International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(3): 3228-3232

Received: 10-03-2018
Accepted: 13-04-2018

Karuna Nidhan Singh
PhD Research Scholars, Faculty of SWE, SVCAET & RS, IGKV, Raipur, Chhattisgarh, India

Abinash Dalai
PhD Research Scholars, Faculty of SWE, SVCAET & RS, IGKV, Raipur, Chhattisgarh, India

Abhishek Kumar Gautam
Student, Vaugh Institute of Agricultural Engineering and Technology (VIAET), SHUATS, Allahabad, Uttar Pradesh, India

Correspondence
Karuna Nidhan Singh
PhD Research Scholars, Faculty of SWE, SVCAET & RS, IGKV, Raipur, Chhattisgarh, India

Design of sprinkler irrigation system for 5 hectare land at Sohawal block in Satna district of Madhya Pradesh

Karuna Nidhan Singh, Abinash Dalai and Abhishek Kumar Gautam

Abstract
Sprinkler irrigation is one of the efficient irrigation system. The layout simply consists of main line, sub-main & laterals. The project in present has a design of sprinkler irrigation system for wheat crop in 5 ha area at Sohawal block in Satna district of Madhya Pradesh where water source is tube well and water level is 21 m BGL. In design of sprinkler irrigation system, all the factors are included according to recommendation of field crop which are peak crop water requirement (7.65 mm/day), irrigation time (88.13 min), no. of sprinklers (80), screen filter (JIS-Model-4 of 25 m^3/hr) and pump required of 5 hp according to head of 38.88 m and discharge of 6.6 LPS.

Keywords: BGL (Below Ground Level), efficient irrigation system, Peak crop water requirement, Screen filter

Introduction
Irrigation is the artificial application of water to land or soil to assist in the production of crops at the time of need. Irrigation includes the development of the water supply, the conveyance system, the method of application, and the waste water disposal system, along with the necessary management to achieve the intended purpose. In more arid areas, rainfall during the growing season falls short of most crop needs and thus irrigation makes up for the shortage. Even in areas of high seasonal rainfall, crops often suffer from lack of moisture for short periods during some part of the growing season. (USDA *et al*, 1984) [9]. the total arable land in India is 160 million hectares (395 million acres). According to the World Bank, only about 35% of total agricultural land in India was reliably irrigated in 2010. Madhya Pradesh is the third largest state of India. It has got total irrigable area of 67.20 lakh hectare and so far 31.89 lakh hectare irrigation potential (about 47.45%) has been created until the year 2013-14 while potential utilized is 23.80 lakh hectares, which is about 74.63% of the potential achieved. The area under sprinkler irrigation is increasing day by day. It is reported that out of 80 m-ha of total irrigated area only 1.45 m-ha is under sprinkler irrigation in India. The area under sprinkler irrigation is the highest in Haryana 0.5 m-ha followed by Rajasthan, Karnataka, and Maharashtra & Madhya Pradesh. About 0.19 m-ha area irrigated by sprinkler in Madhya Pradesh. Sprinkler irrigation creates fine mist in the sprinkling zone resulting in excessive wind drift and evaporation. The operating pressure controls the wetted diameter and the mean water droplet size. (Kranz *et al*, 2005) [7]. Moreover, sprinkler irrigation design and management rules are very site specific, change with the irrigation materials, and most often rely on unstructured experiments and life-long professional experience. Hence, regular evaluation of irrigation systems is of essence to the maintenance of the systems for optimal performance at the designed parameters and also stated that to maximise production efficiency, two irrigation management issues required attention, that is, irrigation scheduling and uniformity. Placing a catch can grid around a single sprinkler head in no-wind conditions and establishing the corresponding overlapping for any sprinkler spacing. (Ascough and Kiker, 2002). The evaluation of sprinkler systems typically involves an assessment of the volumetric discharge rate and the uniformity of the discharge. (Dalton and Raine, 1999) [3].

Material and Methodology
The Sohawal block of Satna district was selected for the experiment. Experiment was carried out in the year 2016-17 with growing season from

1st week of November 2016 to February 2017. The field experiment consisted of design and installation of sprinkler irrigation system, plantation of wheat, irrigation scheduling, field observation and estimation of power requirement of pump. So, the farm water requirement was estimated. The size of pump for water supply to the farm of 5 hectare was determined here. Experiment was conducted at farmer's field of Sohawal block, Satna, located between 24° 34'32" N latitude and 80° 45'46" E longitude and 322 m above the mean sea level. The land was flat and soil was texturally classified as sandy loam. The no. of nozzles & size of nozzles were designed according to the discharge of water requirement for sprinkler irrigation.

Design procedure of Sprinkler Irrigation system involves

- Calculation of peak crop water requirement.
- Selection of impact sprinkler.
- Design and selection of sub main line.
- Design and selection of main line.
- Selection of filters.
- Selection of venturi injector
- Design and selection of pump.

- **Calculation of peak crop water requirement**

$$PWR = \frac{A \times B \times C}{E} \times D \text{ (For area having large spacing) (mm/day)}$$

Where,
A→Potential Evapotranspiration Rate (mm/day)
B→Crop Factor (depend upon growth stage)
C→Canopy Factor ($C=\frac{\text{area of plant shadow at 12 noon}}{(\text{plant spacing} \times \text{row spacing})}$)
E→Efficiency of System (for drip-90% and for sprinkler-80%)

- **Selection of impact sprinkler**

The spacing of sprinkler was varied from 0.5D - 0.7D
Water Application Rate, $WAR = \frac{SD}{(SSS)^2}$ (mm/hr)

Where,
D → Diameter of wetted area
SD → Sprinkler Discharge
SSS→ Sprinkler to Sprinkler spacing

a. Irrigation Time

Irrigation Time = $\frac{PWR}{WAR}$ (hrs)

Where,
PWR→Peak water requirement
WAR→Water application rate

b. Total Time of Irrigation Shift

Total Time of Irrigation Shift = Irrigation Time (IT) + Shifting Time (ST

C. **No. of shift (NOS) possible according to time**

$$NOS = \frac{EA}{\text{Time of Irrigation Shift}}$$

Where,
EA → Electricity available

3. Design and Selection of Sub-main Material

Poly Vinyl Chloride (PVC) or High Density Polyethylene **(**HDPE) pipes are mainly used as sub main material having sizes 50 mm, 63 mm, 75 mm diameter etc.

a. Deciding length by limiting frictional head loss & design tolerance

For deciding length of submain by limiting frictional head loss & design tolerance is normally taken upto 2m or 0.2 kg/cm^2.

b. Calculation of Specific Discharge Rate (SDR, lph/m) –

SDR is mathematically expressed by following formula,

$$\text{SDR of Sub-main} = \frac{\text{No.of Dripper covered by Submain} \times \text{Dripper Discharge}}{\text{Length of Submain}}$$

For Sub-main, the frictional loss is given by Hazen-Williams formula,

$$hr = 5.35 \left(\frac{Q^{1.852}}{D^{4.871}}\right) \times L$$

Where,
h_f →Total energy drop by friction at the end of laterals.
Q → Total discharge at the end of laterals.
D →Internal diameter of pipe in meter
L →length of pipe in meter
C →Hazens-Williams constant (friction factor), 150 assumed for PVC/HDPE.

c. Design and Selection of Mainline Material

Poly Vinyl Chloride (PVC) or High Density Polyethylene **(**HDPE) pipes are mainly
used as main line material having sizes 50 mm, 63 mm, 75 mm diameter and above.

e. Calculation of Mainline Sectional Flow

It is mathematically expressed as,

$$\text{Main line (sectional) flow} = \frac{\text{No.of Drippers covered by Section} \times \text{Dripper Discharge}}{3600} \text{ lps}$$

Calculating frictional loss is given by Hazen-Williams formula,

$$h_f = 5.35 \left(\frac{Q^{1.852}}{D^{4.871}}\right) \times L$$

Where,
h_f → Total energy drop by friction at the end of laterals.
Q →Total discharge at the end of laterals.
D →Internal diameter of pipe in meter
L →length of pipe in meter
C → Hazens-Williams constant (friction factor), 150 assumed for PVC/HDPE.

- **Selection of Filter**

Filter is selected based on its capacity which is calculated by the following formula.
Filter capacity = $3.6 \times Q_{main}$ (m^3/ hr)

Table 1: Various Parameters considered for selection of filter of different types

Filter	Water source	Impurities
Sand separator or Hydro-cyclone filter	Canal, river, dam, farm pond, tube well.	Heavier than water- sand, silt &clay particles.
Sand filter (media filter)	Open water source exposed to sun light-open well, canal, river, dam, farm pond.	Lighter than water –algae & other living organism like plant residue, organic matter etc.
Screen filter Compulsory filter in MIS	All water source	Fine silt & clay particles
Disc filter Precision filter	Open well, tube well, canal, river, dam, farm pond.	Fine silt & clay particles, Algae, plant residue, organic matter etc.

- **Selection of Venturi injector**

The venturi injectors are selected basing upon the sizes ¾'', 1'', 1.25'', 1.5'', 2''

Motive flow of venturi

It is calculated by the following formula.

Motive flow of venturi = $\frac{Q_{main}}{2}$

Table 2: Various Parameters for selection of motive flow of venture

Venturi size (inch)	Motive flow (LPS)	Pressure difference (kg/cm^2)	Suction rates (lph)
2''	5	0.8-1	1400-1900
1.5''	3	0.8-1	800-1200
1.25''	2.5	0.8-1	400-550
1''	1.5	0.8-1	150-300
¾''	0.75	0.8-1	40-60

- **Design and selection of pump**.

Table 3: Design Parameters considered for selection of pump

Suction Head	Vertical distance between the water level to centre of pump.
Delivery Head	Vertical distance between centres of pump to centre of outlet.
Filtration Losses	Frictional head loses in different types of filters. It is assumed hydro cyclone filter 3m, sand filter 3-5m, screen filter-2m.
Mainline Losses	Frictional head losses occur in main line.
Operating Pressure	In general 10m pressured is required for non-pressure compensating and 15m for pc drippers.
Fittings losses	Loss in fittings like bend, elbows, tees, reducers & valves etc & is assumed to be 2m overall.
Venturi Head	Pressure required to operate the venturi or fertilizer application and is assumed to be 5 m.
Elevation	Vertical distance between ground level near to water source to the highest level of ground.

a. Total head required

Total head required (m) = Suction Head +Delivery head +head loss in filters + head loss in mainline + Operating pressure of system + head loss in fittings + head loss in venturi + upward elevation if only.

b. Pump Power Calculation

$$P = \frac{Q \times H}{75 \times a \times b}$$

Where,

Q →Required discharge (LPS)

H →Required total head (m)

a →Efficiency of motor (assumed 85%)

b →Efficiency of pump (assumed 80%)

The pump is selected according to head and discharge, and not to the power (HP)

c. Irrigation Scheduling

Table 4: Various Parameters considered in irrigation scheduling

No. of shift (No.)	Flow (LPS)	Time (Hrs)	Total Time (hrs)
6	6.67	1.63	9.78

Total time is less than electricity available, therefore it is alright.

Observation & Calculation

Here the observation of recording data and calculation of various required values are given below:

Calculation of area -

Area = 200× 250 m = 50000 m^2 = 12.35 acre

Calculation of design

Calculation of peak crop water requirement

$$PWR = \frac{1.2 \times 0.85 \times 6}{0.8} = 7.65 \text{ mm/day}$$

Selection of impact sprinkler

JIS-4 model (Jain Impact Sprinkler) having discharge of 50 lpm, radius of throw of 19m and operating pressure of 2.5 kg/cm^2 was selected.

Spacing was decided by following formula,

Spacing = 0.5 × 38 - 0.7 × 38 = 19 - 26.6

Sprinkler to Sprinkler spacing (SSS) must be multiple of 6m/1QC pipe. SSS was selected as 24 m.

Water Application Rate

$$WAR = \frac{50 \times 60}{24^2} = 5.2083 \text{ mm/hr}$$

Irrigation time

$$IT = \frac{7.65}{5.20}$$

$$= 1.4608 \times 60$$

$$= 88.128 \text{ min}$$

Total Time of Irrigation Shift
Assuming shifting time for sprinkler set is equal to 10 min.
So that,
Total Time of Irrigation Shift = 88.128+10min = 1.6354 hr

No. of irrigation shift possible according to time

$$NOS = \frac{12}{1.6357} = 7.3373$$

We can irrigate the 9 sections by selecting 8 shift to irrigate the wheat crop.

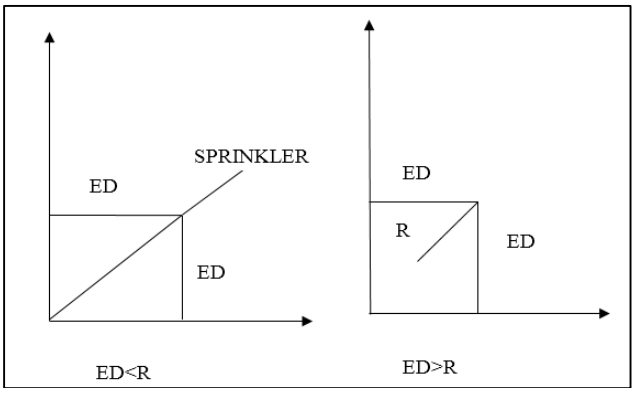

Fig 1: Radii & End distance of sprinkler

$$ED = \frac{R}{\sqrt{2}}$$
$$ED = \frac{19}{\sqrt{2}}$$
ED = 14.435
ED ≈ 14 m

Long Side
ED Adjusted long = 17
No. of division on long side
$\frac{\text{ED long side} - 2\text{ED long}}{SSS}$
$\frac{250 - 2 \times 14}{24} = 9.25$
$\frac{250 - (9.25 \times 24)}{2} = 17$
No of sprinkler on long side
9 + 1 = **10**

Short Side
ED Adjusted short = 16
No. of division on short side
$\frac{\text{ED short side} - 2\text{ED short}}{sss}$
$\frac{200 - 2 \times 14}{24} = 7.16$
$\frac{200 - (7.16 \times 24)}{2} = 16$
No of sprinkler on short side
7 + 1 = **8**

Design & Selection of Sub main

$$SDR_{submain} = \frac{8*50*3600}{184*60} = 130.434 \text{ lph}$$

For SDR Curve, we selected 75mm diameter Quality Control pipe to run 184m length of sub-main pipe. (h_f = 1.6m)

Design & Selection of Mainline

$$Flow = \frac{8*50*60}{3600} = 6.67 \text{ LPS}$$

Table 5: Various Parameter considered in design & selection of mainline

From	To	Length (m)	Flow (LPS)	Diameter (mm)	Class	H_f	Actual h_f
End	Water Source	184	6.67	110	I	4.8	0.8832

Selection of Filter
Filter capacity = 3.6 × 6.67 = 24.012 m^3/hr
JIS-4 model screen filter was selected of discharge 25 m^3/hr with plastic manifold.

Selection of Venturi Injector
Motive flow of venturi – It is calculated by following formula.

$$\text{Motive flow of venturi} = \frac{6.67}{2} = 3.335 \text{ LPS}$$

Design & Selection of Pump
Total head required
It is computed by the following formula,
Total head required = (21 + 2) + 2 + 10 + 2 + 0.8823 +1
= 38.8823 m

Calculation of Pump Power
Selection of pump was done according to Head & Discharge
= (6.67×38.8823)/75
= 3.457 = 3.5 HP
= 5 HP (According to availability)

Technical Diagram

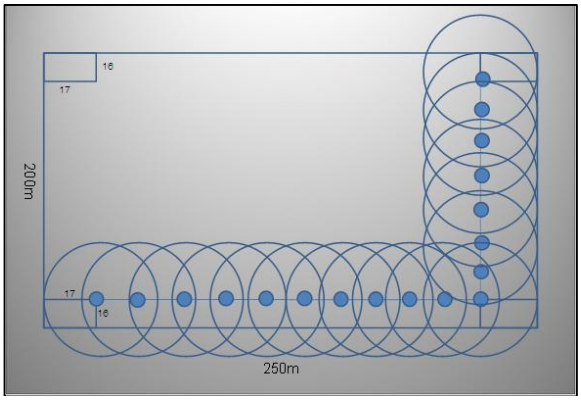

Fig 2: Technical diagram of sprinkler irrigation system

Sprinkler Placement Diagram

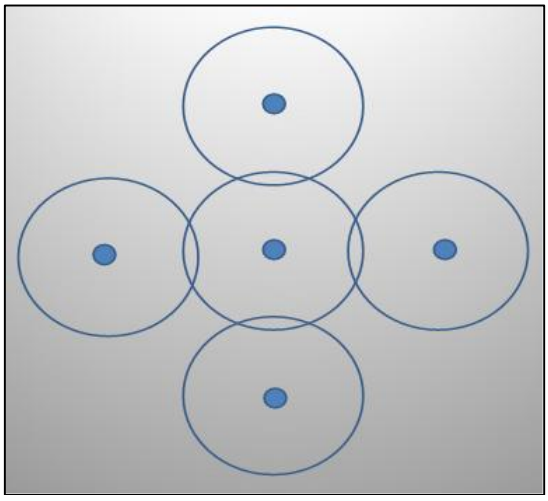

Fig 3: Sprinkler placement in sprinkler irrigation system

Result and Discussion
As recommendation of design of sprinkler irrigation system for Sohawal area in Satna district of irrigated area of 5 ha which is in rectangular form of size 250 x 200 m horizontally and vertically respectively. According to area and

recommendation of materials it was found that the no. of sprinklers in horizontal and vertical directions are 10 and 8 respectively. The discharge of mainline was estimated as 6.67 lph and total head required for irrigation of particular crop was 38.88 m. According to discharge of pump and its head, the pump power was computed as 3.5 HP but the availability of pump power vary from 3 to 5 HP, so 5 HP pump was selected for this experimental design.

System Installation

The following items are suggested for proper design of sprinkler irrigation system & its cost estimation.

Table 6: Design of Sprinkler Irrigation System

Crop	Wheat
Irrigated area	5 ha
Irrigation interval	20
Irrigation period	1.63 hours
Irrigation depth	7.65 mm/day
Size of pump	3.5 HP = (5 HP)
Size of laterals	184 m
No. of nozzles	18
No. of sprinklers	18

Conclusions

In this experiment, the design of sprinkler irrigation was studied and found that the water saving in this system is 70% approximately than surface irrigation method. There were various factors which affected the design of sprinkler & its validation like –air velocity, height of riser pipe, no. of sprinklers, no of nozzles, etc. In this project we found the different factors for proper design of sprinkler irrigation system. The design of sprinkler irrigation system, estimated all the factors viz. peak crop water requirement of 7.65 mm/day, operational irrigation time of 88.13 min, no. of sprinklers of 80, capacity of screen filter of JIS-Model-4 of 25 m^3/hr and 5 HP power of pump required according to head of 38.88 m and discharge of 6.67 LPS.

References

1. Ascough GW, Kiker GA. The Effect of Irrigation Uniformity on Irrigation Water Requirements, Water Resource Commission, South Africa, 2002.
2. Calder T. Efficiency of Sprinkler Irrigation Systems, Department of Agriculture, Australia, 2005.
3. Dalton P, Raine S. Measures of Irrigation Performance and Water Use Efficiency, Department of Environmental and Resource Management, Australia, 1999.
4. https://en.wikipedia.org/wiki/Jain_Irrigation_Systems.
5. Keller J, Bliesner RD. Sprinkle and Trickle Irrigation, Van Nostrand Reinhold, New York.1990; 3-5:86-96.
6. King BA, Stark JC, Kincaid DC. Irrigation Uniformity, University of Idaho, USA, 2000.
7. Kranz B, Yonts D, Martin D. Operating Characteristics of Center Pivot Sprinklers, University of Nebraska-Lincoln Extension, USA, 2005.
8. Merkley GP, Allen RG. Sprinkle and Trickle Irrigation Lecture Notes, Utah State University, USA, 2004.
9. USDA. Engineering Field Handbook on Irrigation, USDA, USA, 1984.
10.