half meter width shown in plate 3.3. The layout of experimental plot was done as per specification mentioned in the layout plan (Fig. 3.3) with the help of measuring tape, rope, bamboo pegs, and manual labours. Total 12 furrow bed was prepared and the size of each bed was 20 m × 0.30 m (length × width) in size, which was again divided (command wise) in two sub plot Control Irrigation and Sensor based treatment wise. In Control Irrigation have two lateral lines and Sensor based treatment have ten lateral lines.

Conventional drip irrigation (Control irrigation) was directly connected by supply pipe and provides irrigation continuously according to crop water requirement. Sensor based treatment was connected by automated soil moisture sensor system and irrigation is provided by based on field capacity of the soil.

3.12 Dibbling

After making furrow bed, the seeds of okra were manually dibbled in the holes at 30 cm spacing followed by special care in watering until the seeds germinated and plants were established (plate 3.4).

3.13 Gap filling

In case of failure of some seeds to germinate and establish well in the field, due attention was given to re-dibbling, thus filling the gap.

Plate 3.3 Field preparation

Manually dibbling spray fertilizer

Plate 3.4 Manually dibbling and spray fertilizer

Plate 3.5 Measurement growth parameter

Plate 3.6 Harvesting and measurement of yield parameters

3.14 Fertilizer management

In this experiment, firstly farm yard manure was uniformly spread during ploughing. The recommended quantity of FYM was 7.5 t/ha. Then recommended quantity of Nitrogen, Phosphorous and Potash at 100kg/ha, 60 kg/ha and 60 kg/ha, respectively was applied. Half dose of nitrogen and full dose of Phosphorous and Potash was spread during seed bed preparation. The remaining dose of nitrogen was then supplied through drip in two different doses at 30 days interval.

3.15 Plant Protection Measures

To protect the crop from various insects, acitamiprid 20 S. P.@ 200 gha^{-1} was applied. For better growth, patanjali Sujiva and patanjali Chetna was applied as foliar application.

3.16 Picking of fruits

The fruits were plucked at the maturity stage. Fruit plucking started from 2^{nd} April 2018 continued till the 10^{th} May 2018. Fruits were harvested at every alternated day. Flowering stage and fruiting stage of okra is shown in plates 3.6.

3.17 Observations recorded

During the experimental work following observations were recorded:

3.17.1 Soil moisture measurement

Moisture of soil was taken during the experiment with the help of digital Time Domain Reflectometer (TDR) and Alfa mart sensor. Soil moisture was taken at 7.6 and 12 cm depth by inserting sensor rod of digital (TDR) below the soil surface. Observation was recorded to know the effect of different irrigation on soil moisture which indirectly affects the crop production. Gravimetric method was used frequently to check the field moisture content.

3.17.2 Weed control

During experiment, effect of different type of irrigation on weed population and condition of weeds was recorded.

3.17.3 Growth and yield parameters

The following observations were recorded during the crop growth period on every 5m of each lateral tagged competitive plants for studying various characters *i.e.* growth character, flowering, fruit set and yield.

i. **Plant height:** Plant height of all the tagged plants was recorded plot wise before last harvesting and averaged. Length was measured in centimetre from the base of the plant to the end of the plant with the help of measuring tape (plate.3.3).

ii. **Number of primary branches per plant:** Number of primary branches of all the tagged plants was recorded plot wise before last harvesting and averaged (plate.3.5).

iii. **Number of fruits per plant:** Number of fruits of all the tagged plants from each plot at the time of harvesting was measured and averaged.

iv. **Length of fruit:** Ten fully elongated flowers were selected randomly of all the tagged plants from each plot and fruit length was measured and averaged (plate 3.6).

v. **Number of days require for first fruiting:** Number of days were taken from dibbling to opening of first fruit in each plot.

vi. **Fruit yield:** Fruit yield of all the tagged plants from each plot at the time of each harvesting was measured and summed up to get the total production per plant.

3.18 Yield calculation

Marketable and total fruit yield tone per hectare was worked out with the help of fruit yield per plot by using the following formula

$$\text{Yield} = \frac{\text{Weight of fruit in kg/plot} \times 10000}{\text{Plot area} \times 1000} \qquad .. (3.10)$$

3.19 Irrigation water measurement

A gravity fed drip irrigation system was used for irrigation. One overhead tank (3.55m) of 750 litres was used and to fill the tank 0.5 hp pump was available.

3.19.1 Conventional drip irrigation

We have two lateral lines in conventional drip irrigation method. In this treatment irrigation water was supplied continuously as a farmer practice and its amount was measured.

3.19.2 Sensor based treatment

Ten lateral lines were taken under this treatment. The sensor system commands the pump ON according to moisture content of the field and OFF the pump when the required amount of water was filled in the tank. In overhead tank floating switch was provided, Floating switch only OFF the pump when set volume is achieved. The height of floating switch was set with the help of the volume of water required for irrigation. The formula used for calculating required volume of irrigation water was follows:

Volume of Irrigation water

$$u = \sum_{i=1}^{n} \frac{M_{1i} - M_{2i}}{100} \times A_i \times D_i \qquad \ldots(3.11)$$

In which,

u = water use from the root zone for one irrigation cycle (mm)

n = number of soil layer sampled in the root zone depth D

M_{1i} = Soil moisture percentage at the time of first sampling in the i^{th} layer

M_{2i} = Soil moisture percentage at the time of second sampling in the i^{th} layer

A_i = Apparent specific gravity of the i^{th} layer of the soil

D_i = Depth of the i^{th} layer of the soil (mm)

Irrigation water requirement

$$I_R = \frac{u \times \pi r^2}{1000} \times \text{No. of Plants} \times 1000 \qquad \ldots.(3.12)$$

Where,

I_R = Irrigation water requirement (l)

r = wetted surface area (m^2)

u= Water use from the root zone for one irrigation cycle (mm)

(Source: Michal, A.M., Irrigation theory and practices second Edition. pp.489)

CHAPTER-IV
RESULTS AND DISCUSSION

The results of the study have been presented and thoroughly discussed in this chapter. The analysis of the experiment has been carried out in three phase, which includes setting up of low cost sensor system for monitoring soil moisture content, calibrate and validate the sensor system in conjunction with the low cost gravity operated irrigation system, performance evaluation of drip irrigation system using soil moisture sensor, at the experimental field of Department of Soil and Water Engineering, SVCAET & RS, Faculty of Agricultural Engineering, IGKV Raipur. The experiment consists of two levels of irrigation water i.e., (i) Convention drip Irrigation (Control), (ii) Sensor based drip irrigation system

4.1 Installing and setting up soil moisture sensor

4.1.1 Electrical connection

The Analog Input Module AI561 can be connected to the following devices via the I/O-Bus S500 Bus Modules, AC500 I/O Modules. Connection of sensor system is shown in fig. 4.1.

The electrical connection is carried out by using a removable 9-pole and 11-pole Terminal Block. These terminal blocks differ in their connection system (spring terminals or screw-type terminals, cable mounting from the front or from the side). The internal power supply voltage for the module's circuitry is carried out via the I/O Bus (provided by a Bus Module or a CPU). Data is shown in appendix A and complete setup is shown in plate 4.1.

The block diagram (fig 4.1) shows the internal construction of the analog inputs show in Appendix A.

A 230 volt single phase was supplied to the circuit. It is divided into two connections viz., neutral and phase.

The neutral was entered into the system through the trip. The phase was connected to the MCB. Two MCB's were used, one was directly connected to the PLC and the other one controlled the phase. When both MCB's and trip were in ON condition, the power was supplied through the complete system.

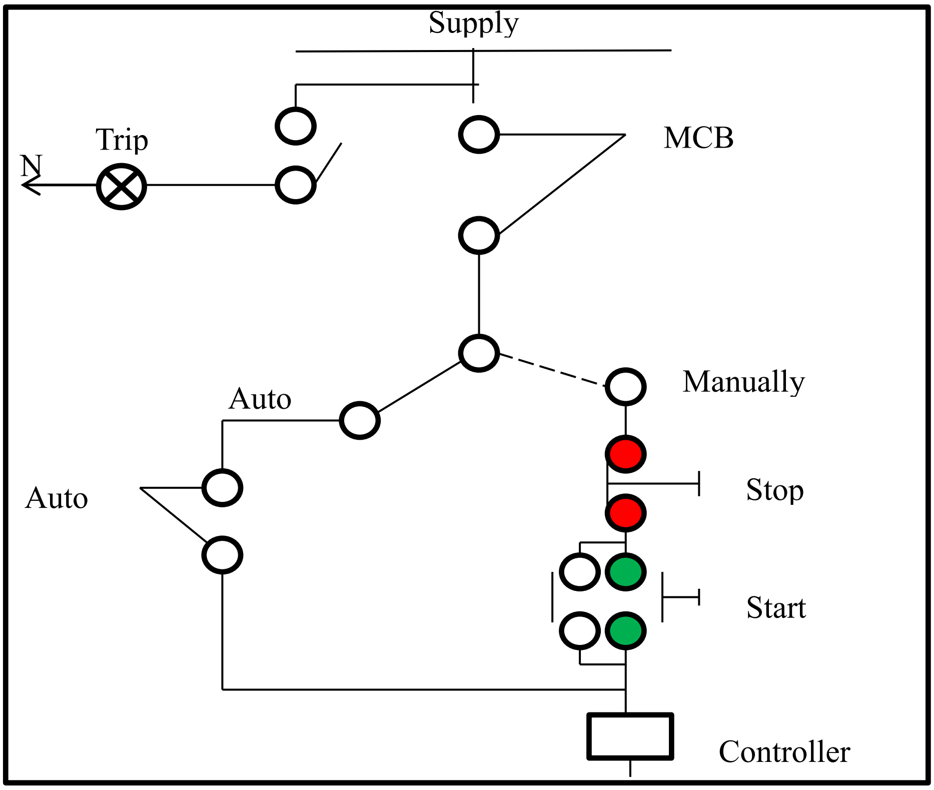

Fig. 4.1: Circuit diagram of sensor system

When power supplied through the MCB, there was two options for the power supply to further: (i) automatic ON/OFF switch for pump and (ii) Manually operated. In manually operated circuit, there were two switches for ON and OFF, according to which the system function. When the system runs on auto mode, then firstly the auto switches on and then power comes on auto relay. Auto relay works on the programming of PLC and according to it, switches on and off. When relay receives command, it gives command to PLC and then the command goes to the pump and water supply system runs. Auto relay connected to the controller and according to the command comes from the controller, the auto relay gets ON and OFF.

4.1.2 Display setting

Single display 0.56" RED LED display was used to show output of sensor system. Status on LED display is shown in Appendix C-1. The displays in adjusting parameter values during calibration & validation by displaying the reading. The display was also important for the average stuats of real time soil moisture content.

4.2 Calibration & Validation of Sensor System

4.2.1 Soil moisture sensor

Soil moisture sensor with two probes was inserted into the soil at 15cm depth. As per moisture content sensor probe sends analog output variation from 0.06 volts to 5 volts to the PLC (Programmable logic controller) unit which in terms read the analog data and converts into digital output in form of moisture content.

4.2.2 Sensor setting

In sensor system used six different input values for checking the accuracy of output and find that 0.06V to 5V current is give more accurate output. There data is shown in Appendix B.

4.2.3 Calibration of soil moisture sensor.

By the help of different soil moisture calibrates the soil moisture sensor and the compared their results are shown is fig. 4.2.

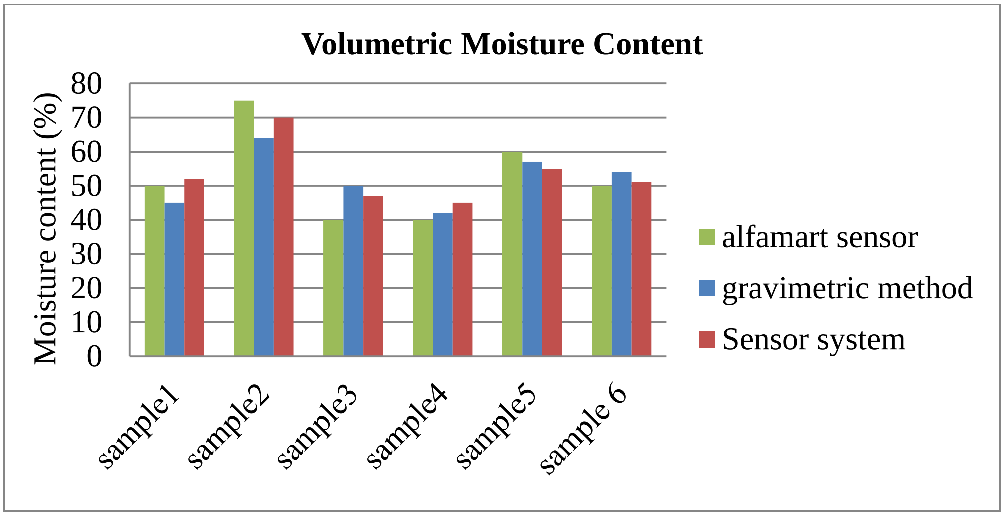

Fig 4.2: Response of different moisture sensors after calibration

4.2.4 Parameterization

The arrangement of the parameter data (input and output) is performed with Control Builder Plus software. The parameter data directly influences the functionality of modules. For non-standard applications, it is necessary to adapt the parameters to a system configuration. Output is shown in plate 4.2 when system is OFF mode.

4.3 Hydraulic Performance of Drip Irrigation System

The maximum average discharge of 1.03 l h^{-1} was recorded for the pressure of 0.25 kg/cm^2. The pressure of 0.25 kg/cm^2 was attained from the gravity force crated by 3.55 m total height from the ground i.e. foundation height of water supply tank stand (2.55 m). Though the pressure created by the tank height itself were variable with the available volume of water inside the tank during delivery, hence every 10 min data was recorded.

In this study, drip irrigation system having a lateral size of 16 mm of diameter and 20 m length with 1.03 l h^{-1} emitters (inline) at 30 cm spacing was used for the study. Twelve laterals from the sub main line and eight hundred and four emission devices having discharge of 1.03 l h^{-1} were selected every 5m distance over these laterals for the study. Irrigation water was supplied for 10 minutes from an over-head tank through gravity, filtered through a screen filter. The flow rate or discharge of emitter was collected in plastic container directly and then measured in measuring cylinder. Discharge of emitters with respect to test time was converted into discharge per hour. Hydraulic performance of drip irrigation system was evaluated on the basis of discharge variation, coefficient of variation, emission uniformity, uniformity coefficient and irrigation efficiency at different operating head for varying durations and horizontal & vertical movement of wetting front advance. The results have been discussed as follows:

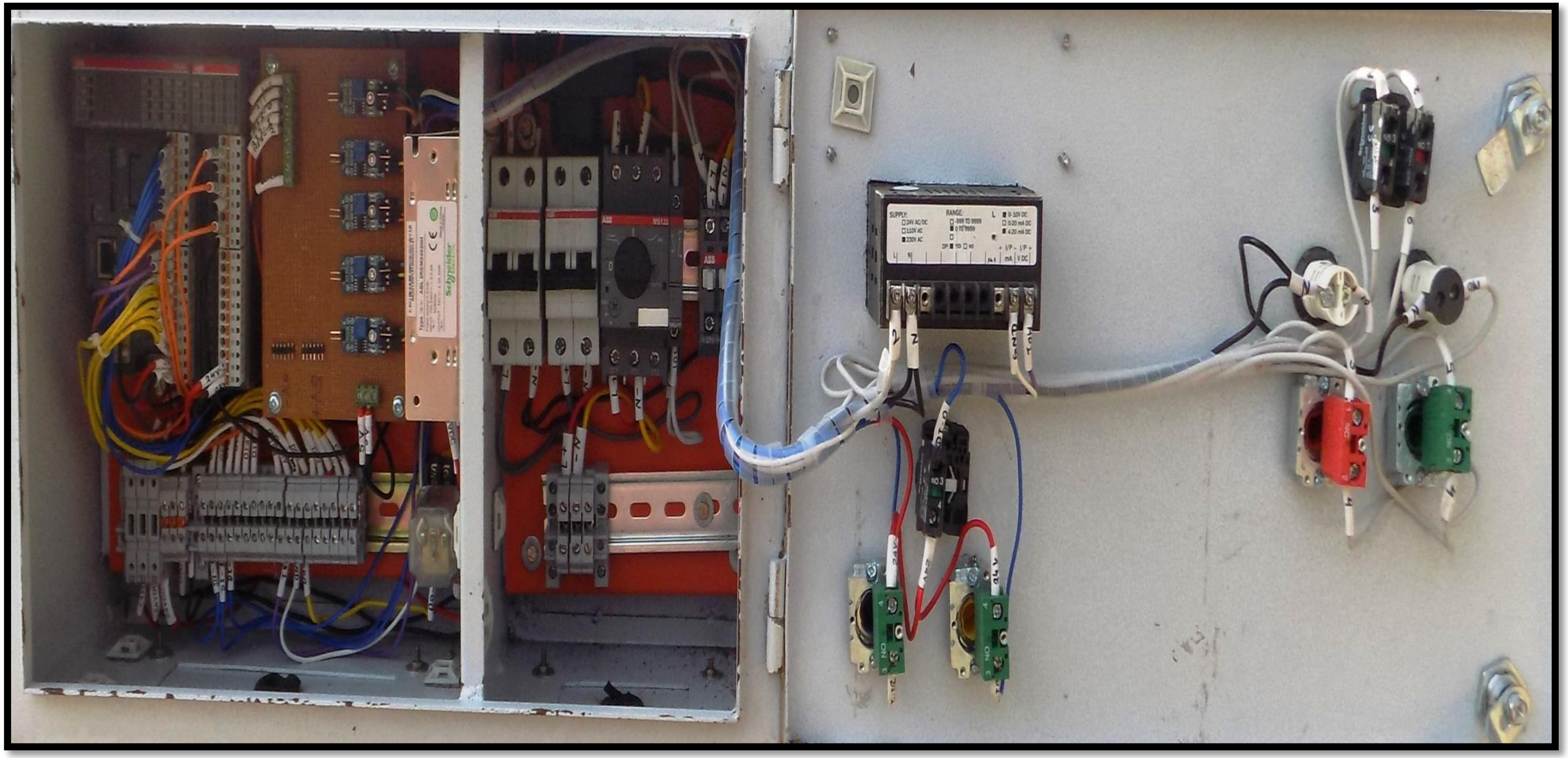

Plate 4.1: Complete setup of sensor system

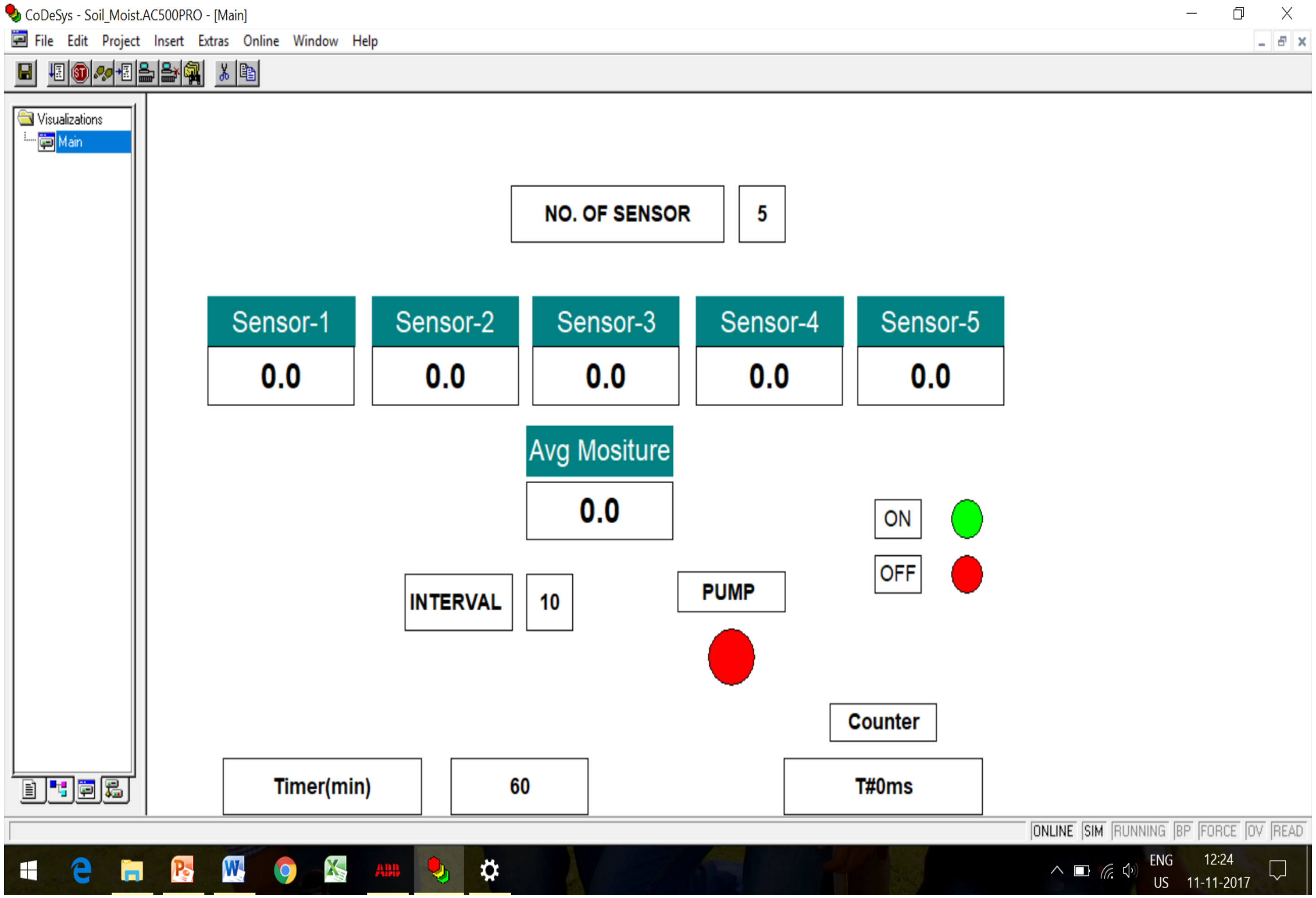

Plate 4.2: Digital output of sensor system when system is OFF

4.3.1 Observation of discharge of drip irrigation system under different operating head

Drip irrigation discharges were measured at different operating head. The discharge obtained from 1.03 l h^{-1} drippers was found to be average discharge 1.03 l h^{-1}. Details of discharge variation are presented in table 4.1.

Table 4.1: Average emitters flow rate under different operating head

Discharge of emitters l h^{-1}						
distance, m	Lateral 2	Lateral 4	Lateral 6	Lateral 8	Lateral 10	Sum
5	1.1	1.09	1.09	1.05	1.02	5.35
10	1.09	1.08	1.06	0.99	0.98	5.2
15	1.07	1.04	1.02	0.98	0.96	5.07
20	1.05	1.03	1	0.97	0.94	4.99
Total	4.31	4.24	4.17	3.99	3.9	20.61
Average	1.0775	1.06	1.0425	0.9975	0.975	1.0305

4.3.2 Emission Uniformity (EU_f)

Emission uniformity is a major parameter for evaluating performance of micro irrigation systems. The emission uniformity was determined so as to see whether the emitting devices are applying the water uniformly or otherwise. The calculated emission uniformity data at every 10 min interval have been presented in table 4.2 and fig 4.3.

Table 4.2: Emission uniformity for every 10 min interval

Emission uniform coefficient (%)							
Head	3.55 to 3.36 m	3.36 to 3.19 m	3.19 to 3.03 m	3.03 to 2.89 m	2.89 to 2.76 m	2.76 to 2.65 m	2.65 to 2.60 m	Total in 65 min.
Qmin	0.19	0.18	0.17	0.16	0.15	0.13	0.04	1.00
Qavg	0.19	0.18	0.17	0.16	0.15	0.14	0.04	1.03
EUf	98.80	97.37	96.95	96.88	96.83	94.85	91.95	96.85

The average emission uniformity (96.85 %) was observed at operating pressure 0.25 kg cm^{-2} at the head of 3.03 to 2.89 m. At a particular spacing, the ratio of minimum rate of discharge to average rate of discharge increased as the operating head increased due to constant emission point per unit length of lateral, and thus the emission uniformity increased as the operating head increased for all emission devices.

4.3.3 Emitter flow variation (Q_{var})

Emitters flow variation, (Q_{var}) of 1.03 l h^{-1} emitter at different operating head, has been presented in Table 4.3and fig 4.4. The maximum average uniformity coefficient 96.63% was observed at head 3.55m. The average emitter flow variation was found 14.55%. From the observed data it is clear that the emitter flow variation mostly depends on the performance of emitter under the field condition, if the ratio between minimum and maximum discharge value is more then it will give low emitter flow variation which will come under non-acceptable range.

Table 4.3: Emitter flow variation under different operating pressure

Emitter flow Variation (%)								
Head	3.55 to 3.36m	3.36 to 3.19m	3.19 to 3.03 m	3.03 to 2.89 m	2.89 to 2.76 m	2.76 to 2.65 m	2.65 to 2.60 m	Total in 65 minutes
Q_{mini}	0.18	0.17	0.16	0.15	0.14	0.12	0.03	0.94
Q_{max}	0.20	0.19	0.18	0.17	0.16	0.15	0.06	1.10
Q_{var}	10.00	10.53	11.11	14.71	15.63	20.69	45.45	14.55

4.3.4 Uniformity coefficient (Uc)

Uniformity coefficient of 1.03 l h^{-1} emitter at different operating head, have been presented in Table 4.4 and fig 4.5. The maximum average uniformity coefficient 96.63% was observed at head 3.55m Thus, for a particular spacing uniformity coefficient increases as the operating head increases for all emission devices. At a particular spacing, the average rate of discharge increases as the operating head increases due to constant emission point per unit length of lateral. Hence uniformity coefficient increases as per the operating head for all emission devices. The average uniformity coefficient was found 95.23%.

Table 4.4: Uniformity coefficient under different operating pressure

Uniformity coefficient (%)								
Head	3.55 to 3.36m	3.36 to 3.19 m	3.19 to 3.03 m	3.03 to 2.89 m	2.89 to 2.76 m	2.76 to 2.65 m	2.65 to 2.60 m	Total in 65 minutes
STD	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05
Mean	0.19	0.18	0.17	0.16	0.15	0.14	0.04	1.03
Uc	96.63	96.06	95.95	94.64	94.22	92.49	86.50	95.23

4.3.5 Application efficiency (E_a)

The application efficiency (E_a) of drip irrigation system was estimated for operating pressures 0.25 kg cm^{-2}, which have been presented in Table 4.5.

Table 4.5: Application Efficiency under different operating pressure

Application Efficiency (%)								
Head	3.55 to 3.36m	3.36 to 3.19 m	3.19 to 3.03 m	3.03 to 2.89 m	2.89 to 2.76 m	2.76 to 2.65 m	2.65 to 2.60 m	Total in 65 min.
Q_{mini}	0.18	0.17	0.16	0.15	0.14	0.12	0.03	0.94
Q_{avg}	0.19	0.18	0.17	0.16	0.15	0.14	0.04	1.03
E_a	95.62	94.05	92.89	90.63	90.15	84.56	68.97	91.22

The maximum application efficiency 95.62% was found at 3.55 to 3.36m operating head (Table 4.5). Thus for a particular spacing application efficiency increases as per the operating head for all emission devices. The average application efficiency was found 91.22%. All these application efficiency data at different operating head are presented in fig.4.6.

4.3.6 Distribution efficiency (E_d)

The distribution efficiency (E_d) of drip irrigation system was estimated for 1.03 l h^{-1} drippers under different operating head, which have been presented in Table 4.6.

Table 4.6: Distribution Efficiency under different operating pressure

Distribution Efficiency (%)								
Head	3.55 to 3.36m	3.36 to 3.19 m	3.19 to 3.03 m	3.03 to 2.89 m	2.89 to 2.76 m	2.76 to 2.65 m	2.65 to 2.60 m	Total in 65 min
DE	97.04	96.74	96.63	95.31	95.11	93.75	89.31	95.97

The maximum distribution efficiency 97.04% was found at 3.55 to 3.36 m operating pressure (Table 4.6). Thus for a particular spacing distribution efficiency increases as per the operating head for all emission devices. The average distribution efficiency was found 95.97%.

4.3.7 Behaviour of wetted soil width and depth at 0.25 kg cm^{-2}

The behaviour of wetted width with wetted depth of soil under drip irrigation has been presented in Fig.4.7 and 4.8. It is clear that in case of clay loam soil wetting front advance obtained in horizontal direction is more compared to vertical direction due to compaction of soil and low permeability because in high compact. Soil water moves laterally more than vertically. The wetted width increased with wetted depth with duration of water application and there data is shown in table 4.7.

4.3.8 Pressure variation in different component of drip irrigation system

The pressure of different components of drip irrigation system were observed by maintaining different operating pressure at head control unit shown in Table 4.8.

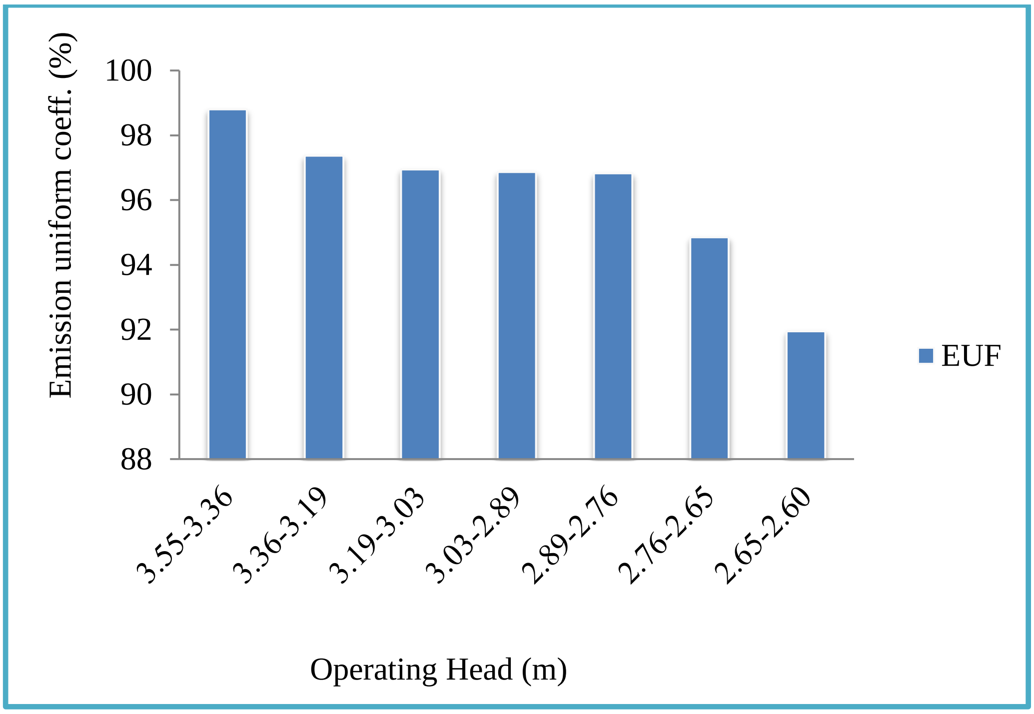

Fig.4.3: Emission uniformity for different operating heads

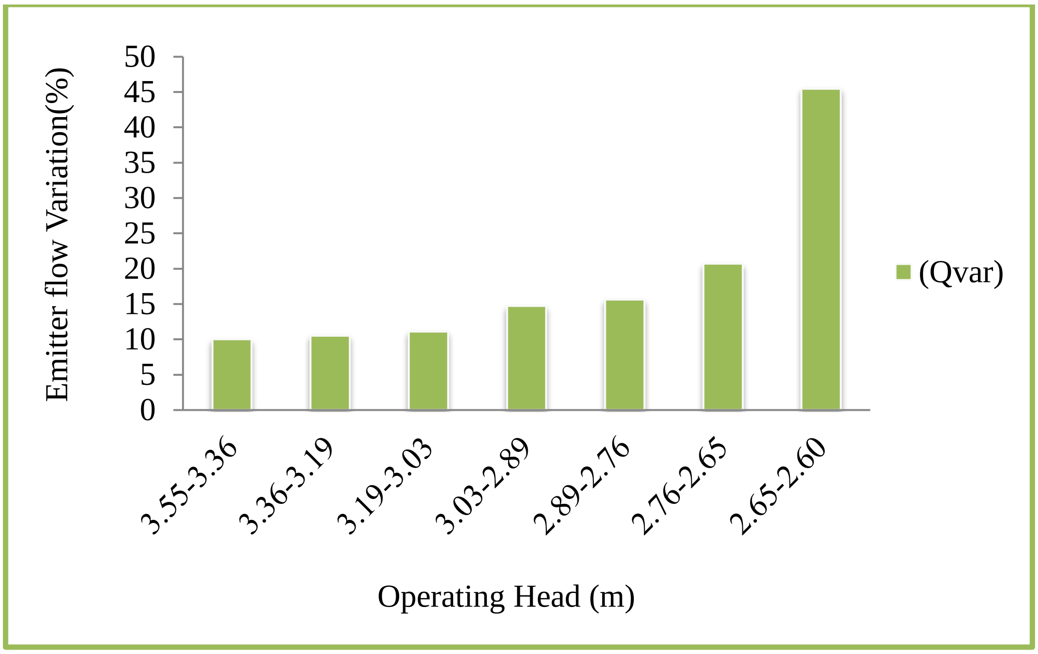

Fig 4.4: Emitter flow variation for different operating heads

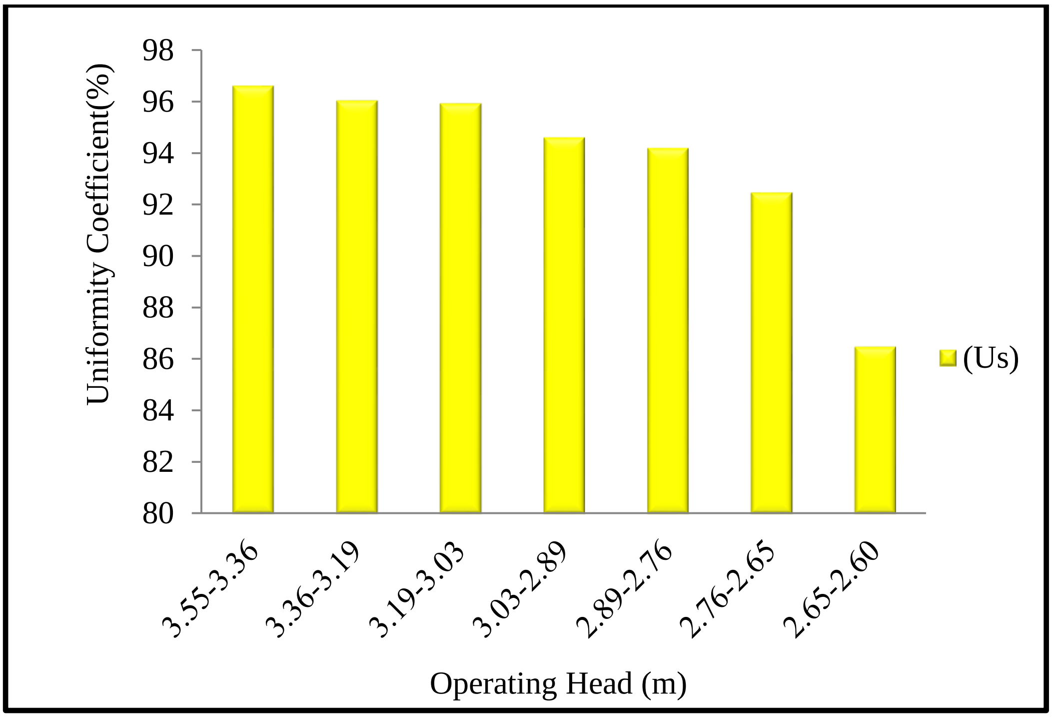

Fig 4.5: Uniformity coefficient for different operating heads

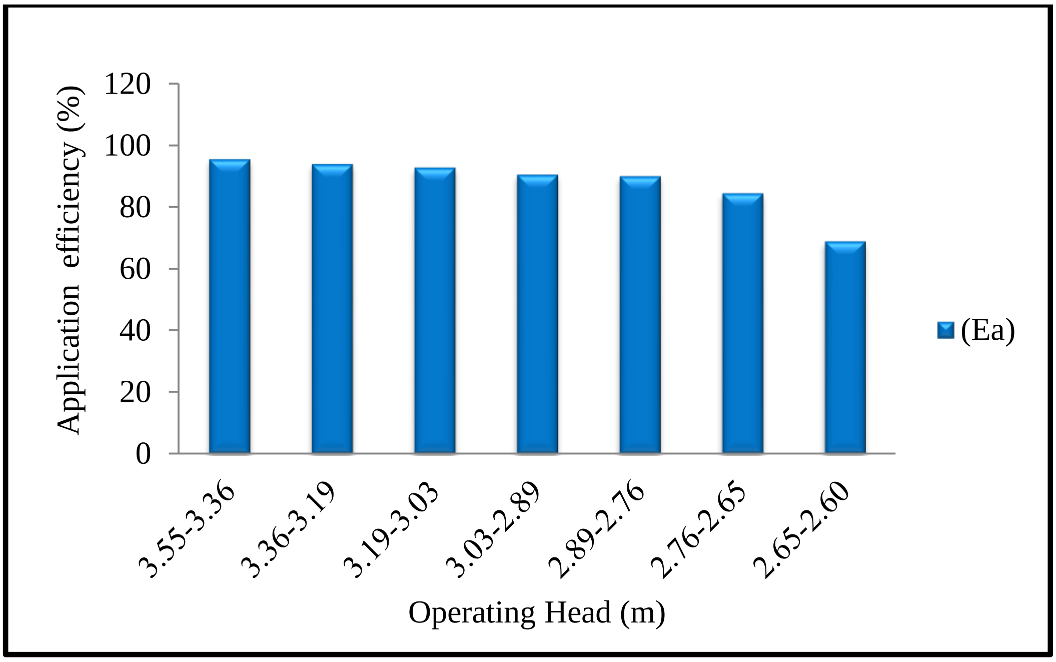

Fig 4.6: Application efficiency for different operating head

During measurement of discharge value under different operating pressure, pressure at different components of drip irrigation system such as head control unit, sub main and the end of first lateral was checked to know the pressure variation in these components.

It was noticed that due to change in pressure at head control unit, pressure at various component of system has also been changed. When pressure 0.4 kg cm^{-2} was maintained at head control unit, then the variation in pressure at sub main was found 0.3 kg cm^{-2} and the end of lateral 0.25 kg cm^{-2} pressures were recorded end of lateral.

Table 4.7: Horizontal and vertical movement of water (cm) w. r. t. elapsed time at 0.25 kg cm^{-2}

Elapsed time							
15 min		30 min		60 min		90 min	
HR	VR	HR	VR	HR	VR	HR	VR
cm	cm	cm	cm	cm	cm	cm	cm
0	8.4	0	12.4	0	20.1	0	22.3
4.2	6.1	5	9	5	14	5	16
		8.3	5.4	10	8	10	11
				11.2	7	14	9
						16.4	7.3

Table 4.8: Observed pressure (kg cm^{-2}) at different component

S.No.	Head control unit (kg cm^{-2})	Sub main (kg cm^{-2})	End of lateral (kg cm^{-2})
1	0.4	0.3	0.25

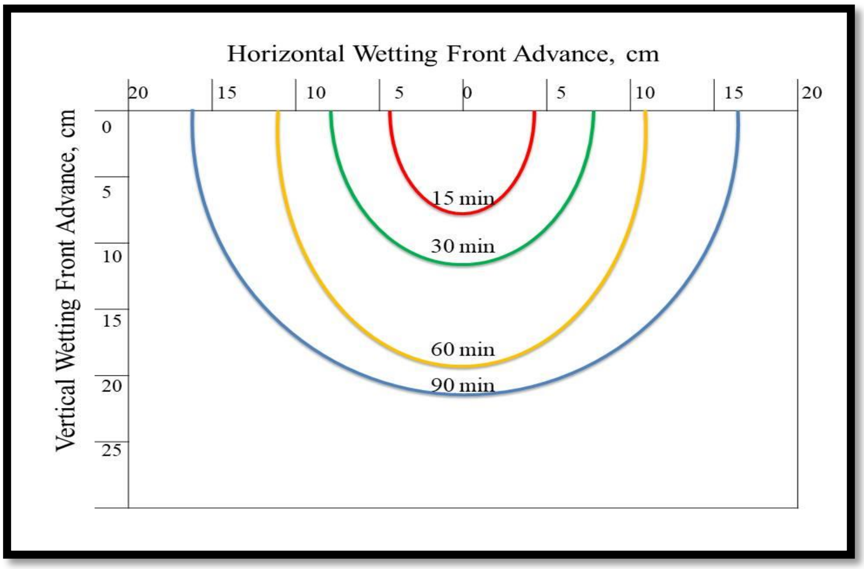

Fig 4.7: Vertical Wetting front advance at different time for clay soil of 1.03 l h^{-1} inline emitter at 0.25 kg cm^{-2}

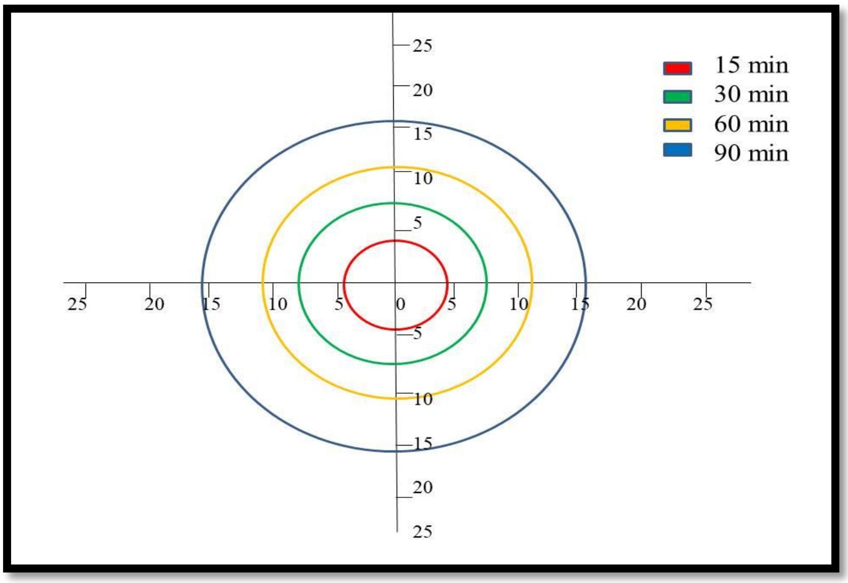

Fig 4.8: Horizontal Wetting front advance at different time for clay soil of 1.03 l h^{-1} inline emitter at 0.25 kg cm^{-2}

4.4 Setting for irrigation requirement of okra crop

The water requirement of okra crop for moisture sensor was calculated on the basis of field capacity of soil, apparent specific gravity of soil and root-zone depth of crop. The expression for this was explained in equation 3.11 under the article 3.11.2.

The field capacity was obtained 27% on V.M.C. basis. 80% and 50% of this value was taken for M_{1i} and M_{2i} respectively. From experiment the value of apparent specific gravity was 1.34 from equation 3.11 calculated values of water requirement was 1.60 cm in term of depth and 6.109×10^{-4} m^3 in terms of volume. This was the water requirement of one plant for one irrigation and accordingly 0.41 m^3 for the field (670 plants) for one irrigation. This was used to setting up for leveller sensor inside the overhead tank. This volume of water when filed in the tank, the sensor put the pump off for stopping the further filling of tank.

4.5 Vegetative growth parameter

The vegetative growth parameters recorded for okra crop were plant height and number of branches per plant. For both the treatments of control irrigation and sensor based treatment, the results obtained and discussion there on is presented in ensuing paragraph. It is seen that the weed intensity was minimum i.e. 11% area covered by weeds in sensor based treatment, whereas 24% canopy area was covered by weeds in used control irrigation. Gernally Nut Grass (Nagarmotha: *Cyprus rotundus*), Cyperus iria, Gale of the wind (*Phyllanthus niruri*), are mostly present in field.

4.5.1 Plant height

The data pertaining to the average plant height of okra as influenced by method of different treatments were recorded at the age of every 30 days of crop. The details of plant height in each treatment of measurement are given in table 4.9. The average plant height increased progressively with increase in age of crop up to 30, 60, 90 days and at the last harvesting of crop. The fertigation was started 30 days after sowing. Regarding the character plant height the effect of irrigation and fertigation treatments was found significant. Though, the maximum plant height i.e. 35.40 cm at 30 days, 77.10 cm at 60 days, 110.90 cm at 90 days and 115.90 cm at last harvest was recorded under irrigation on sensor treatment.

Table 4.9: Plant height at 30, 60, 90 days and at the harvest of okra crop under different treatments.

Treatments		Plant height (cm)			
		30 days crop	60 days crop	90 days crop	At harvested 100 crop
Conventional drip irrigation (Control)	L_1	28.8	64.4	92.23	98.3
	L_2	26.7	63.2	89.60	92.6
Sensor based drip irrigation	L_3	31.2	67.5	110.60	108.3
	L_4	34.7	70.2	104.30	110.6
	L_5	35.4	77.1	95.60	99.6
	L_6	28.2	63.9	93.30	96.3
	L_7	33.2	74.4	110.90	115.9
	L_8	32.5	68.2	99.30	102.3
	L_9	27.9	62.9	92.60	95.6
	L_{10}	30.1	65.4	94.30	98.3
	L_{11}	28.9	63.8	91.90	94.9
	L_{12}	30.4	64.4	92.7	95.6

4.5.2 Number of branches per plant

The data pertaining to the average number of branch per plant of okra as influenced by irrigation treatments were recorded and given in table 4.10. It is seen that the average number of branches per plant increased progressively with increase in age of crop up to 30, 60, 90 days and last harvest of crop, when the variation in average number of branches followed a similar trend as the plant height in different treatments. The average number of branches per plant increased in irrigation period.

Table 4.10: Number of branch per plant at 30, 60, 90 days and at the harvest of okra crop under different treatments.

Treatments		Number of branch per plant			
		30 days crop	60 days crop	90 days crop	At the harvested 100 days
Conventional drip irrigation (Control)	L_1	1.2	2.2	3.2	3.3
	L_2	1.1	2.1	3.3	3.5
Sensor based drip irrigation	L_3	1.2	2.8	3.7	3.9
	L_4	1.2	3	3.9	4.1
	L_5	1.5	3.2	4.5	4.6
	L_6	1.3	2.9	4.4	4.6
	L_7	1.5	3.1	4.8	4.9
	L_8	1.4	3.2	4.2	4.3
	L_9	1.3	2.9	4.4	4.6
	L_{10}	1.2	2.8	3.8	4.2
	L_{11}	1.2	2.6	3.9	4.1
	L_{12}	1.3	3	4.1	4.2

The maximum average number of branches per plant i.e. 1.50 at 30 days crop in both lateral line L_5 and L_7 (Sensor based treatment) and 3.20 at 60 days crop in both lateral L_6 and L_8 and 4.80 at 90 days crop in lateral L_7 and 4.60 at last harvesting stage in laterals L_5, L_6, and L_9 were obtained. The minimum average number of branches per plant i.e. 3.30 was obtained at last harvest in lateral, L_1 (Control irrigation). The increase in average number of branches per plant in irrigation treatments may be attributed to the fact that different level of irrigation through drip irrigation caused maximum branches per plant of okra.

It might be due to the application of proper and well distributed dose of fertilizers which attributed to better nutritional environment in the root zone as well as in plant system. Nitrogen, phosphorus and potassium are most indispensible of all mineral nutrients for growth and development of the plant.

4.5.3 Yield attributing character

The yield attributing characters of okra recorded were number of fruits per plant, yield of fruits per plant (kg), yield of fruits per plot (kg), and yield of fruits per hectare (kg). For all the treatments of sensor based treatment and control irrigation the results obtained and discussion there on is presented in next sub chapters.

4.5.3.1 Number of fruits per plant

The data presented in table 4.11 shown in that number of fruits per plant was significantly influenced by both the treatments. It is clear from data that various irrigation levels had significant effect on the number of fruits per plant. The maximum average number of fruits per plant 15.81 was obtained in L_7 sensor treatment and minimum 14.90 was obtained in L_1 in control irrigation.

4.5.3.2 Yield of fruits per plant (kg)

The weights of okra fruit after picking of yield were measured using the electronic balance and the fruit yield per plant calculated for different treatments. That in the maximum yield per plant is 0.219 kg was obtained in sensor based treatment. The minimum yield per plant is 0.194 kg was obtained in control irrigation. The detailed are given in table 4.11.

4.5.4 Quality characters

The quality characters of okra fruit were determined in terms of weight and length of fruit for both the treatments of sensor based treatment and control irrigation the results obtained and discussion there on are presented in ensuing paragraph. The detailed quality characters are given in table 4.12.

4.5.4.1 Average weight of fruit (gm)

The weight of okra fruit after picking of yield were measured using the pan balance and the mean fruit weight calculated for different treatments. That in the maximum average weight of fruits 13.40 gm was obtained in sensor based treatment. The minimum average weight of fruits 9.40 gm was obtained in control irrigation. The detailed are given in table 4.12**.**

Table 4.11: Number of fruits per plant and fruit yield per plant of okra under different treatments

Treatments		No. of fruits per plant	Fruit yield (kg per plant)	Yield kg per hectare
Conventional drip irrigation	L_1	14.90	0.201	13425.3
	L_2	15.12	0.194	12933.2
	L_3	15.64	0.187	12467.4
	L_4	15.48	0.202	13471.7
	L_5	15.51	0.208	13894.4
	L_6	15.43	0.191	12749.5
Sensor based drip irrigation	L_7	15.81	0.219	14571.5
	L_8	15.37	0.205	13698.8
	L_9	15.56	0.205	13654.4
	L_{10}	15.44	0.209	13963.1
	L_{11}	15.35	0.205	13674.4
	L_{12}	15.41	0.189	12618.3

4.5.4.2 Average length of fruit (cm)

The length of okra fruit after picking of yield were measured using the scale and the mean fruit length calculated for different treatments. It is revealed from the table 4.12. That in the maximum average length of fruits was obtained in sensor based treatment 11.20 cm and the minimum average length of fruits was obtained in control irrigation 9.10 cm.

Table 4.12: Average fruits weight and average fruit length per plant of okra under different treatments

Treatments		Average weight of fruit (gm)	Average length of fruit (cm)
Conventional drip irrigation (Control)	L_1	9.4	9.1
	L_2	10.1	9.3
Sensor based drip irrigation	L_3	11.2	10.2
	L_4	11.5	10.8
	L_5	11.4	10.3
	L_6	10.7	9.5
	L_7	13.4	11.2
	L_8	11.4	10.3
	L_9	12.1	10.4
	L_{10}	13.1	10.9
	L_{11}	11	10.2
	L_{12}	12.4	10.7

4.5.5 Water use efficiency

The amount of water applied (including rainfall) to the production of okra crop is presented in Table 4.13. Irrigation was applied every day in treatments of control irrigation and irrigation through sensor based drip irrigation was applied according to moisture content. Water use efficiency (WUE) is the ratio between crop yield (kg/ha) and total amount of water used (m^3/ha) by the crop (including rainfall). The field water use efficiency under different level of irrigation is presented in Table 4.13.

After calculating total volume of water 4850 m^3 used by Control irrigation and 3116.0 m^3 for the production of okra in one ha area. Based on the result maximum water use efficiency was obtained in Sensor based treatment 46.76 kg ha^{-1} mm^{-1} and the minimum water use efficiency was obtained in Control irrigation 26.66 kg ha^{-1} mm^{-1}.

Table 4.13: Water use efficiency under different treatments

Treatments		Yield kg per hectare	Depth of water cm	Water use efficiency (kg ha^{-1} mm^{-1})
Control irrigation	L_1	13425.3	48.5	27.68
	L_2	12933.2	48.5	26.66
Sensor based treatment	L_3	12467.4	31.16	40.01
	L_4	13471.7	31.16	43.23
	L_5	13894.4	31.16	44.59
	L_6	12749.5	31.16	40.92
	L_7	14571.5	31.16	46.76
	L_8	13698.8	31.16	43.96
	L_9	13654.4	31.16	43.82
	L_{10}	13963.1	31.16	44.81
	L_{11}	13674.4	31.16	43.88
	L_{12}	12618.3	31.16	40.50

CHAPTER - V
SUMMARY AND CONCLUSIONS

Water is becoming a scare resource day by day. The utilizable water resource of the country is not enough to irrigate the entire cultivable area and therefore it calls for an efficient use of available water and it is in this context micro irrigation assumes important role. Therefore it is necessary to adopt efficient irrigation methods that are economically viable, technically feasible and socially acceptable. Now a day, drip irrigation is gaining ground in horticultural crops as it provides water uniformly and directly to the roots of plants through a close network of plastic pipes and emitters. The demand of land and water resources is continuously increasing in the state. It is possible to increase the intensity of cultivation up to 300% or more. Further, large areas of waste/ fallow lands are available in the state which can be brought under cultivation. All this would need water and hence optimum use of the available water is very critical at this juncture.

Contribution of drip irrigation and use of Sensor system in water saving consequently increased crop productivity is well recognized. This technology not only improves farm economy but also provides assurance of realizing full potential of crop productivity against drought during rainy season and facilitates to raise post monsoon crop under limited water resources. The combined effect of drip irrigation and Sensor system on yield, water-use efficiency of okra production, needs to be studied.

The present study was conducted on “Evaluation of Low Cost Soil Moisture Sensor Based Automated Drip Irrigation System” at the experimental field of Department of Soil and Water Engineering, SVCAET & RS, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The aim of the experiment was to integrate and set up a low cost sensor system for monitoring of soil moisture content along with calibration and validation the sensor system in conjunction with the low cost gravity operated drip irrigation system.

Laboratory tests of the soil samples revealed its texture as clay loam. Field capacity (27 %) and Bulk density (1.34 g cc^{-1}) was obtained. Alfa-mart sensor, TDR and gravimetric method were used to measure soil moisture content. Soil moisture sensor system was calibrated between VMC of 80-50% for field capacity of the soil by using Gravimetric method.

Gravity fed drip irrigation system 750 litres overhead (total height 3.55 m) tank was used for irrigation. The experiment constituted two treatments Conventional drip irrigation (Control) and Sensor based drip irrigation. As Control irrigation water is provided based on farmer practice and Sensor based treatment water was provided according to field moisture content. For Control irrigation and Sensor based drip irrigation 2 and 10 lines of laterals were used respectively. Wetting patterns was measured at 0.25 kg cm^{-2} operating pressure. Wetted width and depth of soil after 15, 30, 60 and 90, minutes of water application were recorded. The maximum horizontal wetting front advance was observed to be 4.2, 8.2, 11.2 and 16.4 cm respectively and maximum vertical wetting front advance were recorded as 8.4, 12.4, 20.1 and 22.3 cm respectively from emitters with discharge of 1.3 l h^{-1} at 0.25 kg cm^{-2}.

Drip irrigation discharge of 1.03 l h^{-1} inline emitter was measured at different locations in the field at 10 min interval of different operating head to evaluate out the hydraulic performance of drip irrigation system based on, emission uniformity, emitter flow variation, uniformity coefficient and irrigation efficiencies. Based on the experimental record Emission uniformity (98.80%), Uniformity coefficient (97.94%), Distribution efficiency (97.04%) and Application efficiency (95.62 %) were found maximum at operating head 3.35 m to 3.36 m. The growth characters was progressively increased and influenced by different irrigation treatments. In Control irrigation maximum plant height was 98.30 cm, number of branch per plant was 3.50, number of fruit per plant was 15.12, avg. weight of fruit 10.10 gram, avg. length of fruit was 9.30 cm, yield per plant was 209 gram and water use efficiency was 27.68 kg ha^{-1} mm^{-1} was obtained. In Sensor based treatment maximum plant height was 115.90 cm, number of branch per plant was 4.90, number of fruit per plant was 15.81, avg. weight of fruit 13.40 gram, avg. length of fruit was 11.20 cm, and yield per plant was 234 gram was obtained.

Water use efficiency was found maximum (46.76 kg ha^{-1} mm^{-1}) under sensor based treatment. After calculating total volume of water 4850 m^3 used by Control irrigation and 3116.0 m^3 for the production of okra in one ha area. So Sensor based treatment safe 1734 m^3 of water in one ha area.

CONCLUSIONS

Evaluation of low cost soil moisture sensor based automated drip irrigation system was studied. On the basis of result obtained following conclusions can be drawn:

1. Setting up of soil moisture sensor based drip irrigation system was successfully done in the experimental plot of department of Soil and Water Engineering, Raipur.

2. The development sensor system was successfully calibrated and validated for recording fluctuations of 80-50% of field capacity under okra crop.

3. Sensor treatment gave better result comparison of control irrigation. In terms of water use efficiency (46.76 kg ha^{-1} mm^{-1}). Maximum plant height (115.90 cm) and yield (14571.5 kg ha^{-1}) was also achieved under sensor based drip irrigation treatment.

SUGGESTION FOR FUTURE RESEARCH WORK

- The study can be conducted in poly-house to generate information in controlled condition and to check the preformation of sensor system.
- The study can be conducted for different vegetable crops in different seasons with use of mulches.
- The study can also be conducted in a hectare field (large area) for getting better response of the sensor system.
- The study can be performed under different type of moisture sensors and wireless soil moisture probe.

REFERENCE

Al-Ghobari, H. M. and Marazky, M. S. A. El., 2012. Surface and Subsurface irrigation systems wetting patterns as affected by irrigation scheduling techniques in an arid region. African Journal of Agricultural Research Vol. 7(44), pp. 5562-5576.

Arbat, G., Puig-Bargues, J., Duran-Ros, M., Barragan, J., Cartegena, F.R., 2009. Irrigation Performance and Water Productivity in Ornamental Plant Production in Girona (Spain). Research Gate. Paper Number: 096638.

Bhanu Rekha, K. and Mahavishnan, K., 2008. Drip fertigation in vegetable crops with emphasis on lady's finger (*Abelmoschus esculentus (L.) Moench*) - a review. *Agricultural Reviews*, 29 (4): 298 – 305.

Chavan, M.L., Khodke, U.M. And Jadhav, S.B. 2009. Hydraulic performance of manually operated drip irrigation system. *International J. of Agricultural Engineering*, Vol. 2(2): 273-277.

Dhanekula, H. and Kumar, K. K. 2016. GSM and Web Application Based Real-Time Automatic Irrigation System Using Raspberry Pi 2 and 8051. *Indian Journal of Science and Technology*. Vol.9 No.17.

Dukes, M. D., Munoz-Carpena, R., Bryan, H. and Klassen, W. 2003. *Proc. Fla. State hort. Soc.* 116: pp 80-85.

Elmaloglou, S. and Diamantopoulos, E. 2007. Wetting front advance patterns and water losses by deep percolation under the root zone as influenced by pulsed drip irrigation. *J. Agricultural water management* Vol. 90, 160-163.

Gaur, J.K., Yadav, S.M. and Singh, K.P. 2008. Micro irrigation technology for Horticultural Crops In: Workshop on Micro Irrigation Technology for Horticultural Crops in Chhattisgarh State, November 2007. p. 117-121.

Hezarjaribi, A., Dehghani, A. A., and Kiani, A. 2008. Hydraulic Performance of Various Trickle Irrigation Emitters. *Journals of Agronomy*, Vol.7 (3): 265-271.

Jorden, R., Automation of furrow irrigation. 2017. Information Sheet #1.

Kenjabaev, S., Dernedde, Y., Frede, Hans-Georg and Stulina, G. 2014. Determination of actual crop evapotranspiration (ETc) and dual crop coefficients (K_c) for cotton, wheat and maize in Fergana Valley: integration of the FAO-56 approach and BUDGET. Geophysical Research Abstracts, Vol. 16.

Kumar, S. and Singh, P. 2007. Evaluation of Hydraulic performance of Drip Irrigation System. *J. of Agricultural Engineering*, Vol. 44(2).

Kumar, R., Shankar, V. and Kumar, M. 2011. Evaluation of evapotranspiration models for pea (pisum sativum) in mid hill zone-India. *Universal J. of Environmental Research and Technology*, Vol. 1(3): 329-337.

Kumar, J., Patel, N. and Rajput, T. B. S. 2015. Development and integration of soil moisture sensor with drip system for precise irrigation scheduling through mobile phone. *Journal of Applied and Natural Science 8(4).* pp. 1959-1965.

Kumar, M. K. and Ravi, K. S. 2016. Automation of Irrigation System based on Wi-Fi Technology and IOT. *Indian Journal of Science and Technology*. Vol 9 (17).

Kumar, P. P. and Raja, M. A. 2016. Design and Implementation of Intelligent Irrigation System Using Wireless Sensor Network. *Asian Journal of Research in Social Sciences and Humanities.* Vol.6 No.9, pp. 1105-1117

Kyada, P.M. and Munjapara, B.J. 2013. Study on pressure-discharge relationship and wetting Pattern under drip irrigation system. Vol. 4(2): 274-283.

Manisha, Sinha, J. and Tripathi, M.P. 2015. Studies on hydraulic performance of drip irrigation system under different operating pressure. *International J. of Applied Engineering and Technology*. Vol. 5(2): 58-63.

Mazahrih, N.Th., AL-Zu'bi,Y., Ghnaim, H., Lababdeh, L., Ghananeem, M. and Ahmadeh, H.A. 2012. Determination actual evapotranspiration and crop coefficients of date palm trees (phoenix dactylifera) in the jordan valley. *American-Eurasian J. Agric. & Environ. Sci.*, 12(4): 434-443.

Michal, A.M., 2011. Irrigation theory and practices second Edition. pp.489

Mahadeen, A.Y. 2014.Effect of polyethylene black plastic mulch on growth and yield of two summer vegetable crops under rain-fed conditions under semi-arid region conditions. *American Journal of Agricultural and Biological Sciences* 9 (2): 202-207.

Mohammed A. Almajeed A. Alabas 2013.evaluation the Hydraulic Performance of Drip Irrigation System with Multi Cases. *Global Journal of Researches in Engineering General Engineering*, Volume 13 Issue 2 Version 1.0.

Nagarajan, G. & Minu, R.I. 2018. Wireless Soil Monitoring Sensor for Sprinkler Irrigation Automation System. *J. Wireless Pers Commun.* Vol. 98: 1835-1851.

Nallani. Sandeep. and Hency. V. Berlin., 2015.Low Power Cost Effective Automatic Irrigation System. *Indian Journal of Science and Technology*, Vol 8(23).

Nobal, Abraham., Hema, P. S., Saritha, E. K. and Subramanniam, S. 1998. Irrigation automation based on soil electrical conductivity and leaf temperature. *J. Agricultural Water Management* 45(2000). pp.145-157.

Odofin, A. J., Oladiran, J. A., Oladipo, J.A. and Wuya, E.P. 2011. Determination of evapotranspiration and crop coefficients for bush okra (Corchorus olitorius) in a sub-humid area of Nigeria. *African J. of Agricultural Research,* Vol. 6(17), p. 3949-3953.

Osroosh, Y., Peters, T. R., Campbell, C. S. and Zhang, Q. 2016. Comparison of irrigation automation algorithms for drip-irrigated apple trees. *Computer and Electronics in Agriculture*. 128 pp. 87-99.

Owusu-Sekyere, J. D., Sam-Amoah, L. K., Teye, E. and Osei, B. P. 2012. Crop Coefficient (Kc), Water Requirement and The Effect of Deficit Irrigation on Tomato in The Coastal Savannah Zone of Ghana. International Journal of Science and Nature. Vol. 3(1) pp. 83-87.

Padiyaraju, V., Perumal, P. S., Ganapathy, S., Ramesh, L. S. and Kannan, A. 2015. Dynamic Waypoint Navigation Assisted Agricultural Flying Vehicle for Field Data Collection. *Asian Journal of Research in Social Sciences and Humanities.* Vol.6 No.12, pp. 448-457.

Popale, P.G., Bombale, V.T. and Magar, A.P. 2011. Hydraulic Performance of Drip Irrigation System. *J. Engineering and Technology in India,* Vol. 2(1&2), p. 24-28.

Punamhoro, P. B. N, Chowdhary, B.M. and Kandeyang, S. 2003. Performance of different irrigation methods in okra (*Abelmoschus esculentus* (L.) Moench). *J. Res. BAU,* 15(2): 205-210.

Rani, K. S. S. and Indhumathi, N. 2016. An Efficient Modern Irrigation and Plant Growth Monitoring System Using Sensor Network. *Asian Journal of Research in Social Sciences and Humanities.* Vol.6 No.8, pp.350-359

Reddy, M. Ayyanagowdar, M.S., Nemichandrappa, M., Balakrishnan, P., Patil, M.G., Polisgowdar, B.S. and Satishkumar, U. 2012. *Karnataka J. Agric. Sci.,* 25(4): 475- 478.

Rajagopal, V., Maheshwari, P. Uma. And Deepalakshmi, N. 2016. Precision Irrigation Using Wireless Sensor Networks for Indian Agriculture-A Survey. *Asian Journal of Research in Social Sciences and Humanities*. Vol.6 No.7, pp. 324-333.

Rekha, K.B., Reddy, M.G. and Mahavishnan, K. 2005. Nitrogen and water use efficiency of bhendi (*Abelmoschus esculentus L.* Moench) as influenced by drip fertigation. *J. of Tropical Agriculture,* Vol. 43(1-2): 43-46.

Saha.R., Raghuwanshi, N.S., Upadhyaya, S.K., Wallender, W. W., Slaughter, D.C., 2011. Water sensors with cellular system eliminate tail water drainage in alfalfa irrigation. *Journal of California Agriculture,* Vol.65(4).

Shashi Kant, 2016.Studies on Level of Drip Irrigation and Suitability of Used Plastic Material as Mulch for Growing *Rabi* Marigold (*Tagetes erecta*) Unpublished M.tech Thesis. Department of Soil and Water Engineering, SVCAET & RS, Faculty of Agricultural Engineering, IGKV, Raipur.

Safi, B., Neyshabouri, M.R., Nuzemi, A.H., Massina, S. and Mirlatifi, S.M. 2007. Water Application Uniformity of a Sub Surface Drip Irrigation System at Various Operating Pressure and Tape Lengths. *Turk J. Agric*. For 31, 275-285.

Sahu, R. K. and Rao, V. N. 2005. Faculty of Agricultural Engineering IGKV Raipur, *J. of Drainage and irrigation water management*, 118-135.

Sharma. H., Shukla. M. K. and Bosland, P. W. 2013. Chile root water uptake under partial root drying: a greenhouse drip irrigated study. Conference: 2013 Irrigation Show & Education Conference, At Austin, TX.

Sharma, P. 2013. Hydraulic Performance of Drip Irrigation under Field Condition. IOSR *J. of Agricultural and Veterinary Science*, Vol. 2(1) p. 15-20.

Siddapur, A.D., Polisgowdar, B.S., Hiremath, R., Nemichandrappa, M., kumar, S., Hugar, A.H., Honnali, S.N., and Yadahalli G.S. 2014. Evaluation of surface and drip irrigation methods for marigold flower (*Tagetes erecta* L.) under Raichur condition. Research Article, Acta Biologica Indica, 3(1): 610-616.

Singh, R., Kumar, S., Nangare, D.D. and Meena, M.S. 2009. Drip Irrigation and Black Polyethylene Mulch Influence on Growth, Yield and Water-use Efficiency of Tomato. *African J. of Agricultural Research*, Vol. 4(12), p. 1427-1430.

Sivamani, S., Choi, J., Bae, K., Ko, J. and Cho, Y. 2017. A smart service model in greenhouse environment using event-based security based on wireless sensor network. *Concurrency Computat: Pract Exper*. e4240.

Soomro, Kamran Bukhsh., Sahito, Hakim Ali., Rind, Javaid Akhtar., Bhugro Mal1 and Kaleri, Sakhawat Hussain., 2012. Effect of marginal quality water on Okra, *Abelmoschus Esculentus I*. Yield under drip irrigation system. *Global Advanced Research Journal of Engineering, Technology and Innovation*, **1**(5): 103-112.

Snyder, R.L., Geng, S., Orang, M. and Sarreshteh, S. 2012. Calculation and simulation of evapotranspiration of applied water. *J. of Integrative Agriculture*, 11(3): 489-501.

Stafford, J.V. and Hendrick, J.G. 1988. Dynamic sensing of soil pans. Transactions of the ASAE 31 (1), 9–13.

Stefanos A. N., Kandris. D., Vergados, D. D. and Douligeris, C. 2015. Energy efficient automated control of irrigation in agriculture by using wireless sensor networks. *Computer and Electronics in Agriculture* 113. pp. 154-163.

Tiwari, K.N., Mal, P.K., Singh R.M. and Chattopadhyay, A. 1998. Response of okra (*Abelmoschus esculentus L.Moench*.) to drip irrigation under mulch and non-mulch conditions. *J. Agricultural water management*, 31: 91-102.

Vivek, S., Devaranavadgi, S., Shirahatti, S. and Patil, M.G. 2011. Effect of different drip irrigation levels on growth and yield of bitter gourd (*Momordica chanrantia.* L) in semiarid conditions of Karnataka. *International J. of Agricultural Engineering*, 4(2): 179-182.

Younis, A., Bhatti, M.Z.M., Riaz, A., Tariq, U., Arfan, M., Nadeem, M. and Ahsan, M. 2012. Effect of different types of mulching on growth and flowering of freesia Alba cv. Aurora. *Pak. J. Agri. Sci*. Vol. 49(4): 429-433.

Yuyang, S., Wang, Q. and Wang, C. 2011. Simulated and measured soil wetting patterns for overlap zone under double points sources of drip irrigation. *African J. of Biotechnology*. Vol. 10(63), p. 13744-13755.

APPENDIX

APPENDIX- A

Table: Electrical Connection Analog Input Module AI561

Terminal	Signal	Meaning
1	R0	Burden resistor for input signal 0 for current sensing
2	I0+	Plus pole of input signal 0
3	I0-	Minus pole of input signal 0
4	R1	Burden resistor for input signal 1 for current sensing
5	I1+	Plus pole of input signal 1
6	I1-	Minus pole of input signal 1
7	R2	Burden resistor for input signal 2 for current sensing
8	I2+	Plus pole of input signal 2
9	I2-	Minus pole of input signal 2
10	R3	Burden resistor for input signal 3 for current sensing
11	I3+	Plus pole of input signal 3
12	I3-	Minus pole of input signal 3
13	---	Reserved
14	---	Reserved
15	---	Reserved
16	---	Reserved
17	---	Reserved
18	SG	Signal ground
19	L+	Process voltage L+ (24 V DC)
20	M	Process voltage M (0 V DC)

APPENDIX- B

Table: Different range of input values

Range	-2.5v…+2.5V	-5..+5V	0…..5V	0…..10V	0…..20mA	4mA….20mA	Digital value	
							decimal	hex.
overflow	>2.9397	>5.8795	>5.8795	>11.7589	>23.5178	>22.8142	32767	7FF
Measured	2.9397	5.8795	5.8795	11.7589	23.5178	22.8142	32511	7EFF
value too	:	:	:	:	:	:	:	:
high	2.5014	5.0029	5.0015	10.0029	20.0058	20.0058	27664	6C10
Normal	2.500	5.000	5.000	10.000	20.000	20.000	27648	6C00
range	:	:	:	:	:	:	:	:
	0.0014	0.0029	0.0015	0.0029	0.0058	4.058	16108	0010
	0.0000	0.0000	0.0000	0.0000	0	4	0	0000
Normal	-0.0014	-0.0029				3.9942	-10	FFF6
range or	:	:				:	-16	FFF0
measured	:	:				:	-4864	ED00
value too	-2.50000	-5.000				0	-6912	E500
low								
Measured	-25014	-5.0029					-27664	93F0
value too	:	:					:	:
low	-2938	-5.8795					-32512	8100
Underflow	<-2.9396	<-5.8795	<-0.030	<-0.0600	<-0.1200	<-0.1200	-32768	8000

APPENDIX- C

Table C-1 Statuses of the LEDs:

LED	Status	Colour	LED =OFF	LED = ON	LED flashes
PWR	Process voltage 24 V DC via terminal	Green	CPC module voltage or external 24 V DC supply Voltage is missing	3.3 V system voltage (IO-Bus) and external 24 V DC supply voltage are present	----
ERR	Channel or module error	Red	No error or process voltage is missing	Serious error in the module	Error on 1 or more channels of the module

Table C-2 Specification of the Probe

Range	0 to 100%
Accuracy	±4 %
Power	5V
Dimensions	8.9×1.8×0.7 cm

Table C-3 Different input values to use check accuracy

4 analog input, individually configurable	-2.5V - +2.5 V 5V - +5 V 0 - +5 V 0--+10 V 0-20 mA 4-20 mA

Table C-4 Resolution of the Analog Channel

Voltage bipolar (-2.5v...+2.5V;-5V…+5V)	11 bits plus sign
Voltage unipolar (0V-5V; 0V-10V)	12 bits
Current (0mA-20mA; 4mA-20mA)	12 bits
LED Displays	2 LEDs for process voltage and error messages
Internal supply	Through I/O -Bus
External supply	Through the terminals L+(process voltage 24 V DC) and M (o V DC); the M terminal is connected to the M terminal of the CPU via the I/O- Bus

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