

**Developing design of Automated Micro Irrigation
System for higher water productivity in JNKVV
farms**

THESIS

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Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

**In partial fulfillment of the requirements for
the Degree of**

MASTER OF TECHNOLOGY

In

AGRICULTURAL ENGINEERING

(Soil and Water Engineering)

By

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2019

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This is to certify that the thesis entitled “**Developing design of Automated Micro Irrigation System for higher water productivity in JNKVV farms**” submitted in partial fulfillment of the requirement for the degree of **MASTER OF TECHNOLOGY in Agricultural Engineering (Soil and Water Engineering)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Ms. Shilpee Shrivastava** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.

All the assistance and help received during the course of the investigation has been acknowledged by her.

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LIST OF ABBREVIATIONS

Abbreviations/Symbols	Stands for
ASAE	American society of Agricultural Engineers
AMIS	Automated Micro Irrigation System
Atm.	Atmosphere
B.D	Bulk Density
C	Friction coefficient for pipe
CAE	College of Agricultural Engineering
C_d	Coefficient of discharge
Cm	Centimeter
Cm^2	Centimeter square
U_c	Uniformity coefficient
DDIR	Design daily irrigation requirement
Dia.	Diameter
D_u	Distribution uniformity
D_l	Diameter of lateral
D_m	Diameter of main
ET	Evapotranspiration
ET_c	Crop evapotranspiration
ET_0	Reference evapotranspiration
F.C.	Field capacity
Ft	Foot
GSM	Global system for mobile communication
Ha	Hectare
ΔH	Total head loss
ΔH_l	Friction head loss in lateral
ΔH_m	Friction head loss in main
HDPE	High density polyethylene

JNKVV	Jawaharlal Nehru krishi vishva vidhyalay
K_d	Discharge coefficient
L_l	Length of lateral
L_m	Length of main
lit/sec	Liters per second
lit/hr	Liters per hours
LCD	Liquid crystal display
M	Meter
Mm	Milli meter
mm/m	Millimeter per meter
MAD	Management allowed deficit
mm/day	Millimeter per day
PWP	Permanent wilting point
PVC	Poly vinyl chloride
Rpm	Revolution per minute
UART	Universal asynchronous receiver ,transmitter
X	Discharge exponent

INTRODUCTION

Water required by crops is supplied by nature in the form of precipitation, but when it becomes scarce or its distribution does not coincide with demand peaks, it is then necessary to supply it artificially, by irrigation. Several irrigation methods are available, and the selection of one depends on factors such as water availability, crop, soil characteristics, land topography, and associated cost. In the near future, irrigated agriculture will need to produce two-thirds of the increase in food products required by a larger population (English *et al.*, 2002). The growing dependence on irrigated agriculture coincides with an accelerated competition for water and increased awareness of unintended negative consequences of poor design and management (Cai *et al.*, 2003).

Optimum management of available water resources at farm level is needed because of increasing demands, limited resources, water table variation in space and time, and soil contamination (Kumar and Singh, 2003). Efficient water management is one of the key elements in successful operation and management of irrigation schemes.

Irrigation water management involves determining when to irrigate, the amount of water to apply at each irrigation event and during each stage of plant, and operating and maintaining the irrigation system. The main water management objective is to manage the production system for profit without compromising environment and in agreement with water availability. A major managerial activity involves irrigation scheduling or determining when and how much water to apply, considering the irrigation method and other field characteristics. Under limitations in water availability, it is required to develop new irrigation scheduling approaches focused on to ensure optimal use of available water, and not based on full crop water requirements. The determination of these efficient and effective irrigation schedules (including deficit irrigation strategies) requires the accurate determination of water requirements for the main crops, in order to assist the farmers in deciding when and how much to irrigate their crops.

New technologies such as remote sensing modeling and lysimeter are contributing to obtain a better knowledge of the crop agronomy and irrigation, detecting water stress, determining crop water requirements and obtaining accurate

irrigation schedules. Irrigation technology has made significant advances in recent years. Criteria and procedures have been developed to improve and rationalize practices to apply water, through soil leveling, irrigation system design, discharge regulations, adduction structures, and control equipment. Playán and Mateos (2006) mentioned that modernized irrigation systems at farm level implies selecting the appropriate irrigation system and strategy according to the water availability, the characteristics of climate, soil and crop, the economic and social circumstances, and the constraints of the distribution system.

The state of Madhya Pradesh is basically based on agricultural activities with total geographical area of 30.75 million ha, in which the net cultivable area is 14.62 million ha. Since 2010, the Government of MP has embarked on an ambitious irrigation expansion and modernization plan. New developments, infrastructure modernization and substantial management and operation improvement led to an increase in net irrigation area from 0.85 million ha in 2006 to 3.6 million ha in 2017–2018. These efforts have been rewarded by record annual agricultural growth of 20% in 2013–2016. The state plans to further increase the total irrigated area to 7.2 million ha. by 2025. This will be achieved by maximizing irrigation efficiency and water productivity in both new and existing irrigation systems. It includes development of pressurized irrigation, adoption of micro-irrigation and production of high-value crops.

The state has set the ambitious target of developing pressurized irrigation in 80% of all irrigated areas by 2025 (Anonymous, 2018). Irrigation is an important and essential agricultural practice. The bulk of the irrigation water is sourced from the river, wells, tube wells etc. via various pipeline to direct supply to the field by various surface irrigation method. The existing system has several limitations such as conveyance losses, leaching of soil nutrients, erosion due to flooding, loss of water through evaporation, water wastage which can result to lots of loss of water. Therefore irrigation efficiency is very low similar the water productivity. In the existing system the farmer has to keep continuous watch on the crop that when to irrigate the crop. Beside this, this system does not give answer that how much to irrigate. This also accounts losses to precious amount of ground water. Automated Micro Irrigation System (AMIS) has emerged as a new tool for precise irrigation.

Automated Micro Irrigation System (AMIS) is the use of equipment that allows the irrigation process to proceed with minimum human involvement, except for

periodical inception and routine maintenance. The JNKVV has most area for agriculture research and seed production. It has mostly surface irrigation and sprinkler irrigation in parts.

The efficient irrigation system shall improve its water productivity therefore, the present study is proposed with specific objectives:

1. To study present irrigation status in farm units of JNKVV Jabalpur.
2. To develop design of automated micro irrigation system for higher water productivity.

REVIEW OF LITERATURE

This chapter deals with the literature of the research works that has been carried out in India and abroad, which is related to the proposed objectives.

In the state of MP 47 % (Anonymous 2018) of the cultivable area has assured irrigation, through command areas, tube wells, ponds and wells. In past three decades, the state has developed several command areas though large and medium and small irrigation projects in ten river basins. Water Resource Department manages the water stored during the monsoon, in about 5000 dams and tanks, which is provided mainly for *Rabi* crops and supplemental irrigation for Kharif crops. Apart from these command areas , tube wells and wells are the main source for assured irrigation . Continuous extraction of precious ground water is reducing the water level at an alarming rate. Through these two water resources; irrigation is being provided through various methods of surface irrigation, which causes severe conveyance and evaporation losses up to 60 % . The farmers are using different surface irrigation techniques through manual control in which the farmers irrigate the land at required interval. This process sometimes consumes more water or sometimes the water reaches late due to which the crops get dried.. To increase the productivity, uses of sprinkler and drip irrigation have also increased manifolds. However in this system, the farmer has to keep continuous watch on the crop that when to irrigate the crop. Beside this, this system does not give answer that how much to irrigate. This also accounts losses to precious amount of ground water. Automated Micro Irrigation System (AMIS) has emerged as a new tool to for precise irrigation.

Soil Property Analysis

Anonymous (2001) studied infiltration ate (Table 2.1) of soli profile indicating upper limits for irrigation application rates on various soil texture in the river. More accurate readings can be obtained in field measurement of actual infiltration rates, as they are known to vary between soils of similar texture.

Table 2.1 Indicative Infiltration Rate for Soil Texture

Texture	Infiltration rate (mm/hr)
Sand	13
Loamy sand	12
Sandy loam	10
Light sandy clay loam	7
Sandy clay loam	5
Light clay	5
Light clay	4
Medium clay	3

Bauder (2004) studied on the available water holding capacity of soil is a function of the texture. This is the amount of water that would and could be made available to plant after the soil has been irrigated (Table 2.2)

Table 2.2 Available Water Holding Capacity of Soils

Soil Texture	Inches of water per cubic feet of moist soil
Sandy and fine sand	0.75
Very fine sand, loamy sand	1.00
Sandy loam	1.5
Loam	1.90
Silt loam, silt	2.20
Silty clay loam	1.90
Clay loam, sandy clay loam	1.70

The model presented by Philip (1957) is given as

$$Y = St^{1/2} + At \dots\dots\dots\text{Eq. (1)}$$

Which on differentiation with respect to time and yields

$$I = 0.5St^{-1/2} + A \dots\dots\dots\text{Eq. (2)}$$

Where,

I = infiltration rate, cm/h

Y = cumulative infiltration, cm

T = time, h

S and A = soil constants

According to Philip (1957) the absorptivity, S is dependent on the initial moisture content of the soil while A is property of the medium and is also dependent upon the initial moisture of the soil. The term on the right hand side of the equation (1) described the contribution to the infiltration arising from the capillarity, while second term represents essentially a contribution arising from gravity. According to Hillel (1982), infiltration equation developed by Kostikov's has the form

$$I = Bt^{-n}$$

Where,

I = infiltration rate,

t = time and parameter B and n are empirical constants.

These two constants can be estimated by plotting log i against log t, then log B and n are slope respectively of the resulting straight line.

Gregory *et al.* (2005) introduced the Infiltration methodology by which water moves descending at the soil surface pass in the soil. This system influences surface runoff, soil erosion, and groundwater recharge.. The double-ring infiltrometer is regularly utilized for measuring invasion rates. The utilization of more modest diameter inner and outer rings (15 and 30 cm, separately) with a constant head gave comes about that were factually higher than the ASTM standard test and the falling head test with little rings. The setup of the double-ring infiltrometer with the Mariotte siphon has an efficient technique for leading a double-ring infiltrometer test this testing technique thusly just obliges one man to keep up the head in the outer ring and record the change in water level in the siphon .The consequences of the measured penetration rates from the three diverse testing strategies. Measured penetration rates on the sandy soil went from 22 to 225 mm/h and normal 143 mm/h over all tests. These rates are illustrative of modestly compacted fine sandy soils, for example, has been reported on pasture destinations.

Osuji *et al.* (2010) introduced the infiltration characteristics of soils under four different land-use practices in Southeastern Nigeria. The land-use practices considered were: arable crop land, bush fallow, continuously cultivated land and pineapple orchard. Infiltration rates were determined at the sites using double ring infiltrometer. They found that the average steady were 16.4, 26.4, 23.4 and 19 cm/h for the arable crop land, bush fallow, continuously cultivated land and pineapple

orchard, respectively. Results showed that bush fallow land had the maximum average infiltration rate while arable crop land experienced the least average infiltration rate.

Analysis of Water Productivity

Ali *et al.* (2008) introduced the improvement of water use efficiency is a mean to improve drought tolerance of crops. Crop production expressed in terms of the total biomass or seeds weight or even in monetary units when production is transferred to monetary units. The more common way of express water productivity is as the ratio of yield to water supply or total evapo transpiration (evaporation; the loss of water from the soil, and transpiration: is the loss of water from the plant).

El-Wahed *et al.* (2015) introduced the effect of the sprinkler irrigation system design on irrigation uniformity and its impact on barley crop yield and crop water productivity (CWP). The spring irrigation operating pressures (P) were 200 KPa (P1), 250 KPa (P2) and 300 KPa (P3). The sprinkler riser heights were 100 cm (H1), 125 cm (H2) and 150 cm (H3) from the ground. The results demonstrated that the maximum values of coefficient of uniformity (CU) and distribution uniformity (DU) (91.37 % and 0.85, respectively) were obtained at P3H3, while the minimum values (78.21 % and 0.71, respectively) were obtained at P1H1. Under P3H3 treatment, the highest values of 5.50 t ha⁻¹ and 63.49 cm of grain yield (GY) and barely plant height (PH), respectively were recorded. The highest CWP value (0.75 kg m⁻³) was obtained when the P3H3 treatment was applied, while the lowest yield (0.36 kg m⁻³) was recorded under P1H1 treatment.

Soni *et al.* (2016) introduced that Improved Practice on wheat variety GW-273 were conducted on farmers' fields in Villages Bichhua and Sanjari of Kundam Block of Jabalpur district during Rabi season of the year 2014-15. They found that the yield of wheat in improved irrigation conditions ranges from 24.20 to 42.20 q/ha whereas in farmers' practices it ranges between 16.72 to 38.93 q/ha. The per cent increase in yield with Improved Practice over farmers' practices was recorded in the range of 0.05 to 76.68. The data revealed that improved wheat technology given additional average yield of 7.06 quintal per hectare as yield parameter of the area. Water productivity of farmer practice varies from 0.82 to 1.22 Kg/m³ whereas water productivity of demonstration of improved practice ranging between 0.97 to 1.32 Kg/m³.

Sharma *et al.* (2018) the studies were carried out on farmer's field in few villages of Ganjbasoda block in Vidisha district to evaluate different irrigation technologies (surface border, sprinkler pressurized method) for their effect on yield attributes and water productivity of wheat in vertisol of Vidisha district of Betwa river command. Results revealed that water saving of about 12.5% higher in case of pressurized sprinkler irrigation method as compare with the surface border method. The growth and yield attributing components were considerably improved under pressurized sprinkler irrigation method compare to surface border method. The grain yield was 16.22% higher in pressurized sprinkler method than that in surface irrigation border method. Data also revealed that water productivity of sprinkler irrigated wheat was 30.76% more than the border irrigated wheat.

Analysis of Micro Irrigation System

Mahar *et al.* (2001) developed a methodology to select a sprinkler lateral from different design alternatives for duration shorter than its full life cycle. The selection was made by determining the time period up to which an alternative would be more economical than others. A procedure was developed for selecting a sprinkler lateral in the case of an owner wanting either to change the enterprise or to replace the system before the end of the life cycle.

Valiantzas (2003) developed a new simple equation, which is derived to solve explicitly the economic design problem of sub main lines (micro irrigation manifold and sprinkler irrigation sub mains with pumping. The explicit economic design is demonstrated in two design examples. Comparisons with previous methods and numerical models indicated the good performance of the suggested solution.

Kadam *et al.* (2006) studied the field performance of micro-sprinkler in terms of uniformity as influenced by the operating pressure and micro-sprinkler spacing was evaluated. Uniformity decreased with the increase the spacing from 1.5 X 1.5m to 3.75m X 3.75m. With increase in the operating head from 0.75 to 2.0 kg/cm², uniformity increased. For the rotating head micro-sprinkler, the spacing of 1.5m x1.5m may be used with operating head pressure of 1.0 kg/cm² and 2.25m X 2.2.5m for 2.0 kg/cm².

Romero *et al.* (2006) analyzed the annual water application costs per unit area (ha) and analyzed subunit of sprinkler irrigation systems designed with pipes of different materials. This study concluded that the permanent sprinkler system using

PVC (buried), produced the lowest annual water application cost per unit area in comparison with other three surface solid-set systems. The parameters considered in this study are the total annual cost, water cost, energy and labour.

Bhakar *et al.* (2008) evaluated the performance characteristics of micro-sprinkler was evaluated under various operating conditions in respect of pressure-discharge relationship and field performance in terms of uniformity coefficient, emission uniformity, and distribution uniformity. Suitable operating pressure ranging from 0.75 to 2.0 kg/cm² and spacing between micro-sprinklers 1.5 x 1.5 m, 2.25 x 2.25 m, 3.0 x 3.0 m and 3.75 x 3.75 m were tested for pressure discharge relationship as well as uniformity coefficient, emission uniformity and distribution uniformity under low wind speed condition. Pressure discharge relationship was developed in the form of power equation $Q = 44.45 P^{0.78}$. The emission uniformity was found to be more than 90%. The uniformity coefficient and distribution uniformity increased with increasing operating pressure and decreased with increase in micro-sprinkler spacing. Based on operating conditions it was concluded that the micro-sprinkler should be operated at a pressure range of 1.5 to 2.0 kg/cm² and at a spacing of 1.5 x 1.5 m.

Analysis of Automated Micro Irrigation System

Jin *et al.* (2007) introduced a GSM-SMS remote measurement and control system for greenhouse based on PC based database system connected with base station. Base stations developed by using a microcontroller, GSM module, sensor and actuators. In practical operation, the central station receives and send messages through GSM module. Criterion value of parameters to be measured in every base station is set by central station, and then in base stations parameters including the air temperature, the air humidity.

Ahmed *et al.* (2011) introduced a Low cost soil moisture monitoring system. In this describes a PC controlled irrigation monitoring and controlling system with wireless communication. The design of the overall system is based on: the system must provide consistent soil moisture measurements at low cost; the system must interface with an irrigation system to allow for automatic watering of the soil; and the measurement units must be unobtrusive to everybody activity. PIC is used with Linux wireless system which used Amplitude Modulation to transmit data.

Ingale *et al.* (2012) introduced a circuit which is cheap and reliable to

develop an automated irrigation system. The system provides with several benefits and can operate with less manpower. The system supplies water only when the humidity in the soil goes below the reference. Due to the direct transfer of water to the roots water conservation takes place and also helps to maintain the moisture to soil ratio at the root zone constant to some extent. Thus the system is efficient and compatible to the changing environment. Also the system saves the water and improves the growth of plants.

Chandrasekhar *et al.* (2013) developed an automatic drip irrigation system using low cost sensors and simple circuitry. Irrigation system uses valves to turn irrigation ON and OFF. These valves may be easily automated by using controllers and solenoids. The humidity sensors are constructed using aluminum sheets and housed in easily available materials. The aim is to use the readily available material to construct low cost sensors. Five relays are controlled by the microcontroller through the high current driver IC, ULN2003. Four relays are provided for controlling four solenoid valves, which controls the flow of water to four different parts of the field. One relay is used to shut-off the main motor which is used to pump the water to the field.

Kumar *et al.* (2013) developed soil moisture sensor based automatic drip irrigation system that checks the moisture content in the soil, based on that pumping motor will automatically pumps the water into the field. By using this sensor, we can find whether the soil is wet or dry. If it is dry, pumping motor will pump the water. In this system, the main controlling device is microcontroller. Here soil sensor will give the status of the soil to the microcontroller, based on that microcontroller will display the status of the soil on the liquid crystal display (LCD) and switch on or off the pumping motor through relay. The pumping motor will pump the water into the field by using drip water system until the field is wet which is continuously monitor by the microcontroller. In irrigation process, most parameter of monitoring is soil, so we have to monitor the soil condition, whether the soil is dry or wet. If it is dry, then by using pumping motor, water has to be pumped automatically. The main aim of our system presenting here is to monitor the moisture content in the soil in cultivating field. Based on soil moisture, pumping motor will be automatically switch on or off through relay. This saves the water at the same time and on the other hand the plant can get optimum level of water, so increasing productivity of crop.

Kumar *et al.* (2013) discussed the prototype design of microcontroller based

Intelligent irrigation system which will allow irrigation to take place in zones where watering is required, while bypassing zones where adequate soil moisture is indicated. Most soil moisture sensors are designed to estimate soil volumetric water content based on the dielectric constant (soil bulk permittivity) of the soil. The dielectric constant can be thought of as the soil's ability to transmit electricity. The dielectric constant of soil increases as the water content of the soil increases. This response is due to the fact that the dielectric constant of water is much larger than the other soil components, including air. Thus, measurement of the dielectric constant gives a predictable estimation of water content. Soil moisture sensors measure the water content in soil. A soil moisture probe is made up of multiple soil moisture sensors. One common type of soil moisture sensors in commercial use is a Frequency domain sensor such as a capacitance sensor. Another sensor, the neutron moisture gauge, utilize the moderator properties of water for neutrons. Cheaper sensors -often for home use- are based on two electrodes measuring the resistance of the soil. Sometimes this simply consists of two bare (galvanized) wires, but there are also probes with wires embedded in gypsum.

Luciana *et al.* (2013) used temperature sensor and soil moisture sensor to measure the soil and weather conditions of the field. The temperature and moisture values from the sensors are sensed to the microcontroller and thus current temperature and moisture are compared with predefined values. According to the temperature and moisture value, required amount of water is supplied to the crops. The sensed temperature and moisture were displayed in the liquid crystal display.

Pavithara *et.al.* (2014) introduced the irrigation by monitoring the soil moisture and temperature for the use of sensor .it is an incorporate Bluetooth for remote monitoring which reduce the problem of range with GSM network and saves the SMS cost .it should avoid over irrigation , under irrigation , top soil erosion and system can be changed according to the situation .

Chavan *et al.* (2014) introduced a Zigbee based remote monitoring system as an efficient method to detect the environmental factors such as soil moisture, humidity and temperature. it analyses the values and sends information to the server which can be used when needed.

Rawal *et al.* (2017)introduced a system which can be used to switch on/off the water sprinkler according to soil moisture levels thereby automating the process of irrigation which is one of the most consuming activities in farming. The system

uses information from soil moisture sensor to irrigate soil which helps to prevent over or under irrigation of soil. Thus the system is a potential solution to the problems faced in the existing manual process.

MATERIAL AND METHODS

This chapter deals with the methodology adopted and theoretical considerations made for achieving the objectives of the present study. The details of the methods adopted for the estimation of existing water productivity and the design of automated micro irrigation system are described below:

3.1 General Description of the Area

3.1.1 Location and Extent

Jabalpur is situated between 22°29'N and 20°48'N latitude and 78°21'E and 80°58' E longitude with an altitude of 411.78 meters above mean sea level. As a whole, the farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur occupies an approximate area of 459 hectares. This is divided into various farm units.

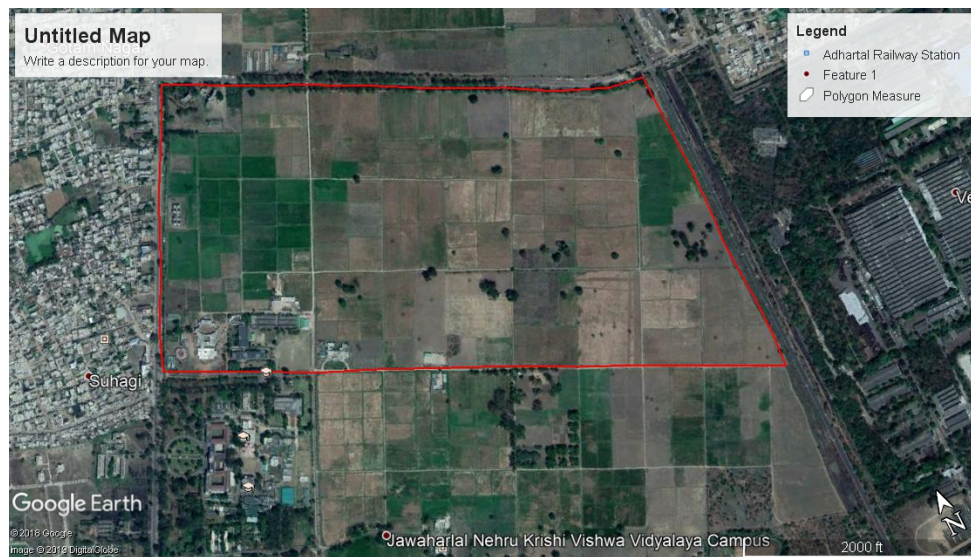


Fig. 3.1 Breeder Seed Production Unit of Soybean, JNKVV Jabalpur

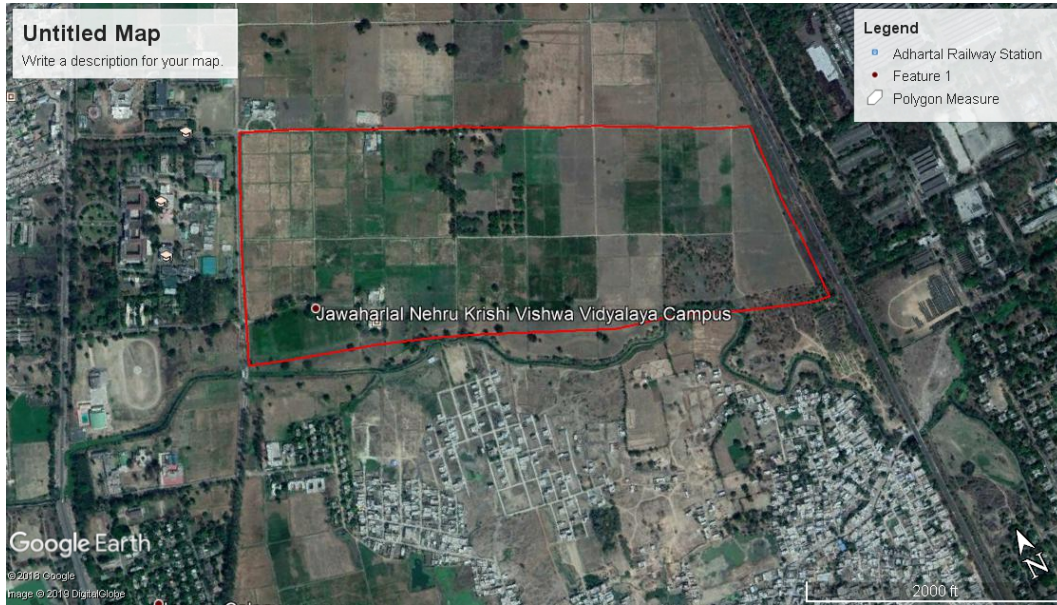


Fig. 3.2 Breeder Seed Production Unit of Groundnut, JNKVV Jabalpur



Fig. 3.3 Vegetable Farm Maharajpur, JNKVV Jabalpur

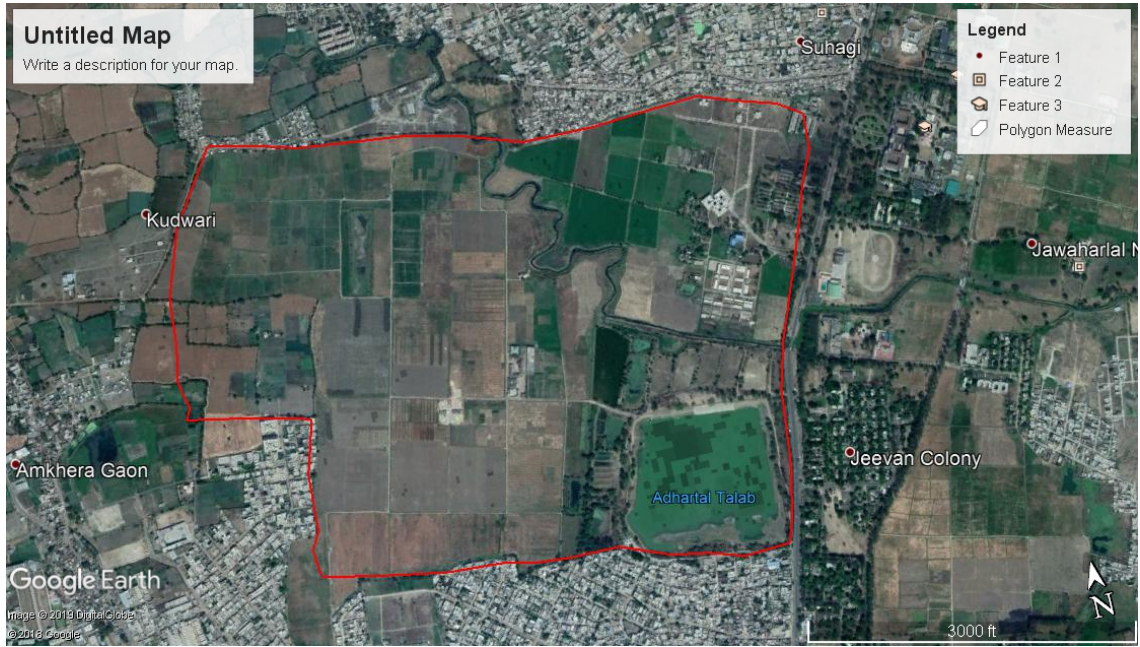


Fig 3.5 Breeder Seed Production unit of Farm Crops, JNKVV Jabalpur



Fig 3.6 Horticulture Farm Imaliya, JNKVV Jabalpur

3.1.2 Climate

The average climatic data of past six years i.e. from 2010 to 2016 were collected from the Meteorological Station, College of Agricultural Engineering, JNKVV, Jabalpur (M.P.) The climate of Jawaharlal Nehru Krishi Vishwa Vidyalaya Farm, Jabalpur, Madhya Pradesh is hot sub humid. The hot (summer) season extends from March to June when soil moisture is grossly deficient and the atmospheric conditions are hot and desiccating. During this season the plant growth activity is at its minimum and soil moisture is the main limiting factor. The rainy season extends from June to September when the moisture conditions are optimum and climate is hot and humid. Thus the general conditions for proper plant growth are most favorable. The cold season persists from mid October to March when soil moisture conditions are not critical for plant growth. Light winter showers usually occurring in the area, however, are useful in replenishing the soil moisture for plant use during early ensuing hot season. May is the hottest month with maximum average temperature raising up to 41.55°C. The coldest months are January and December with minimum average temperature lowering up to 8.62°C. Most of the rainfall is received from south western monsoon which generally breaks in the second week of June. The average annual rainfall is 1434.71 mm of which more than 85 per cent of the rains is received during monsoon months.

Mean Annual Soil Temp. (MAST) of J.N.K.V.V. has been calculated to be 25.54' C($19.02+32.06/2$) and the difference between the Mean Summer Soil Temp. (MSST) and Mean Winter Soil Temp. (MWST) exceeds 50 °C ($30.14-20.31$) = 9.83 °C.

3.2 Methodology for Infiltration Rate of Soil

To have the accurate knowledge of infiltration rate Double ring infiltrometer was used in different farm unit.

Surface characteristics of the soil are important to know the amount of water which goes into the underground water and directly affects the amount of excess water which is to be removed by surface drainage system. The most important and representative property of the soil is the infiltration characteristics. Infiltration is the downward entry of water into the soil and controlled by surface conditions of the ground. The infiltration rate of the soil is determined with the help of the double cylinder infiltrometer. This consists of pounding water in an open bottom cylinder and observing the rate at which the level falls in it. Six sites were selected from the each

unit of field for determination of infiltration characteristics. Precautions were taken at the time of selecting a site that it must be free from shrinkage, cracks and vegetal matters. Mechanical analysis of the soil samples shows that soil type in the study area is clay loam. The equipments used for infiltration test were – cylinders of diameter 60cm and 30cm, driving plate, driving hammer, point gauge, stop watch and a container of known volume. Jute matting was used for avoiding the paddling and evaporation effect in the soil.

Table no. 3.1. Basic Soil Infiltration Rates

S.no.	Soil type	Basic infiltration rate (mm/hr)
1	Clay	1-7
2	Clay loam	7-15
3	Silt loam	15-25
4	Sandy loam	25-40
5	Sand	More than 40

Experimental Procedure:

Infiltration tests were conducted under different field conditions i.e. various farm unit of JNKVV Jabalpur which comes under the study area.

Double ring infiltrometer was used to measure the infiltration rate consists of two concentric metallic cylinders formed by 2 mm thick rolled sheet. The diameter of inner cylinder and outer cylinder was 30cm and 60cm respectively. Infiltration cylinders were placed and pressed firmly into the ground. The driving plate was placed and hammered slowly with the driving hammer to get cylinder going downward into the soil. Cylinders were driven to a depth of 10 cm. the gauge is placed inside at the side of the inner cylinder and reading was taken. The buffer pond was created around the inner cylinder by filling the water in between these two cylinders. The inner cylinder was filled with clean water to approximately 3/4th depth of the cylinder. Immediately after filling the water, the level reading was taken and level starts falling down. The readings of the level of the water were taken by the gauge at predicted time intervals. The observations were taken at an interval of 0.2hour, 0.4hour, 0.6hour, 0.8hour, 1.0hour, 1.2hour, 1.4hour, 1.6hour, and 1.8hour. As elapsed time increases, the rate of infiltration or level falling per unit of time

decreases and hence the interval for taking observation was also increased.

Table 3.2 Observed Infiltration Rate of BSP (Soybean)

S.no.	Time (hour)	Depth (cm)	Incremental depth (cm)	Observed infiltration rate (cm/hr)
1	0.2	1	1	4.98
2	0.4	1.4	0.4	1.98
3	0.6	1.7	0.3	1.5
4	0.8	1.9	0.2	0.996
5	1.0	2.1	0.2	0.996
6	1.2	2.25	0.15	0.75
7	1.4	2.35	0.1	0.498
8	1.6	2.4	0.05	0.246
9	1.8	2.45	0.05	0.246

Table 3.3 Observed Infiltration Rate of BSP (Groundnut)

S.no.	Time (hour)	Depth (cm)	Incremental depth (cm)	Observed infiltration rate (cm/hr)
1	0.2	1	1	4.5
2	0.4	1.3	0.3	2.0
3	0.6	1.6	0.3	1.6
4	0.8	1.9	0.3	0.99
5	1.0	2.0	0.1	0.87
6	1.2	2.2	0.2	0.74
7	1.4	2.42	0.2	0.52
8	1.6	2.4	0.02	0.32
9	1.8	2.4	0.02	0.32

Table 3.4 Observed infiltration rate of Vegetable Farm Maharajpur

S .no.	Time (hour)	Depth (cm)	Incremental depth (cm)	Observed infiltration rate (cm/hr)
1	0.2	1	1	4.50
2	0.4	1.5	0.5	2.3
3	0.6	1.9	0.4	2.0
4	0.8	2.0	0.1	1.9
5	1.0	2.2	0.2	1.2
6	1.2	2.25	0.05	0.96
7	1.4	2.3	0.1	0.52
8	1.6	2.5	0.2	0.34
9	1.8	2.5	0.2	0.34

Table 3.5 Observed Infiltration Rate of Horticulture Farm Imaliya

S .no.	Time (hour)	Depth (cm)	Incremental depth (cm)	Observed infiltration rate (cm/hr)
1	0.2	1	1	4.98
2	0.4	1.4	0.4	1.98
3	0.6	1.7	0.3	1.5
4	0.8	1.9	0.2	0.996
5	1.0	2.1	0.2	0.996
6	1.2	2.25	0.15	0.75
7	1.4	2.35	0.1	0.498
8	1.6	2.4	0.05	0.246
9	1.8	2.45	0.05	0.246

Table 3.6 Observed Infiltration Rate of BSP (Farm Crops)

S .no.	Time (hour)	Depth (cm)	Incremental depth (cm)	Observed infiltration rate (cm/hr)
1	0.2	1	1	4.50
2	0.4	1.5	0.5	2.3
3	0.6	1.9	0.4	2.0
4	0.8	2.0	0.1	1.9
5	1.0	2.2	0.2	1.2
6	1.2	2.25	0.05	0.96
7	1.4	2.3	0.1	0.52
8	1.6	2.5	0.2	0.34
9	1.8	2.5	0.2	0.34

Three equations namely Horton’s equation, Philip’s equation and Kostiakov’s equation were used to determined the infiltration rate.

Horton’s equation

A three parameter empirical model was presented by Horton (1940) has been used in hydrological modeling;

$$I(t) = I_c + (I_o - I_c) e^{-kt} \dots\dots\dots \text{Eq.(3.1)}$$

Where,

I (t) =infiltration rate at time t

I_c =constant and basic infiltration rate

I_o =initial infiltration rate

T =time

The constant k can be estimated by plotting ln (I_o – I_c / I – I_c) against elapsed time t as the slope of resulting line in which Y intercept is zero.

Philips equation

The model represented by Philip (1957) is given as

$$Y = St^{1/2} + At \dots\dots\dots \text{Eq. (3.2)}$$

Which on differentiation with respect to time

$$I = 0.5 St^{-1/2} + A \dots\dots\dots \text{Eq. (3.3)}$$

Where,

I = infiltration rate cm/hr

Y = cumulative infiltration, cm

T = time, hours

The two constant can be estimated by plotting $t^{-1/2}$ against infiltration rate (i), then S and A can be calculated as the slope and intercept of resulting straight line.

Kostikov's Equation

Kostikov (1932) proposed the following model for estimating the infiltration rate

$$I(t) = Bt^{-n} \dots\dots\dots\text{Eq. (3.4)}$$

Where,

I (t) = infiltration rate at time,

t = time

B and n are constant, $B > 0$ and $0 < n < 1$

These two constant estimated by plotting $\log I$ against $\log t$, then $\log B$ and n are calculated as the Y intercept and slope respectively of the resulting straight line.

3.3 Methodology adopted for Crop Water Requirement (CWR)

CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO 56.

CROPWAT 8.0 Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rain fed and irrigated conditions. All calculation procedures used in CROPWAT 8.0 are based on the two FAO publications of the Irrigation and Drainage Series, namely, No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements" and No. 33 titled "Yield response to water".

As a starting point, and only to be used when local data are not available, CROPWAT 8.0 includes standard crop and soil data. When local data are available, these data files can be easily modified or new ones can be created. Likewise, if local climatic data are not available, these can be obtained for over 5,000 stations worldwide from CLIMWAT, the associated climatic database. The development of

irrigation schedules in CROPWAT 8.0 is based on a daily soil-water balance using various user-defined options for water supply and irrigation management conditions. Scheme water supply is calculated according to the cropping pattern defined by the user, which can include up to 20 crops.

CROPWAT 8.0 uses the Penman- Montith method for calculating the reference crop evapo transpiration .these estimates are used in crop water requirement.

3.4 Cropping Intensity

Cropping intensity refers to rising of a number of crops from the same field during one agriculture year. Higher cropping intensity means that a higher portion of the net area is being cropped more than once during one agricultural year. This also implies higher productivity per unit of arable land during one agricultural year.

3.5 Irrigation Intensity

Intensity of irrigation is defined as the percentage of the irrigation proposed to be irrigated annually. Usually the areas irrigated during each crop season (Rabi, Kharif, etc) are expressed as a percentage of the CCA which represents the intensity of irrigation for the crop season.

3.6 Methodology adopted for the Design of Automated Micro Irrigation System

The JNKVV Jabalpur farm comprises five units which are being irrigated through 29 tube wells and 2 Nalas.

Table 3.7 different farm unit and available water sources

S. No	Unit name	Area (ha.)	Water source (Tube Wells)
1	BSP (Soys)	90.00..	10
2	BSP (GN)	80.00	01 + Nala
3	BSP (Veg.)	83.00	06
4	Horticulture Farm Imaliya	23.00	1
5	BSP (FC)	90.00	11

Hydraulic Design of the System

The basic objectives of hydraulic design of automated micro irrigation system is to obtain uniform distribution of water with desired rate of application ,the breakup of jet with small drop size are essential to minimize the structural deterioration of the soil surface. At the time to reduce energy requirement for system operation and to minimize the area of the coverage .following principles were involved in hydraulic design of the system.

1. Calculation of the discharge from the nozzle
2. Recommended pressure and discharge for the nozzle size.
3. Determination of the water spread area of the sprinkler.
4. Determinations of the index for jet break up and drop size.
5. Intake and optimum application rate
6. Selection of the appropriate soil moisture and temperature sensor and the location of the GSM unit.

3.6.1 Discharge from a Sprinkler Nozzle

The theoretical discharge of a sprinkler nozzle was computed from the orifice equation

$$q = C_d a (2gh)^{1/2} \dots\dots\dots\text{Eq.(3.5)}$$

Where,

q = nozzle discharge, m³/sec

a = cross sectional area of sprinkler nozzle, m²

h = pressure head at the nozzle, m

C_d = coefficient of discharge which is a function of friction and contraction losses

The coefficient of discharge of well designed ,small size nozzles varies from about 0.95 to 0.98 .some nozzles have coefficient as low as 0.80 . Normally, the larger the nozzle, the lower is coefficient, where the sprinkler has two nozzles; the discharge is the combine capacity of both.

3.6.2 Recommended Pressure and Discharge for Nozzle Size

In general over a wide range the relationship between pressure head and discharge from the sprinkler would be expressed by,

$$q = K_d \cdot H^x \dots\dots\dots\text{Eq.(3.6)}$$

Where,

q = sprinkler discharge lit/hr

K_d = appropriate discharge coefficient for sprinkler and nozzle combined
and the specific units used

H = sprinkler operating pressure, m

x = discharge exponent, usually 0.5 for sprinkler and micro sprayers.

Discharge coefficient (K_d) decreases slightly with increase in sprinkler operating pressure consequently increase in q .However, for practical purpose it is considered constant for a particular range of operating pressure.

3.6.3 Water Spread Area of Sprinkler

The irrigation area covered by a rotating head sprinkler might be estimated by using the formula suggested by Cavazza (Pillsbury, 1968),

$$A = \pi R^2 \dots\dots\dots \text{Eq.(3.7)}$$

In which, $R = 1.35 (dh)^{1/2}$

Where,

A = area covered by sprinkler, m^2

R = radius of wetted area covered by the sprinkler, m

D = diameter of sprinkler nozzle, mm

h = pressure head at the nozzle, m

Maximum area is covered when sprinkler jet makes an angle of 30 to 32° above horizontal.

3.6.4 Index for Jet Break –up

Break up of jet of water is necessary to obtain the uniformity of coverage and to minimize the droplet size. There is natural tendency of jet to break up because of air resistance. Generally, break up increase with pressure and by having slot in the nozzle .Slow rotation sprinklers, which makes about 0.67-1 rpm for small sprinkler and 0.25 -0.5 rpm for large sprinklers provides good coverage. The following empirical formula suggested by Tanda (Phillsbury, 1968) was used to calculate an index of jet break up.

$$P_d = h/(10 * q)^{0.4} \dots\dots\dots \text{Eq.(3.8)}$$

Where,

P_d = index for jet break up

h = pressure head at sprinkler nozzle, m

q = sprinkler discharge, lit/sec

If the value of P_d is greater than 2, the condition of the drop size is good; if it is 4, then the condition of drop size is best and if it is greater than 4, pressure being wasted.

Drop size is reduced as pressure increases or nozzle size decreases the mean drop diameter increases as the distance from sprinkler increases. Drop size can also be reduced by using means other than high pressure to cause jet break.

3.6.5 Application Rate of Sprinkler

It is extremely important parameter. The rate at which the sprinkler applies water on the soil surface, when a group of them are operating close together is called the application rate. This is measured in mm/hr.

The application rate depends on,

1. The size of the sprinkler nozzle
2. Operating pressure of the system
3. Pacing between the sprinkler

Increasing the nozzle size or pressure and bringing the sprinkler close together, will increase the application rate. When sprinkler application rate is too high, then runoff and erosion can occur. The average rate of application, often called 'precipitation intensity' and is obtained by dividing the discharge of sprinkler by its spacing.

Application rate = sprinkler discharge (lit/hr) / (lateral spacing, m * sprinkler spacing, m)

$$I = q / (S_l * S_m) \dots\dots\dots\text{Eq.(3.9)}$$

Where,

I = application rate, mm/hr

q = discharge of sprinkler, lit/hr

S_m = lateral spacing along the main or sub main, m

S_l = sprinkler spacing along the lateral, m

Normally, sprinkler irrigation systems are designed, such that no runoff occurs. Thus, the rate at which a sprinkler system is designed to apply water is less than the infiltration capacity of the soil that is the maximum rate at which water can enter the soil at a given time.

3.6.6 Sprinkler Spacing

Sprinkler selection is the process of choosing the sprinkler for the farm irrigation system. Sprinkler are normally selected on the basis of cost, operating pressure requirement and ability to provide designed daily irrigation requirements (DDIR) with acceptable uniformity without runoff. In addition to this, sprinklers must have proper nozzle angle, droplet size, distance of throw and application pattern characteristics for particular crop, soil and wind conditions.

There are numerous types and makes of sprinklers available with different manufacturers. The actual selection is based largely upon design information furnished by the manufacturer. It is necessary to procure the information of the sprinkler from the supplier. These brochures include the information in respect of operating pressure, corresponding discharges, throw diameter and rate of application.

Table 3.8 Sprinkler Discharge and Diameter of Spray at Different Operating Pressure

Nozzle size (mm)	Pressure of sprinkler (kg/cm ²)	Diameter of spray (m)	Discharge		Application rate at various sprinkler spacing (mm/hr)	
			lit/sec	lit/hr	12m*12m	13m*13m
3.2	1.5	22	0.1389	500	3.47	2.95
	2.0	23	0.1583	570	3.95	3.37
	3.0	25	0.1944	700	4.86	4.14
	4.0	26	0.225	810	5.62	4.79
3.5	1.5	23	0.1611	580	4.02	3.43
	2.0	24	0.1833	660	4.58	3.90
	3.0	26	0.2250	810	5.62	4.79
	4.0	27	0.2583	930	6.45	5.50
4.0	1.5	23	0.2027	730	5.06	4.31
	2.0	25	0.2361	850	5.90	5.02
	3.0	27	0.2861	1030	7.15	6.09
	4.0	28	0.3277	1180	8.19	6.98

Each manufacture should recommend a combination of nozzle sizes and operating pressure to give best break up of stream and distribution pattern for uniform application. Generally, single nozzle sprinklers are recommended only for small nozzles with limited diameter of coverage or for part circle sprinklers. Because the distribution and coverage depends on the angle of the stream from the horizontal and the rate of application, sprinklers should be selected from manufacturer's table given in the Appendix 1, 2 and 3.

3.6.7 Sprinkler Spacing

The basic criteria used for the selection of spacing for any given sprinkler nozzle pressure and wind velocity combination is the uniformity of water distribution. To achieve uniform distribution of water, it is necessary to overlap the area of influence of the sprinklers. The overlapping area increases with the increases in wind velocity. Table 3.9 may be used as a guideline in the design of sprinkler under different wind conditions.

Table 3.9 Recommended Sprinkler Spacing under windy conditions

S. no.	Wind velocity (km/hr)	Maximum spacing	
		Square spacing	Triangular spacing
1	0 to 4.8	55% of diameter	60% of diameter
2	4.8 to 9.6	50% of diameter	55% of diameter
3	9.6 to 19.2	45% of diameter	50% of diameter
4	Above 19.2	40% of diameter	45% of diameter

In general a coefficient of uniformity (U_c) of at least 85% is recommended for delicate and shallow rooted crops , such as potatoes and most other vegetable .A U_c between 75 and 83 % is generally adequate for deep rooted field crops, such as alfalfa , corn , cotton and sugar beets. Tree and vine is above 70%. However, when applying chemicals through the system a U_c above 80% is recommended. Where, systems have low U_c due to wind, then chemical should be applied only during no wind condition.

3.6.8 Design of Sprinkler Laterals

Lateral convey water from mainline or sub main to the individual sprinkler. A lateral has equally spaced sprinklers along its length. Lateral should be laid across prominent slopes to minimize the variation of pressure along the lateral and it is not possible to have same pressure at each outlet. Lateral should be located at right angle to the prevailing wind direction, whenever possible. As the water flow along the lateral in the beginning the flow will be equal to the combined discharge through the sprinkler. However, it is not convenient to design the lateral for a tapering section. A uniform diameter of lateral is adopted. The total flow rate entering the lateral is calculated and a trial diameter of pipe is selected, which then needs to be checked for frictional losses.

The American Society of Agricultural Engineering (1978) recommended that the total pressure variation in the lateral practically should not be more than 10 % of the design lateral pressure. Thus, if the design lateral pressure is 4 kg/cm², the pressure at any sprinkler along a lateral should not be less than 3.55 kg/cm² or greater than 4.34 kg/cm².

If the lateral runs uphill or downhill, allowance for this difference in elevation should be made in determining the variation in head. If the water runs uphill, less pressure will be available at nozzle; if it runs downhill there will be a tendency to balance the loss of head due to friction.

Different formulae used for estimating the head losses due to friction for different Discharge through the pipe network of sprinkler irrigation system was mentioned below.

1. Scobey's equation

Scobey (1930) gave an equation for friction or head loss in sprinkler lateral, which is expressed as,

$$\Delta H = 4.10 * 10^6 * K_s * Q^{1.9} * D_l^{-4.9} * L_l * F \dots\dots\dots\text{Eq.(3.10)}$$

Where,

ΔH = total friction loss in lateral, m

K_s = Scobey's coefficient for retardation

L_l = length of lateral pipe, m

Q = total discharge, lit/sec

D_l = inside diameter of lateral, mm

F = correction factor, based on number of sprinklers on one lateral

Suggested values of F are given in Appendix 4. Recommended value of K_s for design purpose are 0.32 for new transit pipe, 0.40 for steel pipe or portable aluminum pipe with couplers and 0.42 for portable galvanized steel pipe couplers.

The size of lateral is selected so that the friction loss (ΔH) is within allowable limits adjusted for elevation difference along the line. The selected lateral diameter should be the closest nominal size available commercially.

2. The Hazen-Williams equation :

This is the most commonly used equation for estimating the frictional loss in sprinkler laterals of various pipe material and is given by,

$$\Delta H_l = K * (Q/C)^{1.852} * D_l^{-4.871} * (L/100) * F \dots\dots\dots \text{Eq. (3.11)}$$

Where,

ΔH_l = total friction loss in lateral, m

L_l = length of lateral pipe, m

Q = total discharge, lit/sec

D_l = inside diameter of lateral, mm

F = outlet factor, depends on number of outlet (sprinklers) on one lateral

K = conversion constant, equal to $1.212 * 10^{12}$ for metric units

C = the friction coefficient which depends on pipe material as given in table 3.10, dimensionless

Table 3.10 Values of C for use in the Hazen-Williams equation

S .no.	Pipe material	C
1	Plastic (PVC)	150
2	Epoxy coated steel	145
3	Cement asbestos	140
4	Galvanized steel	135
5	Aluminum (with couplers)	130
6	Steel (new)	130
7	Steel (15 years old) or concrete	100

The Hazen- Williams equation was developed from study of water distribution system that used 75mm or larger diameters pipe and discharge greater than 3.2

lit/sec. Under these flow conditions, the Reynolds number is greater than 5×10^4 and the formula computes friction loss satisfactorily. However, for small diameter smooth walled pipe used in the sprinkler system, Hazen-williams equation with $C = 150$, under estimate the frictional losses. Hence for simplicity a simple equation developed for use with smooth plastic pipes less than 125 mm in diameter can be used.

The design capacity of sprinkler on a lateral with uniform spacing should be based on the average operating pressure. Where the frictional loss in the laterals is within 20% of average pressure, the average head for design in a sprinkler lateral line can be expressed approximately by Fig 3.6

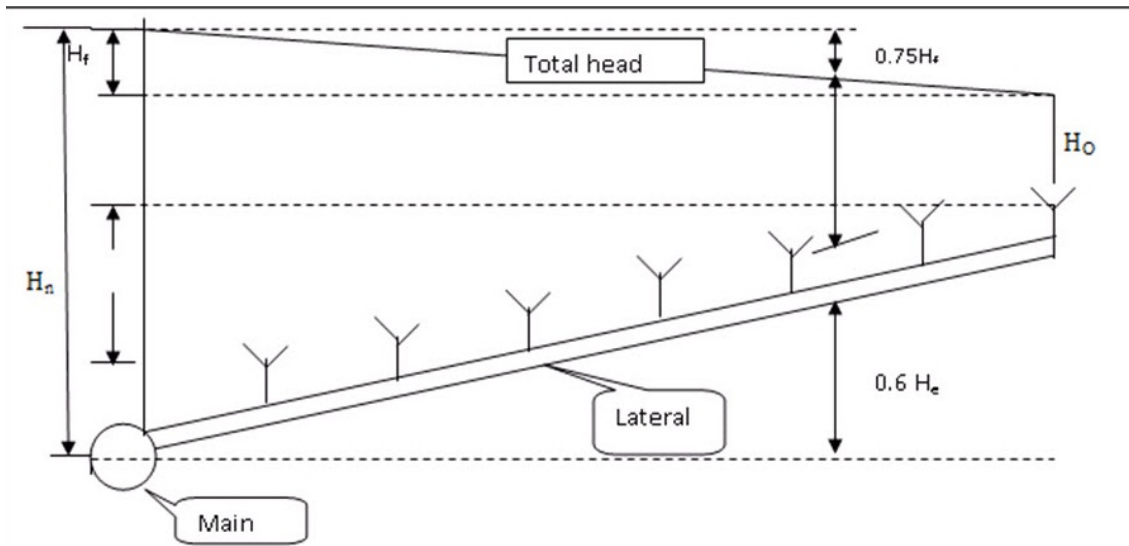


Fig 3.6 Pressure Profile in a Sprinkler Lateral Laid Uphill

$$H_a = H_o + 0.25 \Delta H + 0.4 H_e \dots\dots\dots \text{Eq.}(3.12)$$

Where,

H_a = average pressure at the nozzle, m

H_o = nozzle pressure at the farthest end of line, m

ΔH = friction head loss in lateral, m

H_e = maximum difference in elevation between the junction with the main

And the farthest sprinkler on the lateral, m

Making the allowance for the difference in elevation along the lateral and for riser height, head at the mainline due to lateral can be expressed as,

$$H_n = H_o + \Delta H \pm H_e + H_r \dots\dots\dots\text{Eq.(3.13)}$$

Where,

H_n = head at the main line, m

H_r = riser height, m

' H_e ' is positive for uphill and negative for downhill from equation 3.12. , H_o can be written as ,

$$H_o = H_a - 0.25\Delta H - 0.4 H_e \dots\dots\dots\text{Eq.(3.14)}$$

Substituting this value of H_o in equation 3.14

$$H_n = H_o + 0.75H \pm 0.6 H_e + H_r \dots\dots\dots\text{Eq. (3.15)}$$

This will be ensuring that all sprinklers in the lateral operate within the permissible limits of the desired discharge.

3.6.9 Design of Mainline and Sub main

The mainline and sub main conveys the required quantity of water at desired pressure to all the lateral lines. The selection of main line and sub main lines should be based on economic consideration. The diameter of the main line would depend on system capacity, which will be decided by total number of laterals operated at a time. As a thumb rule, the mainline friction loss of about 3 m for small system and 12 m for large system may be allowed. The head loss due to friction was calculated by using following equation,

$$\Delta H = 4.10 * 10^6 * K_s * Q^{1.9} * D^{-4.9} * L \dots\dots\dots\text{Eq.(3.16)}$$

Where,

ΔH = total friction loss in mainline or sub main, m

K_s = Scobey's coefficient for retardation

L = length of pipe, m

Q = total discharge, lit/sec

D_1 = inside diameter of pipe, mm

3.6.10 Pressure Requirement of the System

The total requirement of the system depends on the sprinkler operating pressure, riser pipe height, head loss due to friction in main and sub main and head loss due to fixtures and pumping water level. The head loss due to fixtures is considered as a local head loss and should be approximately equal to 10 % of sprinkler operating pressure.

The total head loss was determined by ,

$$H_t = H_n + H_m + H_j + H_s \dots\dots\dots\text{Eq.}(3.17)$$

Where,

H_t = total design head required for pump, m

H_n = maximum head required at the mainline to operate the
Sprinklers on lateral at required average pressure, m

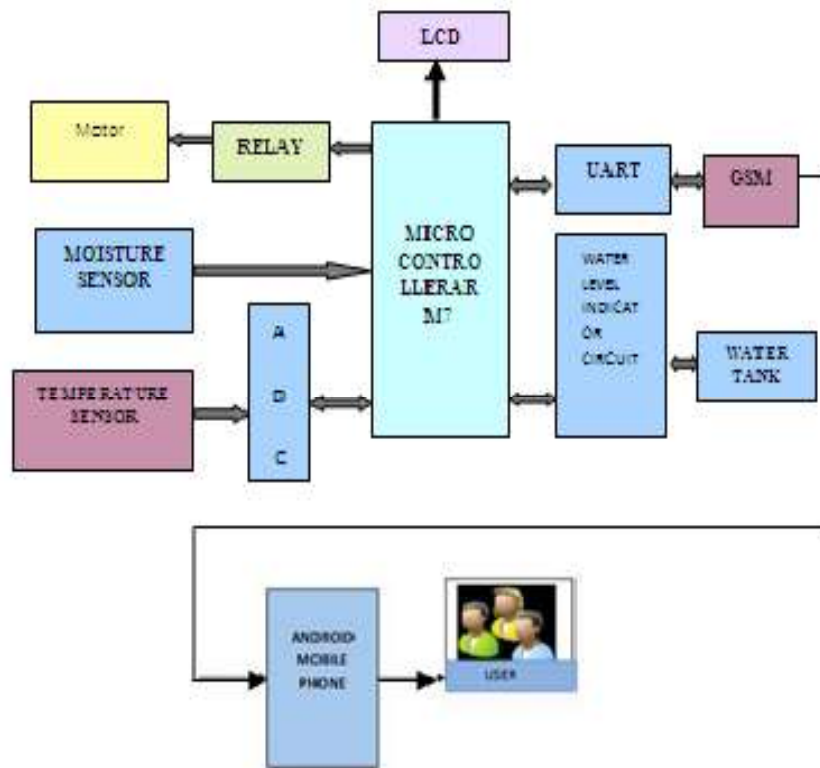
H_m = maximum friction loss in the main line

H_j = elevation difference between the pump and the junction
of the lateral and the main ,m

H_s = elevation difference between the pump and the
water supply after drawdown , m

3.6.11 GSM Based Irrigation Control System

The connections between the two mobiles are done using GSM. The GSM module and microcontroller are connected using UART (universal asynchronous receiver / transmitter). When the moisture sensor senses the low moisture content of the soil, it gives a signal to the microcontroller. The microcontroller then gives a signal to the called mobile (which is kept in the auto answering mode). The called mobile activates the buzzer. Therefore when calling mobile calls, that buzzer is heard indicating the valve needs to be open. By pressing the button in the called function, the signal is given back to the microcontroller. The microcontroller gives signal to the valves which causes it to get open. The water is given to the plant and when the moisture content becomes sufficient, the sensor senses this and gives back the signal to the microcontroller and the buzzer becomes off. Then by pressing the button in the calling function again, the valve is made off. The power supply needed by the controlling system is +5V. The entire unit is as shown in Fig.3.7. An UART is responsible for performing the main task in serial communications with computers. The device changes incoming parallel information to serial data which can be sent on a communication line. A second UART can be used to receive the information. The UART performs all the tasks, timing, parity checking, etc. needed for the communication. The only extra devices attached are line driver chips capable of transforming the signals to line voltages and vice versa. The Microcontroller is a general purpose 32-bit microprocessor, which offers high performance and very low power consumption.



**Fig 3.7 Block Diagram of Irrigation Control System
GSM Module**

A GSM modem is a wireless modem that works with a GSM wireless network. Computers use AT commands to control modems. Both GSM modems and dial-up modems support a common set of standard AT commands. So we can use a GSM modem just like a dial-up modem. The main difference between them is that a dial up modem sends and receives data through a fixed telephone line while a wireless modem sends and receives data through radio waves. GSM is one of the most vital components in our set up since all the communication between the users and centralized unit takes place through this modem. An external GSM modem is connected to a computer through a serial cable or a USB cable. Like a GSM mobile phone, a GSM modem requires a SIM card from a wireless carrier in order to operate. The current status of the soil will be send to the farmer as SMS.

Structure of GSM Module

At present the GSM module is used for Remote Control activities such as Gate Control, Temperature Control etc. GSM/GPRS module consists of a GSM/GPRS

modem assembled together with power supply circuit and communication interfaces (like RS-232, USB) for computer. The MODEM is the soul of such modules. They generate, transmit or decode data from a cellular network, for establishing communication between the cellular network and the computer. These are manufactured for specific cellular network (GSM/UMTS/CDMA) or specific cellular data standard (GSM/UMTS/GPRS/EDGE/HSDPA) or technology (GPS/SIM). They use serial communication to interface with the user and need Hayes compatible AT (Attention) commands for communication with the computer (any microprocessor or microcontroller system).

An RS-232 port was once a standard feature of a personal computer for connections to modems, printers, mice, data storage, un-interruptible power supplies, and other peripheral devices. However, the limited transmission speed, relatively large voltage swing, and large standard connectors motivated development of the universal serial bus which has displaced RS-232 from most of its peripheral interface roles. Many modern personal computers have no RS-232 ports and must use an external converter to connect to older peripherals. Some RS-232 devices are still found especially in industrial machines or scientific instruments.

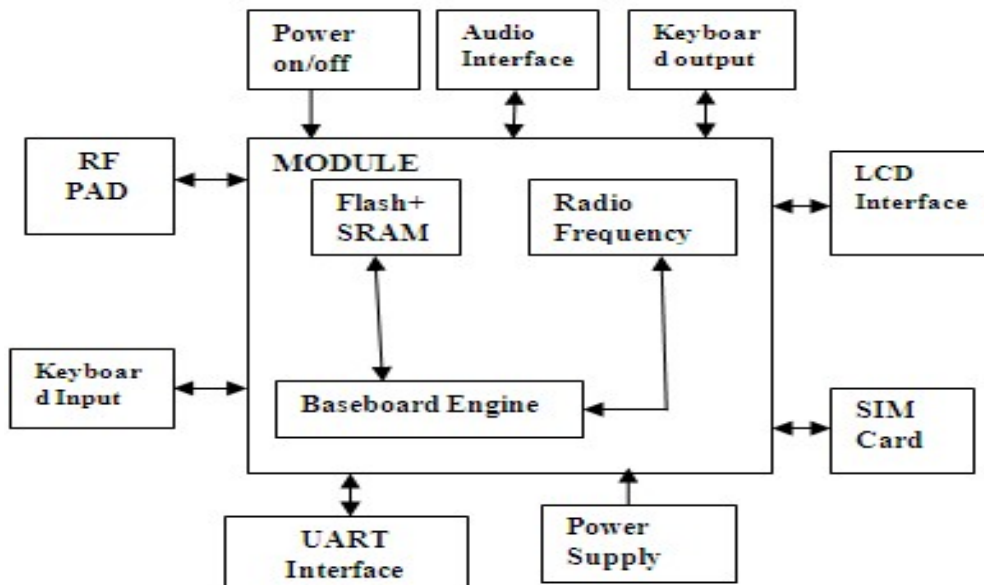


Fig.3.8 GSM Module Structure

Microcontroller (Atmega328)

Atmega328 is an 80C51 microcontroller with 16/32/64 KB flash and 1024 B of data RAM. We choose to run the application with the conventional 80C51 clock rate (12 clocks per machine cycle). The flash program memory supports both parallel programming and in serial ISP. Parallel programming mode offers gang programming at high speed. ISP allows a device to be reprogrammed in the end product under software control. The Micro Controller reads the input digital signal from the ADC and puts these values on its output pins so that it can be forwarded to the computer software. The ADC is interfaced at pins from AD0 to AD7 where the signals are sent and these signals are forwarded on the port 3 pins.

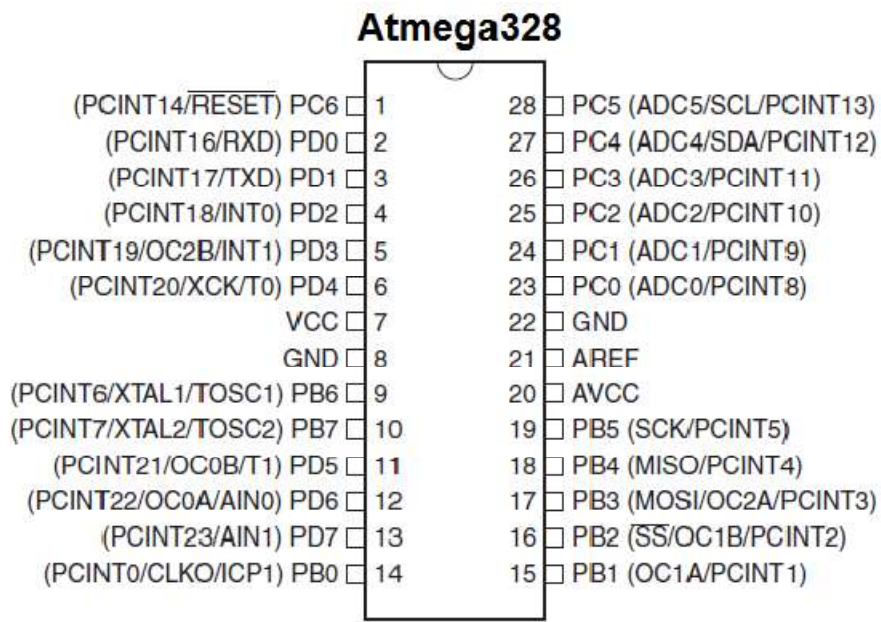


Fig 3.9 Atmega 328 Microcontroller

Sensors

Soil moisture sensors measure the water content in soil. A soil moisture probe is made up of multiple soil moisture sensors. One common type of soil moisture sensors in commercial use is a Frequency domain sensor such as a capacitance sensor. Another sensor, the neutron moisture gauge, utilize the moderator properties of water for neutrons. Soil moisture content may be determined via its effect on dielectric constant by measuring the capacitance between two electrodes implanted in the soil. Where soil moisture is predominantly in the form of free water (e.g., in sandy soils), the dielectric constant is directly proportional to the moisture content. The probe is normally given a frequency excitation to permit measurement of the

dielectric constant. The readout from the probe is not linear with water content and is influenced by soil type and soil temperature. In this sensor two probes were used to be dipped into the soil as per moisture indication was found in the Analogue Output variations from 0.60volts - 5volts Input Voltage 5V DC.

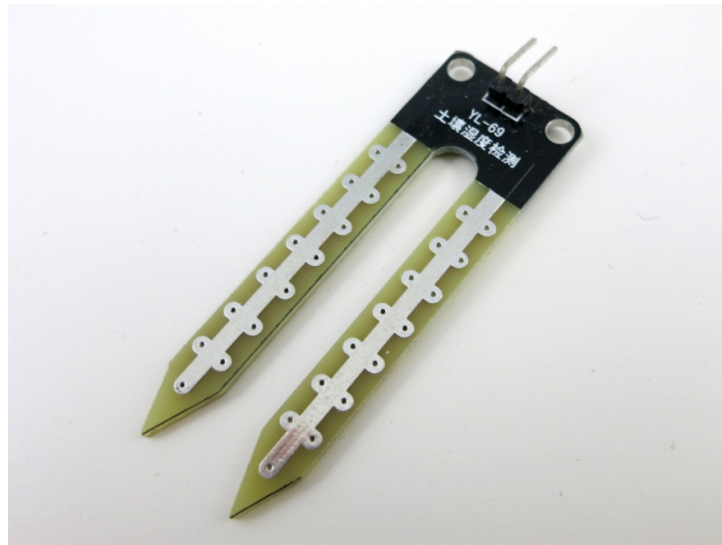


Fig 3.10 soil moisture sensor

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in °C). With an LM35, temperature can be measured more accurately than using a thermostat. The sensor circuitry is sealed and not subject to oxidation. The LM35 generates a higher output voltage than thermocouples and may not require the output voltage be amplified.

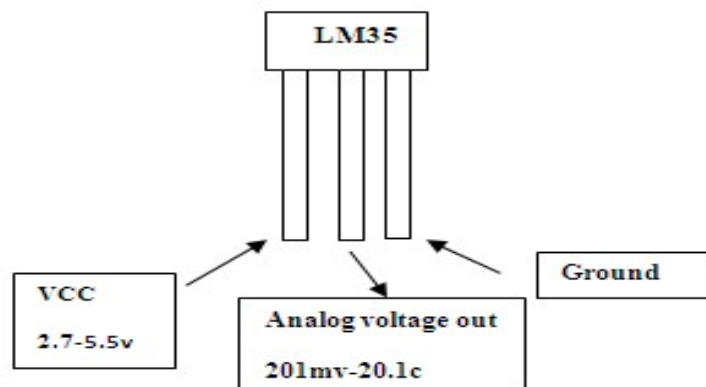


Fig.3.11 Precision Centigrade Temperature Sensors

The complete GSM unit was located at the side of the field for the proper maintenance and proper operation of the system

3.7 Methodology to Determine Crop Water Productivity

The crop water productivity was worked out by dividing the Total yield of the crops by total water used.

$$\text{Water Productivity (kg ha}^{-1} \text{ mm}^{-1}) = \text{Total Yield (kg ha}^{-1}) / \text{Total Water Used (mm)} \dots\dots\dots \text{Eq.3.18}$$

The depth of irrigation (water used) was calculated by dividing the amount of irrigation with plot area.

3.7.1 Net depth of Water Application

This the quantity of water that is applied during irrigation so as to replace the water utilized during by the crop during evapo-transpiration (Davis, 2015). The calculation of the net depth of water application needs the following variable parameters:

- Allowable soil moisture depletion (P)
- Available soil moisture (FC-PWP)
- Effective root zone depth of the crop (RZD)

Depending on the crop sensitivity to water stress, the soil moisture should be permitted to deplete partially (Wilson, 2015). On average, a depletion of 50% of the available moisture is allowable. The net depth to be applied per irrigation is expressed as:

$$d_{\text{net}} = (\text{FC-PWP}) \times \text{RZD} \times P \dots\dots\dots \text{Eq.(3.19)}$$

Where,

d_{net} = net depth of water application per irrigation for a given crop (mm)

FC = soil moisture at field capacity (mm/m)

PWP = soil moisture at the permanent wilting point (mm/m)

RZD = depth of soil that the roots exploit effectively (m)

P = allowable moisture permitted for depletion by the crop before the next irrigation.

In order to express the depth of water in terms of the volume, the proposed area for irrigation is multiplied by depth:

$$V = 10 \times A \times d \dots\dots\dots \text{Eq.(3.20)}$$

Where,

V = volume of water to be applied (m^3)

A = area proposed for irrigation (ha)

d = net depth of water application (mm)

The yield and the area of grown crop would be determined with the help of Directorate of Farm and various farm unit offices of JNKVV Jabalpur.

RESULTS AND DISCUSSION

The present chapter deals with the material and methods adopted and results obtained as per the objectives.

4.1 Soil Properties

Soil is the store house of the water. The crop /trees take water from the soil; therefore it is essential to understand the various soil properties which influence water movement .In these context three important soil properties have been determined.

4.1.1 Textural Classification of the Soil

Soil samples collected from the field of different vegetal cover i.e. tree area, crop area, tree plus crop area and open field comes under the problematic area. Samples were analyzed by mechanical analysis method and results obtained are presented in the table 4.1.

Table 4.1 Classification of Soil Texture of the study area

S.No.	Location	Sand %	Silt %	Clay %	Soil type
1	Tree area	49.1	18.4	32.5	Clay loam
2	Crop area	43.20	22.9	31.6	Clay loam
3	Tree + Crop area	45.5	22.9	31.6	Clay loam
4	Open area	43.1	22.2	34.7	Clay loam

From the USDA textural classification, according to the percentage of sand, silt and clay found in the samples the surface texture of major area is clay loam. Analysis shows that the clay contain of the soil ranges from 30 to 35 %, silt 18 to 23 % and sand 43 to 50 % and hence soils of the study area are classified as clay loam soils.

4.1.2 Bulk Density of the Soil

Soil samples were collected from the fields of different land cover and land use of the problematic area and the bulk density was determined by taking undisturbed soil samples of known volume with help of core cutter from a depth of 0 to 15 cm. the values of bulk density obtained from different locations are presented in Table 4.2.

Table 4.2 Bulk density of soils of the different locations of the Study area

S.No.	Location	Bulk density g/cc
1	I	1.54
2	II	1.50
3	III	1.48
4	IV	1.56
5	V	1.54

The bulk density in the field was found minimum in tree + crop area as 1.48 g/cc and maximum in the field of open area i.e. 1.56 g/cc.

4.1.3 Infiltration Characteristics of the Soil

The standard double cylinder infiltrometer was used to determine the infiltration rate of the soil. The tests were conducted at five locations in the study area.

Observed infiltration data at open field of various farm unit of JNKVV was fitted to the selected infiltration model likely i.e. Kostikov's model, Philip's model and Horton's model and the model parameters were determined by liner relationship simple calculation has been done to find out the model parameters. Table 4.3 represent values of infiltration model of various farm unit .

Table 4.3 Infiltration Model for various Farm Units

s. no.	Name of farm unit	Model	Equation
1	BSP (soybean)	Horton's	$I = 0.246 + (4.98 - 0.246) e^{-2.7t}$
		Kostikov's	$I = 2.6 t^{-1/2} - 1.9$
		Philip's	$I = 0.65 t^{-1.33}$
2	BSP(ground nut)	Horton's	$I = 0.32 + (4.45 - 0.32) e^{-2.7t}$
		Kostikov's	$I = 2.6 t^{-1/2} - 1.9$
		Philip's	$I = 0.65 t^{-1.33}$
3	Vegetable farm Maharajpur	Horton's	$I = 0.34 + (4.50 - 0.34) e^{-2.7t}$
		Kostikov's	$I = 2.6 t^{-1/2} - 1.9$
		Philip's	$I = 0.65 t^{-1.33}$
4	BSP (farm crop)	Horton's	$I = 0.32 + (4.44 - 0.32) e^{-2.7t}$

		Kostikov's	$I = 2.6 t^{-1/2} - 1.9$
		Philip's	$I = 0.65 t^{-1.33}$
5	Horticulture farm Imaliya	Horton's	$I = 0.245 + (4.90 - 0.245) e^{-2.7t}$
		Kostikov's	$I = 2.6 t^{-1/2} - 1.9$
		Philip's	$I = 0.65 t^{-1.33}$

The fitted models were used to estimate the infiltration rate fig. 4.1 to 4.5 present the observed and estimated infiltration range at open field in various farm unit of JNKVV Jabalpur.

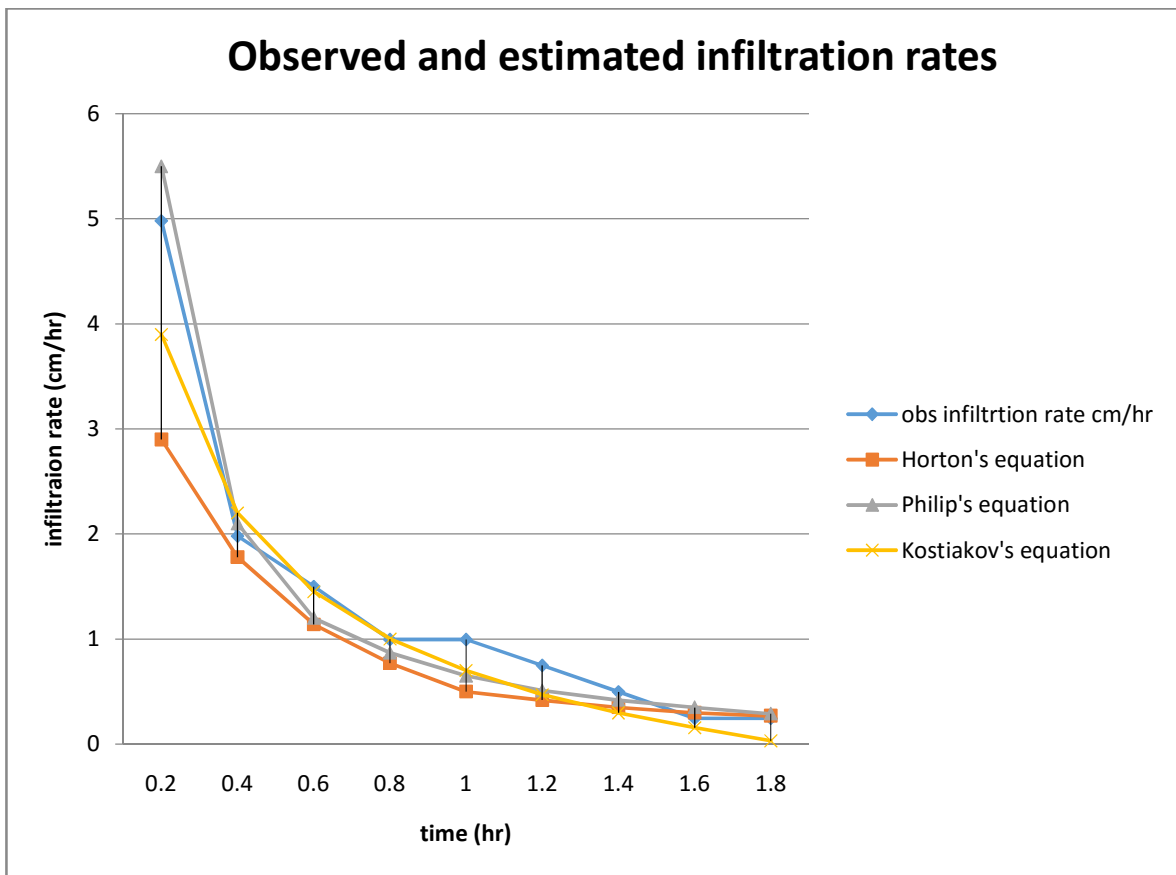


Fig 4.1 Observed and Estimated Infiltration Rates for BSP (Soybean)

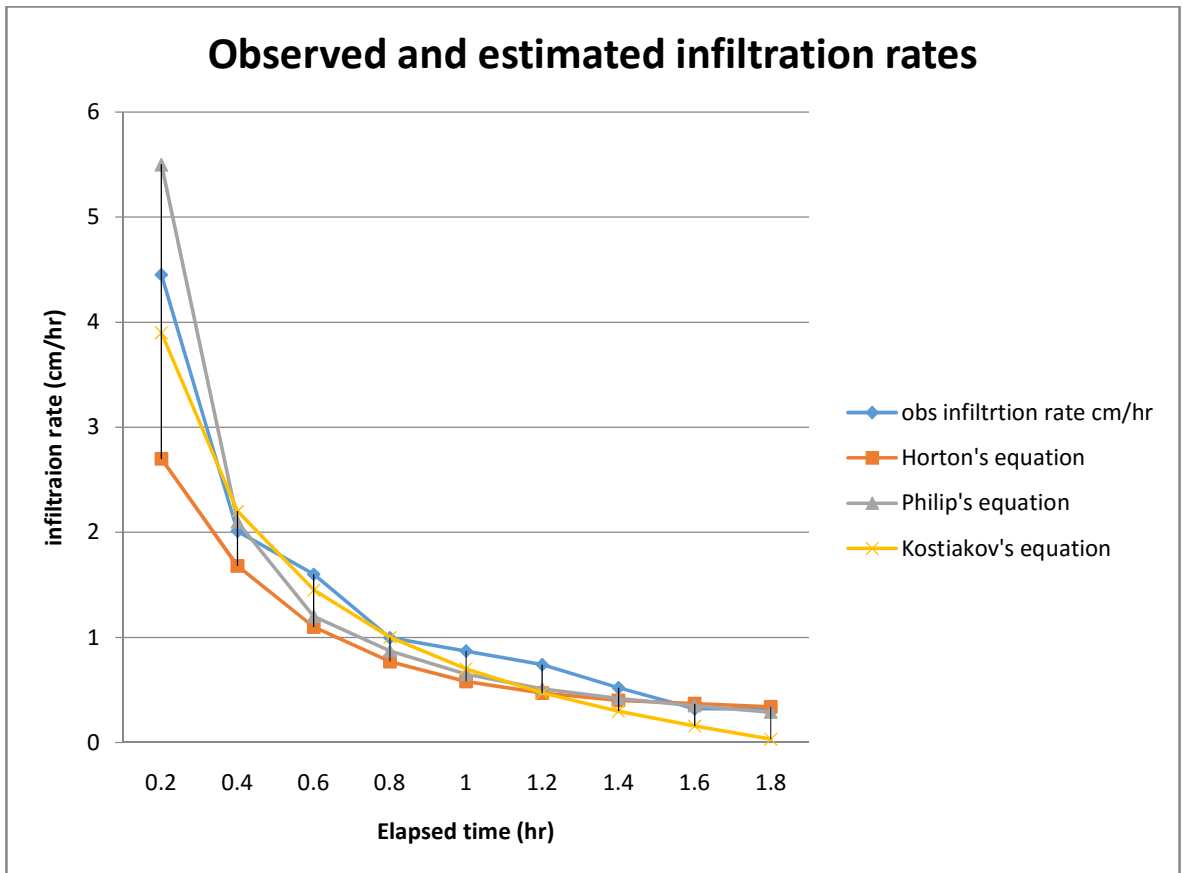


Fig 4.2 Observed and Estimated Infiltration Rates for BSP (groundnut)

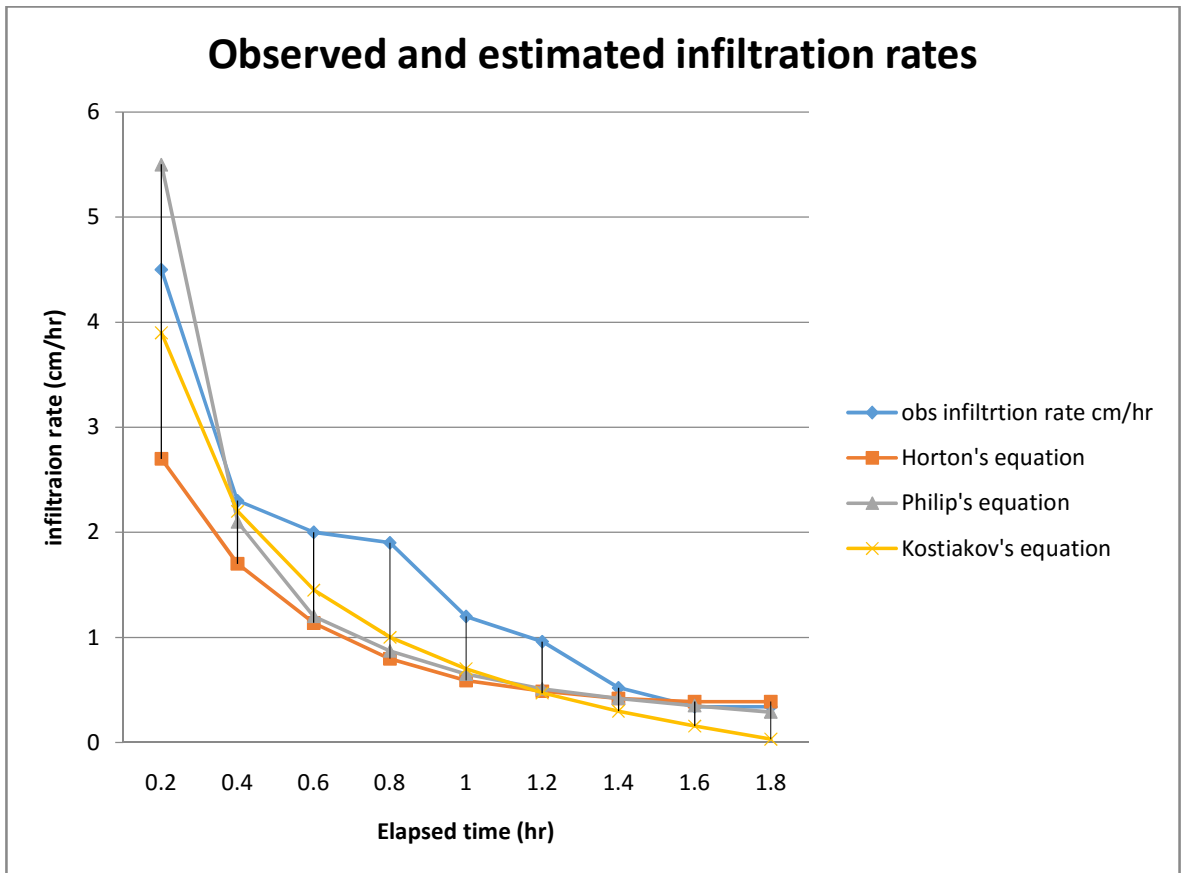


Fig 4.3 Observed and Estimated Infiltration Rates for Vegetable Farm Maharajpur

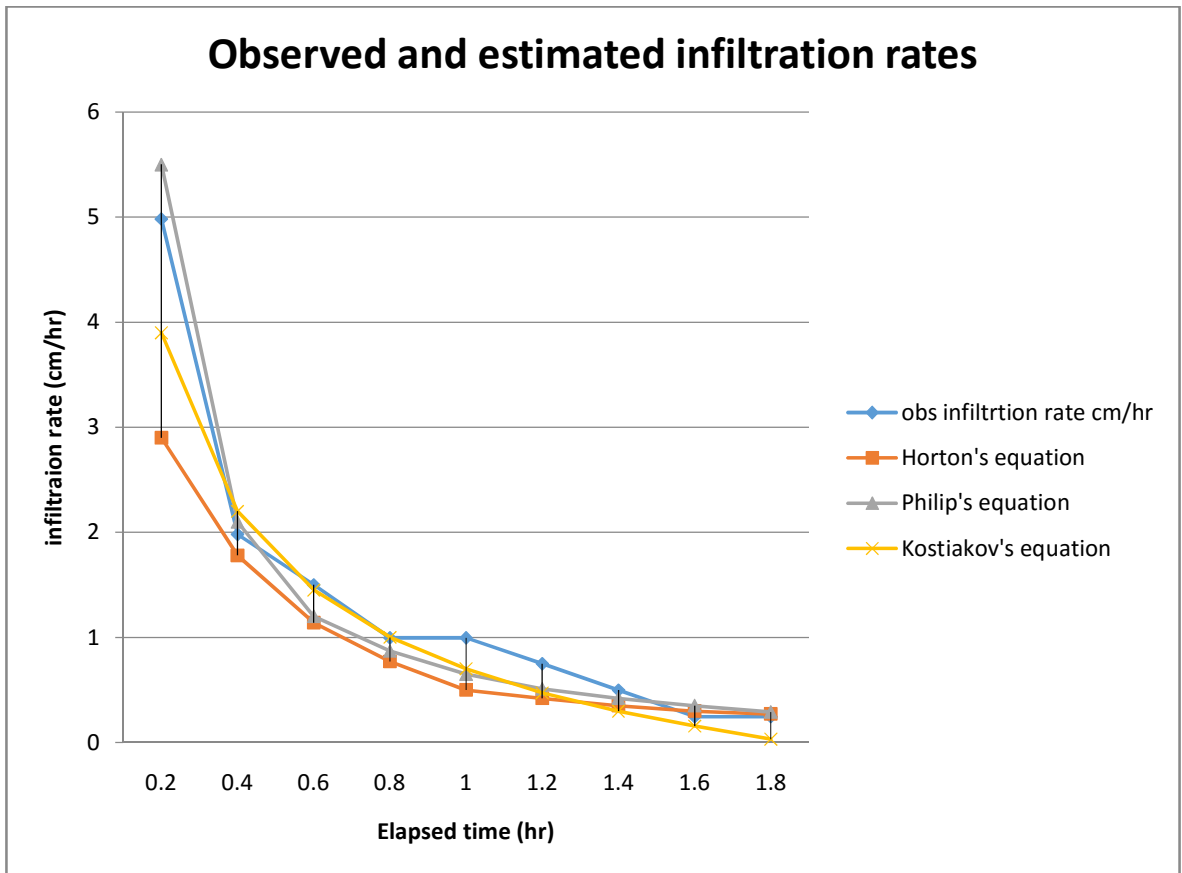


Fig 4.4 Observed and Estimated Infiltration Rates for Horticulture Farm Imaliya

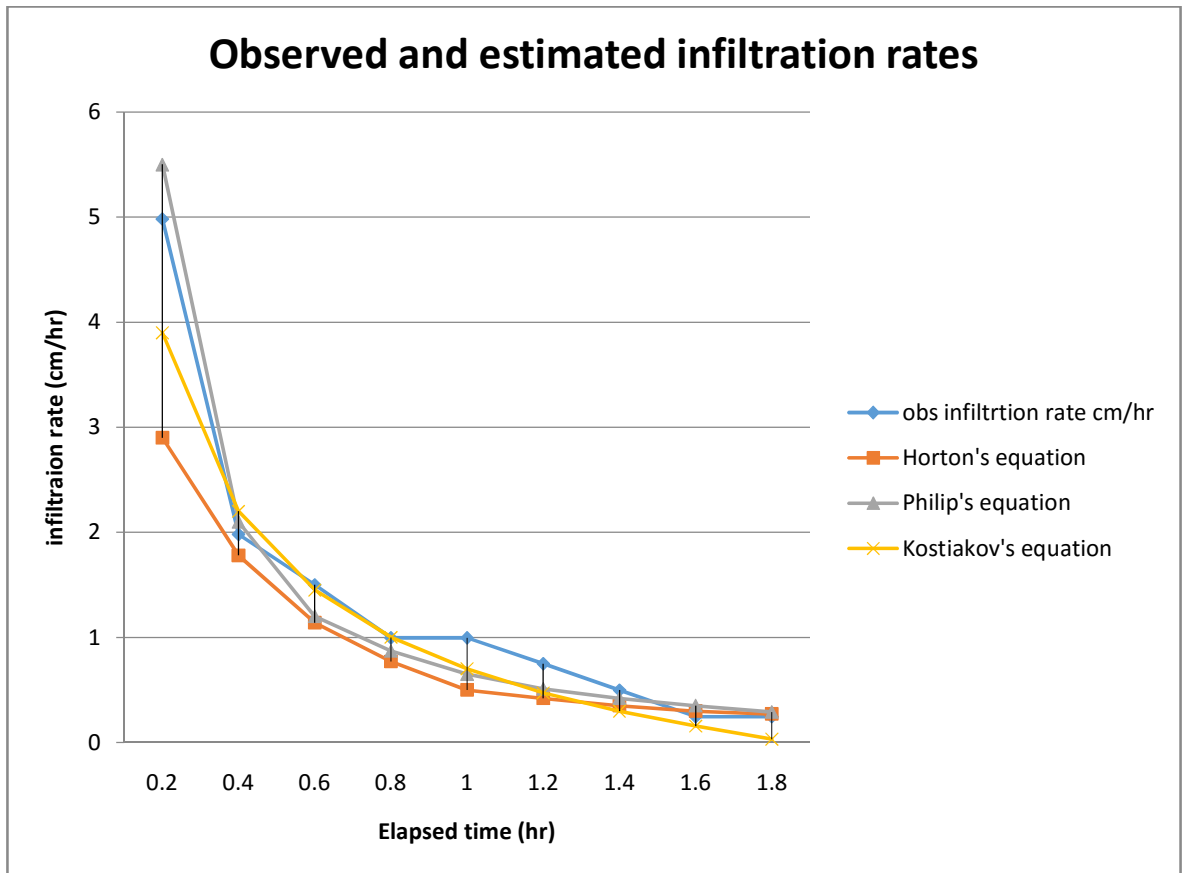


Fig 4.5 Observed and Estimated Infiltration Rates for BSP (Farm Crop)

4.2 Crop Water Requirement

The water requirement of wheat crop simulated by CROPWAT model has been given in tables. Water requirement of wheat crop simulated by CROPWAT model was 210 mm for the whole crop season during 2016-17. The wheat crop season was divided into four stages *i.e* Initial stage, development stage, mid stage and late stage. The effective rainfall during whole crop season was 4.8mm during years 2016-17. In the initial stage of wheat crop growth, it needed minimum quantity of water (17.5 mm / decade) in the November month and ET_c was 17.5 mm/decade. The crop water requirement increased by increasing the growth stage of wheat crop. The highest crop water requirement (85.3 mm / decade) recorded in the late stage of growth which was 40 % of total water requirement of wheat crop during the years 2016-17.

Similarly the water requirement of Rice , Gram , Arhar ,Soybean, Pea ,Moong and Urd was 326.8mm ,86.0 mm ,286.8 mm, 76.4 mm ,124.9 mm, 306.0mm and 406.1 mm respectively and the effective rainfall during the whole crop season of these crops was 193.5mm ,169.1 mm, 5.1 mm, 160.7 mm, 6.5 mm, 11.3mm and 173.9 mm respectively.

The software mainly CROPWAT 8.0 has been used in this study to calculate various parameters. The software provides the ET_c , effective rainfall and irrigation requirement in mm/dec. Here dec stands for a period of ten days.

Table 4.4 Water Requirement of Wheat Crop using CROPWAT Model

Month	Decade	Stage	K_c	ET_c mm/day	ET_c mm/dec	Eff. Rainfall mm/dec	Irrigation Requirement mm/dec
Nov.	2	Init	0.50	1.17	7.0	0.0	7.0
Nov.	3	Deve	0.50	1.05	10.5	0.0	10.5
Dec.	1	Deve	0.68	1.26	12.6	0.1	12.5
Dec.	2	Deve	0.97	1.54	15.4	0.0	15.4
Dec.	3	Mid	1.19	1.86	20.5	0.0	20.4
Jan.	1	Mid	1.21	1.85	18.5	0.1	18.4
Jan.	2	Mid	1.21	1.82	18.02	0.2	17.9
Jan.	3	Mid	1.21	2.10	23.1	0.5	22.6
Feb.	1	Mid	1.21	2.39	23.9	1.0	22.9
Feb.	2	late	1.12	2.47	24.7	1.3	23.4
Feb.	3	Late	0.88	2.18	17.4	0.9	16.5
March	1	Late	0.64	1.76	17.6	0.5	17.1
March	2	Late	0.46	1.38	5.5	0.1	5.4
					214.8	4.8	210.0

Table 4.5 Water Requirement of Rice Crop using CROPWAT Model

Month	Decade	Stage	K _c	ET _c mm/day	ET _c mm/dec	Eff. Rainfall mm/dec	Irrigation Requirement mm/dec
July	2	Init	1.05	4.04	24.2	9.8	16.0
July	3	Init	1.05	3.77	41.5	21.0	20.5
Aug.	1	Init	1.05	3.51	35.1	29.1	6.0
Aug.	2	Deve	1.06	3.27	32.7	35.3	0.0
Aug.	3	Deve	1.08	3.37	37.0	26.3	10.8
Sep.	1	Deve	1.11	3.47	34.7	12.9	21.8
Sep.	2	Mid	1.13	3.54	35.4	4.2	31.2
Sep.	3	Mid	1.13	3.45	34.5	7.8	26.8
Oct.	1	Mid	1.13	3.37	33.7	14.6	19.1
Oct.	2	Mid	1.13	3.28	32.8	17.8	15.0
Oct.	3	Mid	1.13	3.06	33.7	12.1	21.6
Nov.	1	Mid	1.13	2.85	28.5	2.4	26.1
Nov.	2	Mid	1.13	2.63	26.3	0.0	26.3
Nov.	3	Mid	1.13	2.35	23.5	0.0	23.5
Dec.	1	Late	1.08	1.99	19.9	0.1	19.8
Dec.	2	Late	0.98	1.56	15.6	0.0	15.6
Dec.	3	Late	0.88	1.37	15.1	0.0	15.0
Jan.	1	late	0.78	1.19	11.9	0.1	11.7
					516.1	193.5	326.8

Table 4.6 Water Requirement of Gram Crop using CROPWAT Model

Month	decade	Stage	K _c	ET _c mm/day	ET _c mm/dec	Eff. Rainfall mm/dec	Irrigation Requirement mm/dec
Nov.	2	Init	0.40	0.93	5.6	0.0	5.6
Nov.	3	Init	0.40	0.83	8.3	0.0	8.3
Dec.	1	Deve	0.45	0.83	8.3	0.1	8.2
Dec.	2	Deve	0.68	1.08	10.8	0.0	10.8
Dec.	3	Deve	0.93	1.45	16.0	0.0	16.0
Jan.	1	Mid	1.12	1.71	17.1	0.1	17.0
Jan.	2	Mid	1.13	1.69	16.9	0.2	16.7
Jan.	3	Mid	1.13	1.96	21.5	0.5	21.0
Feb.	1	Mid	1.13	2.23	22.3	1.0	21.3
Feb.	2	Mid	1.13	2.49	24.9	1.3	23.6
Feb.	3	Mid	1.13	2.79	22.3	0.9	21.4
March	1	Late	1.10	3.00	30.0	0.5	29.5
March	2	Late	0.96	2.88	28.8	0.2	28.6
March	3	Late	0.80	2.65	29.2	0.1	29.1
Apr.	1	Late	0.65	2.34	23.4	0.1	23.3
Apr	2	late	0.55	2.16	6.5	0.0	6.5
					291.9	5.1	286.8

Table 4.7 Water Requirement of Arhar Crop using CROPWAT Model

Month	decade	Stage	K _c	ET _c mm/day	ET _c mm/dec	Eff. Rainfall mm/dec	Irrigation Requirement mm/dec
Jun	3	Init	0.40	1.81	3.6	1.8	3.6
July	1	Init	0.40	1.66	16.6	12.9	3.7
July	2	Deve	0.47	1.82	18.2	16.4	1.8
July	3	Deve	0.74	2.67	29.4	21.0	8.4
Aug.	1	Mid	1.00	3.35	33.5	29.1	4.5
Aug.	2	Mid	0.06	3.27	32.7	35.3	0.0
Aug.	3	Mid	1.06	3.29	36.2	26.3	9.9
Sep.	1	Mid	1.06	3.31	33.1	12.9	20.2
Sep.	2	Late	0.90	2.82	28.2	4.2	24.0
Sep.	3	Late	0.55	1.67	16.7	7.8	8.9
Oct.	1	late	0.35	1.04	1.0	1.5	1.0
					249.3	169.1	86.0

Table 4.8 Water Requirement of Soybean Crop using CROPWAT Model

Month	decade	Stage	K _c	ET _c mm/day	ET _c mm/dec	Eff. Rainfall mm/dec	Irrigation Requirement mm/dec
Jun	3	Init	0.40	1.81	3.6	1.8	3.6
July	1	Init	0.40	1.66	16.6	12.9	3.7
July	2	Deve	0.52	2.00	20.0	16.4	3.6
July	3	Mid	0.93	3.34	36.7	21.0	15.8
Aug.	1	Mid	1.04	3.47	34.7	29.1	5.6
Aug.	2	Mid	1.04	3.21	32.1	35.3	0.0
Aug.	3	Mid	1.04	3.22	35.5	26.3	9.2
Sep.	1	Late	1.00	3.11	31.1	12.9	18.2
Sep.	2	Late	0.63	1.98	19.8	4.2	15.6
Sep.	3	Late	0.40	1.22	1.22	0.8	1.2
					231.3	160.7	76.4

Table 4.9 Water Requirement of Urd crop using CROPWAT Model

Month	decade	Stage	K _c	ET _c mm/day	ET _c mm/dec	Eff. Rainfall mm/dec	Irrigation Requirement mm/dec
Mar.	3	Init	0.40	1.32	4.0	0.0	4.0
Apr.	1	Init	0.40	1.44	14.4	0.1	14.3
Apr.	2	Init	0.40	1.56	15.6	0.0	15.6
Apr.	3	Deve	0.47	1.93	19.3	0.0	19.3
May	1	Deve	0.67	2.87	28.7	0.0	28.6
May	2	Deve	0.86	3.88	38.8	0.0	38.8
May	3	Mid	1.05	4.83	53.1	0.2	52.9
Jun	1	Mid	1.09	5.18	51.8	3.6	48.2
Jun	2	Mid	1.09	5.32	53.2	5.3	47.8
Jun	3	Mid	1.09	4.94	49.4	9.1	40.3
July	1	Mid	1.09	4.53	45.3	12.9	32.4
July	2	Mid	1.09	4.20	42.0	16.4	25.6
July	3	Mid	1.09	3.92	43.1	21.0	22.1
Aug.	1	Late	1.07	3.57	35.7	29.1	6.6
Aug.	2	Late	0.92	2.86	28.6	35.3	0.0
Aug.	3	Late	0.76	2.35	25.8	26.3	0.0
Sep.	1	Late	0.59	1.84	18.4	12.9	5.5
Sep.	2	Late	0.48	1.50	6.0	1.7	3.9
					573.2	173.9	406.1

Table 4.10 Water Requirement of Pea Crop using CROPWAT Model

Month	decade	Stage	K _c	ET _c mm/day	ET _c mm/dec	Eff. Rainfall mm/dec	Irrigation Requirement mm/dec
Oct.	3	Init	0.40	1.09	3.3	3.3	3.3
Nov.	1	Init	0.40	1.01	10.1	2.4	7.7
Nov.	2	Deve	0.41	0.97	9.7	0.0	9.7
Nov.	3	Deve	0.61	1.26	12.6	0.0	12.6
Dec.	1	Deve	0.85	1.56	15.6	0.1	15.5
Dec.	2	Mid	1.08	1.71	17.1	0.0	17.1
Dec.	3	Mid	1.13	1.76	19.4	0.0	19.3
Jan.	1	Mid	1.13	1.73	17.3	0.1	17.1
Jan.	2	Late	1.07	1.60	16.0	0.2	15.8
Jan.	3	Late	0.67	1.17	7.0	0.3	6.8
					128.1	6.5	124.9

Table 4.11 Water Requirement of Moong Crop using CROPWAT Model

Month	decade	Stage	K _c	ET _c mm/day	ET _c mm/dec	Eff. Rainfall mm/dec	Irrigation Requirement mm/dec
Mar.	2	Init	0.40	1.20	7.2	0.1	7.1
Mar.	3	Init	0.40	1.32	14.5	0.1	14.4
Apr.	1	Deve	0.46	1.65	16.5	0.1	16.5
Apr.	2	Deve	0.66	2.59	25.9	0.0	25.9
Apr.	3	Deve	0.87	3.57	35.7	0.0	35.7
May	1	Mid	1.02	4.39	43.9	0.0	43.9
May	2	Mid	1.03	4.62	46.2	0.0	46.2
May	3	Mid	1.03	4.71	51.8	0.2	51.6
Jun	1	Late	0.91	4.30	43.0	3.6	39.4
Jun	2	Late	0.57	2.78	27.8	5.3	22.4
Jun	3	Late	0.37	1.66	3.3	1.8	3.3
					315.9	11.3	306.5

4.3 Present Irrigation Status in the farm units of JNKVV Jabalpur

The JNKVV Farm Jabalpur has been found to be the area of breeder seed production unit was 350 ha which is divided into various farm unit with 29 tube wells and 2 nalas as the source of available water and the total cultivated area was found 282 ha for all three season i.e. Kharif, Rabi and summer, therefore the cropping intensity of different farm units of JNKVV Jabalpur varies from 140-150% and the irrigation intensities during Kharif, Rabi and Summer have been found to be 80.85%, 76.59% and 10%, respectively.

4.4 Design of Automated Micro Irrigation System

At the present time, the farmer have been using various irrigation techniques through the manual control in which the farmers irrigate the land at the regular intervals this process many a times consume more water or sometimes the water reaches late due to which the crops they dried. Water deficiency can be detrimental to plants before visible wilting occurs. Slowed growth rate, lighter weight fruit follow slight water deficiency .this problem can be perfectly rectified if we use automated micro controller based irrigation system in which the irrigation will take place only when there will be intense requirement of water.

Keeping the above in view it has been decided to design a sensor based automated micro irrigation system for different units of JNKVV Farm as described in chapter III.

As described in chapter III, the total area of the BSP (soybean) unit is 90 ha BSP (Groundnut) is 80 ha, BSP (Farm Crop) is 90 ha and Vegetable farm Maharajpur is 83 ha. Each unit is divided into four ha each. This area at present is been irrigated through 10 tube wells,1 tube well ,11 tube wells and 6 tube wells respectively using surface method of irrigation .

First the discharge of each nozzle has been calculated using equation 3.8 and it was found to be 0.32 lit/sec. The size of the nozzle has been calculated using equation 3.12 And the diameter of the nozzle was found to be 4.1mm therefore nozzle size has been selected as 4.0 * 2.5 mm. the system was designed according to the cropping pattern of various season like Kharif, Rabi and Summer.

The discharge of laterals has been computed and was found to be 2.73 lit/sec. the total number of sprinkler was found to be 7 in number on a lateral and total no. of laterals was found to be 3,2 and 4 during Kharif ,Rabi and Summer in number for a

unit of 4 ha. Therefore 257 numbers of laterals are required for the total area in Kharif season similarly 172 laterals for Rabi season and 344 laterals for summer season were required for the total area. For determining the diameter of lateral pipe the head loss has been computed using equation 3.13 And was found to be 0.15 m as the frictional loss is less than 20% of operating pressure, hence the pipe of 75 mm outer diameter has been selected as lateral. For the determining the diameter of the sub main, head loss due to sub main pipe has been computed using equation 3.13 And was found to be 2.98 m which is less than 10 % of operating head available, hence the 110mm outer diameter has been selected for the sub main and main line.

In the present study it has been decided to use sensors for estimating soil moisture and soil temperature. The criteria for selecting the sensors were that it should be of low cost. Therefore a common used soil moisture sensor commonly known as Frequency domain sensors will have to be used at the depth of 1.5-6 cm depth at every 12 ha. Therefore total number of soil moisture sensors for BSP (Soybean) and BSP (Farm Crop) will be 8 in numbers required, similarly for BSP (Groundnut) and Vegetable farm Maharajpur it will be 7 in number.

Similarly to measure the soil temperature, soil temperature sensor namely LM 35 will have been proposed to use at the same depth. The number of temperature sensors will be required 8 in BSP (Soybean) and BSP (Farm Crop). Similarly for BSP (Groundnut) and Vegetable farm Maharajpur it will be 7 in number

These sensors have been connected with the micro controller ATMEGA 328. Complete GSM module unit is proposed to install at the side of the field and near the road for the proper operation of system. There are 4 complete GSM unit proposed to use.

Sample calculation

A field having 4ha (240m*160m) of area with 100 % cropping intensity in Kharif, Rabi and summer has been selected for the design of AMIS. Irrigation rate of 8mm/hr, root zone depth of clay loam soil 0.90m, water holding capacity is 160mm/m and management allowable deficit (MAD) is 50% has been considered.

Peak water used for Kharif - 5mm/ day

Rabi - 4mm/ day

Summer - 7mm/ day

Crop	Kharif	Rabi	Summer
Soybean	2 ha	-	-
Arhar	2 ha	-	-
Wheat	-	2 ha	-
Gram	-	2 ha	-
Urd	-	-	2 ha
Moong	-	-	2 ha

Step 1-Net Irrigation Depth = (MAD* water holding capacity * root zone depth)/100
= (50 *160 *0.90) / 100 = 72 mm

Step 2- Irrigation Interval

During Kharif, $72/5 = 15-1 = 14$ days
During Rabi, $72/4 = 18 - 1 = 17$ days
During summer, $72/7 = 10 -1 = 9$ days

Step 3- Area to be irrigated per day

During Kharif, $4/14 = 0.28$ ha
During Rabi, $4/17 = 0.23$ ha
During summer, $4/9 = 0.44$ ha

Step 4- Gross demand per day

During Kharif, $5/0.8 = 6.25$ mm/day
During Rabi, $4/0.8 = 5$ mm/day
During summer, $7/0.8 = 8.75$ mm/day

Step 5- volume of water required per irrigation (m³)

Area to be irrigated /day *gross demand *irrigation interval

During Kharif, $0.28*10^4 *6.25*10^{-3} * 14 = 245$ m³
During Rabi, $0.23 *10^4 *5 * 10^{-3} * 17 = 195.5$ m³
During summer, $0.44 *10^4 *8.75 * 10^{-3} * 9 = 346.5$ m³

Step 6-System discharge required (m³/hr) considering pumping for 8 hr per day

During Kharif, $245/8 = 30.6$ m³/day = 8.5 lit/sec
During Rabi, $195.5/8 = 24.4$ m³/hr = 6.75 lit/sec

During summer, $346.5/8 = 43.3 \text{ m}^3/\text{hr} = 12.0 \text{ lit/sec}$

From Appendix -2 Select medium capacity sprinkler having twin nozzle of 4.0 * 2.5 mm size and 0.39 lit/sec with 12 * 12 m spacing resulting 10mm/hr application rate which is less than the basic infiltration rate of soil.

Step 7- Rechecking the operating time required during peak demand in different season

Operating time required (hr) = $\frac{\text{Gross Depth (mm/day)} * \text{irrigation interval (days)}}{\text{rate Of precipitation (mm/hr)}}$

During Kharif, $(6.25 * 14)/10 = 8.75\text{hr}$

During Rabi, $(5 * 17)/10 = 8.5\text{hr}$

During summer, $(8.75 * 9)/10 = 7.8\text{hr}$

As the availability of power is for 8 hr. a day for 10 days, the irrigation can be effected easily.

Step 8- No. of sprinkler per day = area irrigated per day/spacing of sprinkler

During Kharif, $0.28 * 10^4 / (12 * 12) = 19$

During Rabi, $0.23 * 10^4 / (12 * 12) = 16$

During Summer, $0.44 * 10^4 / (12 * 12) = 30$

Step 9- Design discharge required of lateral = No. of sprinkler * discharge of one sprinkler

During Kharif, $19 * 0.39 = 7.41 \text{ lit/sec}$

During Rabi, $16 * 0.39 = 6.24 \text{ lit/sec}$

During summer, $30 * 0.39 = 11.7 \text{ lit/sec}$

Step 10 – No. of lateral operated per day

= Total no of sprinkler operated per day / No. of sprinklers on one lateral

During Kharif, $19/7 = 3 \text{ nos}$

During Rabi, $16 / 7 = 2 \text{ nos}$

During summer, $30/7 = 4 \text{ nos}$

Considered lateral length of 80 m, 7 sprinklers was placed at 12 m distance on each lateral.

Design of lateral

Length of lateral = 80 m

No. of sprinkler on one lateral = 7

Discharge of one lateral = $7 * 0.39 = 2.73 \text{ lit/sec}$

Operating pressure = $3 \text{ kg/cm}^2 = 30\text{m}$

Riser height = 1 m

Select HDPE lateral of 75 mm outer diameter, hence the inner diameter was 70.8mm

Using equation 3.13

$\Delta H = 0.15\text{m}$

Which is less than 10% of pressure head, hence it was accepted. Select 75 mm outer diameter HDPE lateral.

Design of Sub main (manifold)

The critical condition is during Kharif, when 3 lateral are operated at a time

Discharge of manifold = $3 * 2.73 = 8.19 \text{ lit/sec}$

Length of manifold = 240m

Select 90 mm outer diameter HDPE pipe as manifold.

Using equation 3.20

($F = 0.52$ for sprinkler 3 from the appendix -4)

$\Delta H = 2.98\text{m}$

As the head loss is less than the 10 % of operating head available, select the manifold of 90 mm diameter.

Design of main

Select 90 mm outer diameter HDPE pipe having 85.8 mm diameter as main

From equation 3.20

$\Delta H = 1.9 \text{ m}$

Total head loss was 26 m.

In this sample calculation there are various steps have been taken which were concluded below:

In the first step net depth of irrigation has been calculated which is found to be 72mm. In the second step irrigation interval has been observed which was found 14, 17 and 9 days for Kharif, Rabi and summer season respectively.

In the third step 0.28ha, 0.23ha and 0.44 ha area has been selected for irrigation per day during Kharif, Rabi and summer season respectively. In the fourth step of calculation gross demand of water was estimated to be 6.25mm/day, 5mm/day and 8.75mm/day for Kharif, Rabi and summer season, respectively.

In the step five volume of water required per irrigation was calculated which was found 245 m^3 for Kharif season, 195.5 m^3 for Rabi and 346.5 m^3 for summer. In the

sixth step system discharge required, considering pumping for 8 hour per day has been calculated which was found to be 8.5 lit/sec for Kharif ,6.75 lit/sec for Rabi and 12 lit/sec for summer season. In the next step the operating time required during peak demand has been rechecked which was found to be 8.5 hour ,8.5 hour and 7.8 hour for Kharif, Rabi and summer season ,respectively.

In the next step number of sprinkler required has been calculated which were found to be 19, 18 and 30 for Kharif, Rabi and summer season respectively .In the next step discharge from the lateral has been computed which was found to be 7.41 lit/sec for Kharif, 6.24 lit/sec for Rabi and 11.7 lit/sec for summer. Number of lateral operated per day was found to be 3, 2 and 4 in number for Kharif, Rabi and summer season respectively.

In the next step diameter of the lateral and discharge through the lateral has been determined which is 80 m and 2.73lit /sec respectively. And the diameter of the sub main and main line was found to be 90 mm and the length of the manifold was found to be 240m .and the total head loss was estimated 26m.

4.5 Water productivity of different farm units for JNKVV Jabalpur

Water productivity of different farm units has been computed by dividing the yield of crops to the depth of irrigation applied.

Table 4.12 Existing Water Productivity of BSP (Farm Crop) unit

Season	Crop	Area (ha)	Yield (kg/ha)	Depth of irrigation (m)	Water productivity (kg/m ³)
Summer	Soybean	1.6	570	0.45	0.12
	Urd	1.9	354	0.05	0.68
	Moong	4.8	609	0.10	0.59
Rabi	Pea	8.55	862	0.20	0.42
	Gram	24.8	401	0.20	1.32
	Wheat	24.45	2466	0.47	0.52
Other	Musturd	0.5	360	0.30	0.12

Table 4.13 Existing Water Productivity of BSP (Ground nut) unit

Season	Crop	Area (ha)	Yield (kg/ha)	Depth of irrigation (m)	Water productivity (kg/m ³)
Summer	Soybean	2.0	530	0.19	0.27
	Moong	1.0	300	0.95	0.32
Rabi	Wheat	54.0	3024	0.45	0.67
	Gram	6.0	500	0.20	0.24
	Musturd	3.0	400	0.32	0.15
Kharif	Paddy	54.5	941	0.90	0.10
	Soybean	4.0	600	0.20	0.30
	Arhar	13.0	850	0.09	0.85
	Moong	1.0	420	0.11	0.39

Table 4.14 Existing Water Productivity of Vegetable Farm Maharajpur unit

Season	Crop	Area (ha)	Yield (kg/ha)	Depth of irrigation (m)	Water productivity (kg/m ³)
Summer	Soybean	6.0	590	0.20	0.29
	Moong	1.0	450	0.15	0.30
	Urd	1.0	372	0.10	0.37
Kharif	Paddy	15.0	952	0.92	0.10
	Soybean	15.5	600	0.19	0.34
	Moong	0.30	290	0.10	0.26
Rabi	Wheat	20.0	2200	0.40	0.55
	Gram	10.0	401	0.20	1.13
	Pea	2.0	860	0.20	0.42

Table 4.15 Existing Water Productivity of BSP (Soybean) unit

Season	Crop	Area (ha)	Yield (kg/ha)	Depth of irrigation (m)	Water productivity (kg/m ³)
Summer	Soybean	7.0	577	0.19	0.29
Kharif	Soybean	8.0	570	0.19	0.29
	Paddy	45.0	850	0.85	0.15
	Arhar	10.0	848	0.10	0.83
	Urd	0.5	372	0.10	0.37
Rabi	Wheat	40.0	2124	0.37	0.57
	Gram	10.0	411	0.20	1.46
	Pea	5.0	850	0.20	0.89
	Musturd	1.0	360	0.32	0.11

From these above tables it observed that , the existing water productivity of different farm units of JNKVV for wheat crop varies from 0.21 to 0.33 kg/m³, for Rice 0.31-0.33 kg/m³ ,for Gram 0.29-1.46 kg/m³ ,for Soybean 0.28-0.61 kg/m³ and for the other crops viz. Arhar ,Moong ,Urd ,Pea and Musturd it has been found to be 0.80-0.83 kg/m³, 0.20-0.50 kg/m³, 0.30-0.61 kg/m³, 0.41-0.45 kg/m³ and 0.06-0.21 kg/m³ ,respectively.

In this study according to the literature with the use of Automated Micro Irrigation System, water productivity of wheat can be improved by 1.64 kg/m³ with the 26% of less water use .This 26% is the net saving of precious ground water. In the case of Gram crop increase in water productivity has been estimated to be by 2 kg/m³ with the 51% of water saving and the crop yield will be increase by 49 %. Similarly for soybean it can be increased by 1.5kg/m³ with the 40% of precious ground water saving. For the moong crop water productivity can be increased by 0.5kg/m³ .

SUMMARY, CONCLUSIONS AND SUGGESTION FOR FURTHER WORK

Summary

In this study it has been proposed that to develop the design of Automated Micro Irrigation System for higher water productivity in JNKVV farms. The JNKVV farms were divided into different breeder seed production units these units have 29 tube wells and 2 nalas. First of all, texture of the soil and soil characteristics like water holding capacity of soil and infiltration rate of soil has been calculated.

After that to fulfill the first objective total cultivable area of JNKVV farms has been estimated, cropping intensity and intensity of irrigation has been found. Due to use of border method and sprinkler method of irrigation there much more losses of irrigation water takes place.

To overcome these water losses and to attain higher the water productivity of farm Automated Micro Irrigation System has been designed for various farm units according to the different cropping pattern of different season and crop water requirement of major shown crops. Automated Micro Irrigation system has been design with the soil moisture sensor, soil temperature sensors, microcontroller and GSM module.

Then the existing water productivity of various crops has been estimated for different farm units of JNKVV Jabalpur by dividing the yield of the crop to the depth of water applied, which is estimated by the survey of the farm units. Hence it has been found to be low because of various losses of water take place. With the use of AMIS we can save more water than the surface irrigation method and improve the water productivity.

Conclusions

- The cropping intensity of different farm units of JNKVV Jabalpur varies from 140%-150% and irrigation intensities during Kharif, Rabi, and summer are 80.85% , 76.59% and 10% respectively.
- Automated micro sprinkler irrigation system designed for different farm units of JNKVV Jabalpur, the optimum size of nozzle has been found to be 4.0 * 2.5 mm. The diameter of the lateral has been found to be 75 mm with the discharge of 2.75 lit/sec. The diameter of the manifold to fulfill the need of water has been found to be 110mm with the discharge rate of 8.19lit/sec.
- Frequency domain sensor (soil moisture sensor) and LM 35 sensors (soil temperature sensor) are need to be install at the depth of 1.5- 6cm depth in each 12 ha area. Therefore the total number of sensors for all farm units is 30 and the total GSM units is 04(four) in number.
- The existing water productivity of different farm unit of JNKVV for wheat crop varies from 0.21 to 0.33 kg/m³, for Rice has 0.31-0.33 kg/m³, for Gram 0.29-1.46 kg/m³, for Soybean 0.28-0.61 kg/m³ and for other crops viz Arhar ,Moong ,Urd ,Pea and Musturd are 0.80-0.83 kg/m³, 0.20-0.50 kg/m³, 0.30-0.61 kg/m³, 0.41-0.45 kg/m³ and 0.06-0.21 kg/m³, respectively. With the use of Automated Micro Irrigation System, water productivity of wheat, Gram, Soybean and Moong crops may be attained as much as 1.64 kg/m³, 2 kg/m³, 1.5kg/m³ and 0.5kg/m³.

Suggestion for Further work

On the basis of results obtained from the study following suggestion for future work are proposed:-

- Looking to scattered units of JNKVV farm it is suggested to make a tank of 20 ft * 20 ft in each unit. Water from different pump units will be poured into these tanks.
- The water from all the pumps will be collected in this tank and from there water will be supplied at desired locations.
- In these tanks a pump of 30 hp would be required to irrigate the field at a time.

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APPENDIX-1

Performance of Low Capacity Twin Nozzle Sprinkler (Naan 5022)

Nozzle size, mm	Operating pressure , Kg/cm ²	Diameter of spray, m	Discharge, lit/sec	Application rate,mm/hr for 12 m * 6m
2.5*2.5	2.0	20.5	0.18	8.8
	3.0	21.0	0.22	10.8
	4.0	21.5	0.25	12.4
2.8*2.5	2.0	22.0	0.20	10.1
	3.0	22.0	0.25	12.5
	4.0	23.0	0.29	14.3
3.0*2.5	2.0	22.0	0.22	11.0
	3.0	23.0	0.27	13.6
	4.0	24.0	0.31	15.6
3.2*2.5	2.0	22.0	0.24	11.8
	3.0	23.0	0.29	14.6
	4.0	24.0	0.34	16.8
3.5*2.5	2.0	22.0	0.26	13.1
	3.0	24.0	0.32	16.1
	4.0	25.0	0.38	18.5
4.0*2.5	2.0	23.5	0.31	15.7
	3.0	25.5	0.38	19.2
	4.0	26.0	0.44	21.9

(*standard nozzle)

Source: Naan product catalogue

APPENDIX-2

Performance of Medium Capacity Heavy-duty Twin Nozzle Plastic Sprinkler (Naan 5035)

Nozzle size, mm	Operating pressure , Kg/cm ²	Diameter of spray, m	Discharge, lit/sec	Application rate, mm/hr for 12 m * 6m
3.5*2.5	2.0	25.0	0.26	6.5
	3.0	26.5	0.32	8.1
	4.0	27.5	0.37	9.2
	5.0	28.0	0.41	10.2
4.0*2.5	2.0	25.5	0.31	7.8
	3.0	27.0	0.39	9.8
	4.0	28.0	0.45	11.3
	5.0	29.0	0.50	12.5
4.5*2.5	2.0	26.5	0.36	8.9
	3.0	28.0	0.46	11.4
	4.0	30.0	0.53	13.2
	5.0	33.0	0.58	14.6
5.0*2.5	2.0	26.5	0.44	11.0
	3.0	29.0	0.54	13.5
	4.0	31.5	0.63	15.6
	5.0	33.5	0.71	17.7
5.5*2.5	2.0	27.0	0.52	13.1
	3.0	32.0	0.64	16.0
	4.0	35.0	0.74	18.4
	5.0	35.5	0.82	20.5
6.0*2.5	2.0	27.0	0.61	15.1
	3.0	33.0	0.74	18.4
	4.0	35.5	0.86	21.5
	5.0	36.0	0.96	24.0

APPENDIX-3

Performance of Heavy-duty General-Purpose Twin Nozzle (Naan 254)

Nozzle size, mm	Operating pressure , Kg/cm ²	Diameter of spray, m	Discharge, lit/sec	Application rate,mm/hr for 12 m * 6m
5.0*3.2	4.0	37	0.72	6.0
	5.0	40	0.79	6.6
	6.0	42	0.86	7.2
5.5*3.2	4.0	39	0.79	6.6
	5.0	42	0.89	7.4
	6.0	44	0.99	8.2
6.0*3.2	4.0	41	0.93	7.8
	5.0	45	1.04	8.6
	6.0	47	1.13	9.4
6.3*3.2	4.0	41	0.99	8.2
	5.0	45	1.10	9.2
	6.0	47	1.20	10.0
7.0*4.2	4.0	43	1.27	10.6
	5.0	47	1.40	11.7
	6.0	51	1.53	12.7
7.5*4.2	4.0	43	1.41	11.8
	5.0	48	1.58	13.1
	6.0	51	1.71	14.2
8.5*4.2	4.0	44	1.72	14.3
	5.0	49	1.89	15.8
	6.0	52	2.07	17.2

(* standard nozzle)

Source: Naan product catalogue

APPENDIX – 4

Values of F used when the distance to the first Sprinkler equals the Sprinkler Spacing

Number of outlets	For Hazen-William equation m=1.85	For scobeys equation m = 1.90	For Dary-Weisbatch equation m = 2.00
1	1.000	1.000	1.000
2	0.639	0.634	0.625
3	0.535	0.528	0.518
4	0.486	0.480	0.469
5	0.457	0.451	0.440
6	0.435	0.433	0.421
7	0.425	0.419	0.408
8	0.412	0.410	0.398
9	0.409	0.402	0.391
10	0.402	0.396	0.385
11	0.397	0.392	0.380
12	0.394	0.388	0.376
13	0.391	0.381	0.373
14	0.387	0.381	0.370
15	0.384	0.379	0.376
16	0.382	0.377	0.365
17	0.380	0.375	0.363
18	0.379	0.373	0.361
19	0.377	0.372	0.360
20	0.376	0.370	0.359
22	0.374	0.368	0.357
24	0.372	0.366	0.355
26	0.370	0.364	0.353
28	0.369	0.363	0.351

30	0.368	0.362	0.350
35	0.365	0.359	0.347
40	0.354	0.357	0.345
50	0.361	0.355	0.343
100	0.356	0.350	0.338
More than 100	0.351	0.345	0.333

Source: vermeiren and Jobling (1980)

APPENDIX- 5

Monthly Metrological data of JNKVV Jabalpur of year 2017

Month	T max	T min	Sun Shine hrs.	Rainfall (mm)	Mean Rh	Wind Speed
January	23.85	8.75	6.65	0.85	68	2.925
February	27.175	9.47	9.325	3.3	62.75	2.925
March	31.175	11.95	9.97	0.7	48.25	3.3
April	39.4	18.12	10.15	0	31.62	4.92
May	40.95	22.65	9.75	0.1	29.5	5.75
June	39.77	23.95	8.57	18.5	44.0	6.06
July	33.3	24.47	4.87	55.05	72.62	7.05
August	29.95	23.67	3.45	110.12	81.37	6.35
September	31.5	23.82	5.12	25.92	77.35	5.20
October	32.45	21.97	6.65	48.37	75.00	3.625
November	32.60	16.92	8.625	2.3	62.25	2.85
December	28.65	9.32	7.625	0	57.75	2.60

VITA

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