

ABSTRACT

In arid and semi-arid areas in India, water requirement for irrigation purpose is a major problem. In recent times various micro irrigation systems like drip irrigation and sprinkler irrigation systems are used to take the maximum use of water which is supplied very limitedly. Due to economy, minimum labour work, Government subsidy and maximum output among all irrigation systems, sprinkler irrigation system has become very popular. The sprinkler system irrigates the field drop by drop and thus it is widely used as it checks the wastage of water through seepage and evaporation. Conveyance losses are also minimum. Sprinkler irrigation system applies water uniformly to the soil surface. When irrigation sprinklers are installed in conventional manner then due to non-uniform water distribution, variation in the area of wetting diameter, ground slope, varied nozzle pressure we cannot get required efficiency and uniformity. The study area is situated in Kodram village in Banaskantha District, Gujarat. The total area of the field is 2.49 Ha. The study will be carried out in a part of a field which is 0.53 Ha in area. In this study experiments are performed to evaluate the specifications of the system by the manufacturer to find out the : area irrigated by individual sprinkler, uniformity coefficient of irrigation, individual sprinkler discharge, wetted area radius. The calculated values by experiment are compared with the values provided by the manufacturer.

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Chapter 1 : INTRODUCTION

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1.1 Project Background

Studies carried out across different countries including India have confirmed that irrigation plays an important role in water use efficiency, yield of crops, enhancing cropping intensity and productivity of crops. Water is becoming increasingly scarce worldwide due to various reasons. Most of the countries located in arid and semi-arid regions like South Asia, Middle-East and South Saharan Africa, the problems of water scarcity is expected to be aggravated further. In spite of having the largest irrigated area in the world, India too has started facing severe water scarcity in different regions. Owing to various reasons the demand for water for different purposes has been continuously increasing in India, but the potential water available for future use has been declining at a faster rate. Hence need has arisen to use Micro irrigation techniques apart from traditional Surface irrigation methods to take the maximum advantage of the water supplied for irrigation. Unlike Surface irrigation method, Micro irrigation Method supplies water directly to the root zone of the crop, instead of land, and therefore, the water losses occurring through evaporation and distribution are completely absent. Though both drip and sprinkler irrigation method of irrigation are treated as Micro Irrigation method, there are distinct characteristics differences between the two in terms of flow rate, pressure requirement, wetted area and mobility. Sprinkler irrigation method sprinkles water similar to rainfall into the air through nozzles which subsequently break into small water drops and fall on the field surface. In India, the area under sprinkler irrigation has increased from 0.67 Mha in 1997-1998 to 1.63 Mha in 2004-05 to 2.44 Mha in 2009-10 and further to 6.58 Mha in present. But there is more to achieve in terms of application efficiency in sprinkler irrigation system. Here in this project, by the study of Rotating type center-pivot sprinklers installed in semi-arid region uniformity co-efficient, nozzle pressure, area of areal spray of individual sprinklers are tested and checked whether they are as per specifications of the provider of sprinkler system.

1.2 Objectives

- To study conventional sprinkler irrigation system installed in a farm.
- To find uniformity co-efficient of the sprinkler irrigation system.
- To draw the water contours of the farm having sprinklers installed.
- To study the effect of wind and ground slope in sprinkler irrigation.
- To check the area of the wetting circle of individual sprinklers.
- To measure individual sprinkler discharge.

Chapter 2 : INTRODUCTION TO SPRINKLER
IRRIGATION

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2.1 Definition

Sprinkler irrigation is a method of applying water to the surface of the soil in the form of a spray, which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air through sprinklers so that it breaks up into small water drops, which fall to the ground. The pump supply system, sprinklers and operating conditions must be designed to enable a uniform application of water.

2.2 History of Sprinkler Irrigation

This method of irrigation was started at about 1900. The first agricultural sprinkler systems were an outgrowth of city lawn sprinkling. Before 1920 sprinkling was limited to tree crops, nurseries and orchards. Most of the systems were stationary overhead-perforated pipe installations or stationary over tree systems with rotating sprinklers. These systems were expensive to install but often fairly inexpensive to operate. Portable sprinkler systems developed with the introduction of light weight steel pipe and quick couplers in the early 1930s, resulted in reduction of equipment cost and increased number of sprinkler installation. The number of sprinkler installations has increased rapidly since 1950 owing to the development of more efficient sprinklers, lightweight aluminium pipe, more efficient pumps, and to the widespread distribution of low cost electrical power and fuels for internal combustion engines. Sprinklers have been used on all soil types and on lands of widely different topography and slopes and for many crops.

2.3 Adaptability of Sprinkler Irrigation

Some of the conditions, which favour sprinkler irrigation, are as follows.

- When light application of water is required for seeding and young plants.
- In humid regions sprinklers are most useful because increase in humidity is less.
- Soils too porous for good distribution by surface methods.

- Land having steep slopes and easily erodable soils.
- Irrigation stream too small to distribute water efficiently by surface irrigation
- Undulating land too costly to level sufficiently for good surface irrigation
- When maximum productivity is needed.
- When assessment of water is to be done.
- Soils with low water holding capacities and shallow rooted crops, which require frequent irrigation
- Automation and mechanization are practical.
- Labour available for irrigation is either not experienced in surface methods of irrigation or is unreliable, good surface irrigation requires trained reliable labour
- Higher application efficiency can be achieved by properly designed and operated systems.
- Land preparation is uneconomical and time consuming.

2.4 Types of Sprinklers

Various types of sprinkler systems have been developed in response to economic and labour conditions, topographic conditions, special water application needs and the availability of water and land resources. Several major types of sprinklers are described here.

2.4.1 Fixed Nozzle Sprinkler

In this type of system parallel pipes having a line of small holes are installed at about 15 meters apart and supported on rows of posts. Water is discharged at right angles perpendicularly from the pipeline. The entire 15 m width between pipelines may be irrigated by turning the pipes through about 135°. This type of sprinkler was the early system and it is rarely used in practice.



Fig. 1 : Fixed Nozzle sprinkler

2.4.2 Perforated Pipe Sprinkler

In this method, perforations in the lateral pipes are drilled on the top surface and sides in a specially designed pattern to spray the water uniformly. The lateral pipes are placed on the land surface at a suitable spacing. When the water is supplied to the lateral pipes, it comes out the perforations in the form of spray.



Fig. 2 :Perforated Pipe sprinkler

The sprays are directed from both the sides of the pipe and can cover a strip of land of 6 to 15 m width. The rate of application of water is usually greater than 2 cm depth per hour. The operating pressure of these sprinklers is usually in the range of 50 to 250 kN/m². This type of sprinkler system is generally used for irrigation of orchards and nurseries.

2.4.3 Rotating Sprinkler



Fig. 3 : Rotating sprinkler

The rotating sprinkler consists of one or two nozzles mounted on a body which is rotated slowly about vertical axis by the action of a deflecting vane connected to it. The jet of water issuing from one of the nozzles impinges on the vane and thrusts it aside.

The rotating sprinklers are placed on the riser pipes and are located just above the crops to be irrigated. As such the height of the riser pipes depends upon the maximum height of the crop. However, the minimum height of the riser pipe is 0.3 m when the riser pipe is of 25 mm diameter and 0.15 m when it is of 20 mm diameter. The riser pipes along with the sprinklers are fixed at regular intervals along the length of the lateral pipes and their spacing is so adjusted that the water spread areas of the adjacent sprinklers partially overlap with each other in order to achieve uniform application of water.

The required discharge of each sprinkler depends upon the water application rate, spacing of the sprinklers along the lateral pipelines and the spacing of the lateral pipelines along the main pipeline.

Chapter 3: COMPONENTS OF SPRINKLER SYSTEM

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3.1 Typical Sprinkler System Layout

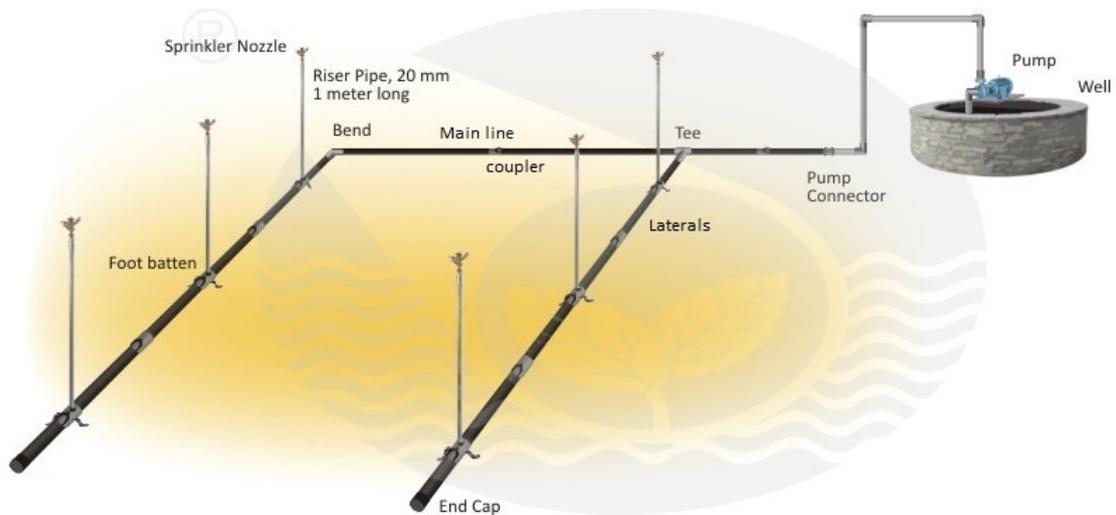


Fig. 4 : Sprinkler System Layout

3.2 Pressure Generating Unit



Fig. 5 : Pumping Unit

Sprinkler irrigation systems distribute water by spraying it over the fields. The water is pumped under pressure to the fields. The pressure forces the water through sprinklers or through perforations or nozzles in pipelines and then forms a spray. A high

speed centrifugal or turbine pump can be used for operating sprinkler irrigation for individual fields. Centrifugal pump is used when the distance from the pump inlet to the water surface is less than eight meters. For pumping water from deep wells or more than eight meters, a turbine pump is used.

3.3 Water Carrier Units

3.3.1 Mainline and Sub-mains

The Tubings consist of mainline, sub-mains. Main line conveys water from the source and distributes it to the sub-mains. The sub-mains convey water to the laterals which in turns apply water to the sprinklers. PVC is usually used for main lines. HDPE (high density poly ethylene) pipes are used for sub-mains. These tubing should be easily joined, leak proof, durable and Strong enough to last uneven static and dynamic loads.

3.3.2 Laterals

This comes out of the sub main to deliver water to the sprinkler nozzles. The position of the lateral may be permanent, as in a solid set, or moveable as in the hand move and side- roll systems. The distance between sprinkler nozzles along a lateral is termed as the lateral spacing which plays major role in success of sprinkler system.

3.3.3 Couplers

Couplers are used for connecting two pipes and uncoupling quickly and easily. Essentially a coupler should (a) provide a reuse and flexible connection (b) not leak at the joint (c) be simple and easy to couple and uncouple (d) be light, non-corrosive, durable.

3.4 Water Delivery Units

3.4.1 Riser Pipes

Sprinklers are placed on the riser pipes and are located just above the crops to be

irrigated. The height of the riser pipes depends upon the maximum height of the crop. However, the minimum height of the riser pipe is 0.3 m when the riser pipe is of 25 mm diameter and 0.15 m when it is of 20 mm diameter. The riser pipes are fixed at regular intervals along the length of the lateral pipes and their spacing is so adjusted that the water spread areas of the adjacent sprinklers partially overlap with each other in order to achieve uniform application of water.



Fig. 6 : Riser Pipe

3.4.2 Sprinkler Head

Sprinkler head distribute water uniformly over the field without runoff or excessive loss due to deep percolation. Different types of sprinklers are available. They are either rotating or fixed type. The rotating type can be adapted for a wide range of application rates and spacing.

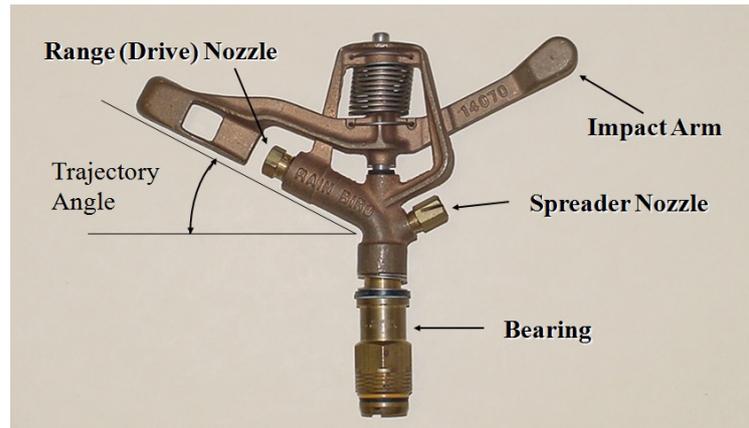


Fig. 7 : Sprinkler Head

Sprinkler head consists of Range Nozzle, Impact arm, Spreader Nozzle and Bearing. They are effective with pressure of about 10 to 70 m head at the sprinkler. Pressures ranging from 16 to 40 m head are considered the most practical for most farmers. Fixed head sprinklers are commonly used to irrigate small lawns and gardens. Perforated lateral lines are sometimes used as sprinklers. They require less pressure than rotating sprinklers. They release more water per unit area than rotating sprinklers. Hence fixed head sprinklers are adaptable for soils with high intake rate.

3.5 Fittings and Accessories

The following are some of the important fittings and accessories used in sprinkler system.

- (a) Water meters:** It is used to measure the volume of water delivered. This is necessary to operate the system to give the required quantity of water.
- (b) Flange, couplings and nipple :** They are used for proper connection to the pump, suction and delivery.
- (c) Pressure gauge:** It is necessary to know whether the sprinkler system is working with desired pressure to ensure application uniformity. Therefore Pressure gauges are used.



Fig. 8 : Pressure Gauge

(d) Bend, tees, reducers, elbows, hydrants, butterfly valve and plugs.

(e) Fertilizer applicator: Soluble chemical fertilizers can be injected into the sprinkler system and applied to the crop. The equipment for fertilizer application is relatively cheap and simple and can be fabricated locally. The fertilizer applicator consists of a sealed fertilizer tank with necessary tubings and connections. A venturi injector can be arranged in the main line, which creates the differential pressure suction and allows the fertilizer solution to flow in the main water line.

(f) Booster Pumps : Booster pumps are used when additional pressure is required in some particular place of the already pressurized system. They could be used to provide adequate pressure for small areas that lie at elevation considerably above the principal area to be irrigated, to derive the turbine in a hose reel or self-propelled gun travelers. The use of booster pumps under such conditions removes the need to carry high pressures from the main pumping plant for relatively small fraction of the total pressure that is needed on high pressure or discharge area.

Chapter 4 : SOIL-WATER INTERACTION IN
SPRINKLER SYSTEM

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4.1 Wetting Pattern

The wetting pattern from a single rotary sprinkler is uniform. Normally the area wetted is circular (see top view). The circular area on the ground where water is projected from the sprinkler head is called Wetting Circle. The diameter of the wetting circle is called the Wetting diameter.

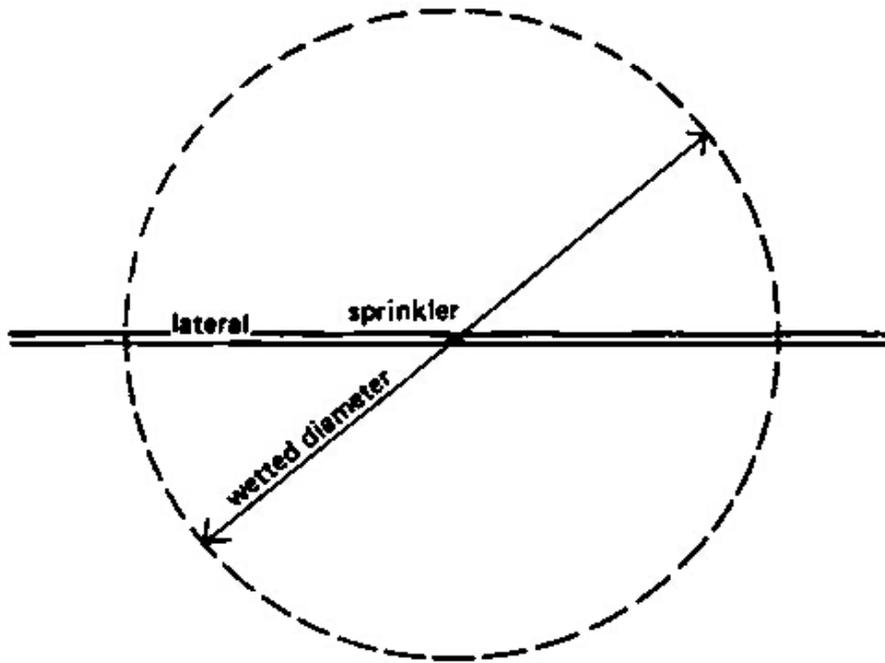


Fig. 9 : Top view of Wetting circle



Fig. 10 : Side view of Wetting circle

The precipitation rate from individual sprinkler heads is not uniform throughout the wetting circle. The heaviest wetting is close to the sprinkler (see side view). To get a desirable water distribution uniformity two adjacent sprinklers should be spaced such that there is some overlap of the precipitation. As a general rule, the spacing between the sprinklers is kept between 50-60% of the "wetting diameter. This determines the maximum spacing between sprinklers.

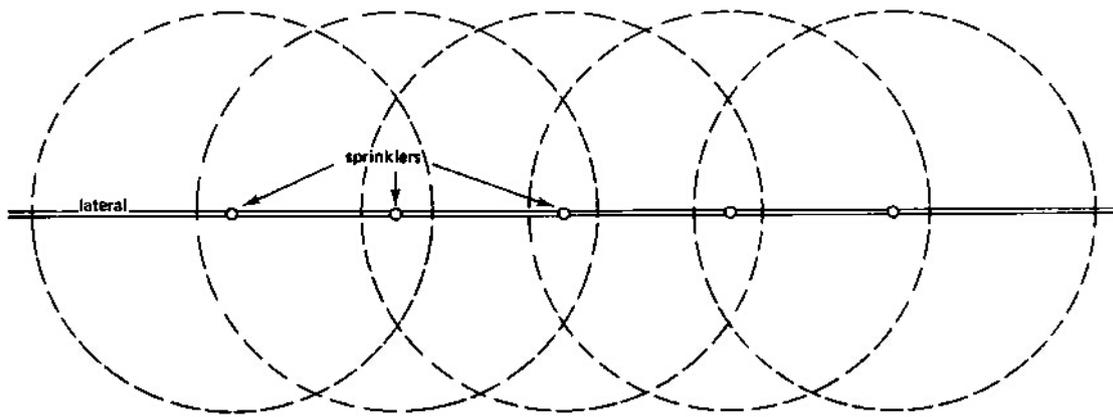


Fig. 11 : Top view of Overlapping of Wetting circles

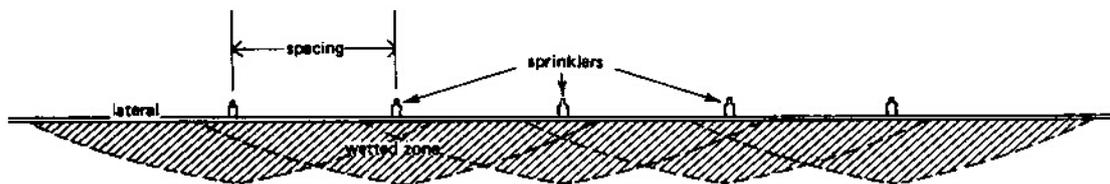


Fig. 12 : Side view of Overlapping of Wetting circles

The uniformity of sprinkler applications can also be affected by wind and water pressure. Spray from sprinklers is easily blown about by even a gentle breeze and this can seriously reduce uniformity. To reduce the effects of wind the sprinklers can be positioned more closely together.

4.2 Water Infiltration Rate of Soil

If water Infiltration rate is lower than the water application rate by sprinkler system, then water remains on the soil surface too long or infiltrates too slowly to supply the crop with sufficient water to maintain acceptable yields. Although the infiltration rate of water into soil varies widely and can be greatly influenced by the quality of the irrigation water, soil factors such as structure, degree of compaction, organic matter content and chemical make-up can also greatly influence the infiltration rate. For various types of soil structures infiltration rate varies as per Table 1.

Soil Structure	Infiltration Rate Limit (mm/hr)	Avg. rate (mm/hr)
Sandy	12 - 250	50
Sandy loam	13 - 76	25
Loamy	8 - 20	13
Clay loam	2.5 - 15	8
Clay	0.3 - 5	2

Table 1 : Infiltration Rate for different soils

4.3 Water Application Rate

Water Application rate is the average height of the collected water that has fallen on the ground from the sprinklers over a specified period of time, measured as mm per hour. If the application rate is higher than the infiltration rate of the soil, runoff will occur, particularly in heavy soils and uneven surfaces. Therefore, the precipitation rate is an important factor to consider when selecting the type of sprinkler to use. Generally, small sprinklers have a slower application rate, thereby lowering their ability to cause runoff damage.

4.4 Water Quality

The quality of irrigation water is determined by various chemical and physical characteristics, whereby aspects like temperature and oxygen content are usually of minor importance. The salinity or total concentration of soluble salts is the most important parameter, since growth of the majority of crops is affected by total concentration of ions rather than by any specific ion. Although dissolved salts may contain valuable plant nutrients, irrigation with salty water may lead to soil salinization, which will impede the water uptake of the plant.

Water quality refers to what extent the quality of a water supply is suitable for a specific use. In irrigation water evaluation, emphasis is placed on the chemical and

physical characteristics of the water and seldom are any other factors, such as biological characteristics, considered important. Specific uses have different quality needs and one water supply is considered more acceptable if it produces better results or causes fewer problems than an alternative water supply. When evaluating water quality, emphasis should focus on relating the potential problem to the field situation since solutions to water quality problems usually must be implemented at the farm level rather than at the project level.

**Chapter 5 : DESIGN NORMS FOR SPRINKLER
SYSTEM**

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5.1 System Capacity

The capacity of the system is the continuous flow rate required to irrigate the specified area within the selected operating schedule. It may be estimated as a function of the gross irrigation requirement, area, and operating schedule as follows.

$$Q = \frac{2.778 i_g A}{N_{op} T_{op}}$$

Where,

Q = continuous flow rate required, l/s

i_g = gross irrigation requirement, mm

A = total irrigated area, ha

N_{op} = number of days of operation per irrigation interval, d

T_{op} = hours of operation per day, h/d

5.2 Design Discharge

Depending on type of sprinkler, nozzle size and operating pressure, design discharge can be calculated as follows.

$$q = 1.882 C_d D^2 P$$

Where,

q = discharge of sprinkler, l/s

C_d = discharge coefficient for nozzle and sprinkler ≈ 0.96

D = inside diameter of nozzle, inch

P = water pressure at nozzle, psi

Discharge (gpm) for straight bore nozzles of various sizes operating for a range of nozzle pressures is shown in Table 2.

Nozzle Size		NOZZLE PRESSURE, psi															
inches	/64"	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
3/32	6	1.2	1.39	1.50	1.61	1.71	1.80	1.89									
7/64	7	1.7	1.90	2.05	2.19	2.32	2.45	2.57									
1/8	8	2.2	2.48	2.68	2.86	3.03	3.20	3.35	3.50	3.65	3.78	3.92	4.04				
9/64	9	2.8	3.13	3.39	3.62	3.84	4.05	4.24	4.43	4.61	4.79	4.96	5.12				
5/32	10	3.5	3.9	4.2	4.5	4.7	5.0	5.2	5.5	5.7	5.9	6.1	6.3				
11/64	11	4.3	4.7	5.1	5.4	5.7	6.0	6.3	6.6	6.9	7.2	7.4	7.6				
3/16	12	5.1	5.6	6.0	6.4	6.8	7.2	7.5	7.9	8.2	8.5	8.8	9.1				
13/64	13	6.0	6.5	7.1	7.6	8.0	8.4	8.9	9.2	9.6	10.0	10.3	10.7				
7/32	14	6.9	7.6	8.2	8.8	9.3	9.8	10.3	10.7	11.2	11.6	12.0	12.4				
15/64	15	7.9	8.7	9.4	10.1	10.7	11.2	11.8	12.3	12.8	13.3	13.8	14.2				
1/4	16	9.0	9.9	10.7	11.4	12.1	12.8	13.4	14.0	14.6	15.1	15.7	16.2				
17/64	17	10.	11.2	12.1	12.9	13.7	14.4	15.1	15.8	16.5	17.1	17.7	18.3				
9/32	18	11.	12.5	13.5	14.5	15.4	16.2	17.0	17.7	18.5	19.2	19.8	20.5				
5/16	20	14.	15.5	16.7	17.9	19.0	20.0	21.0	21.9	22.8	23.6	24.5	25.3				
11/32	22	17.	18.7	20.2	21.6	22.9	24.2	25.4	26.5	27.6	28.6	29.6	30.6	31.5	32.4	33.3	34.2
3/8	24	20.	22.3	24.1	25.7	27.3	28.8	30.2	31.5	32.8	34.0	35.2	36.4	37.5	38.6	39.7	40.7
13/32	26	23.	26.2	28.3	30.2	32.0	33.8	35.4	37.0	38.5	40.0	41.4	42.7	44.0	45.3	46.6	47.8
7/16	28	27.	30.3	32.8	35.0	37.2	39.2	41.1	42.9	44.7	46.3	48.0	49.5	51.1	52.6	54.0	55.4
15/32	30	31.	34.8	37.6	40.2	42.7	45.0	47.2	49.3	51.3	53.2	55.1	56.9	58.6	60.3	62.0	63.6
1/2	32	33.	37.0	40.0	42.8	45.3	47.8	50.1	52.4	54.5	56.6	58.5	60.5	62.3	64.1	65.9	67.6
17/32	34	38.	41.8	45.1	48.3	51.2	54.0	56.6	59.1	61.5	63.8	66.1	68.3	70.4	72.4	74.4	76.3
9/16	36	42.	46.9	50.6	54.1	57.4	60.5	63.5	66.3	69.0	71.6	74.1	76.5	78.9	81.2	83.4	85.6
5/8	40	52.	57.9	62.5	66.8	70.9	74.7	78.3	81.8	85.2	88.4	91.5	94.5	97.4	100.	103.	105.
11/16	44	63.	70.0	75.6	80.8	85.7	90.4	94.8	99.0	103.	106.	110.	114.	117.	121.	124.	127.

Table 2 : Variation in Discharge as per varied nozzle diameter and nozzle pressure

5.3 Required Number of Sprinklers

The required number of sprinklers can be estimated by dividing the system capacity by design discharge for the nozzle selected. This is given by :

$$N = \frac{Q}{q}$$

Where,

N = No. of sprinkler

Q = System capacity

q = design discharge per nozzle

The final solution for the number of sprinklers will be decided based on the lateral

and mainline spacing. The lay out of the laterals and mainline will determine the actual number of sprinklers. The number of nozzles to be operated simultaneously times the design discharge per nozzle will determine the final system capacity.

5.4 Application Rate

The application rate to the soil surface must be less than the intake rate of the soil to avoid runoff. The lower limit of the application rate must take in to account that there will be safe evaporation and wind drift of water from the nozzle. Thus, the discharge rate of the nozzle should be high enough that adequate water remains after evaporation and wind drift to enable a reasonable amount of water to be infiltrated in to the root zone.

The gross application rate,

$$A_{rg} = \frac{360 Q}{S_l S_m}$$

Where,

A_{rg} = gross application rate, cm / hr

Q = nozzle discharge, l/s

S_l = lateral spacing, m

S_m = mainline spacing, m

Part of the gross application will go to evaporation and wind drift and the remainder will be applied to the soil surface.

The net application rate,

$$A_{rn} = A_{rg} [1 - L_s]$$

Where,

A_{rn} = net application rate, cm / hr

A_{rg} = gross application rate, cm / hr

L_s = evaporation and wind_drift fraction

5.5 Spray angle

The sprinkler spray angle influences how high the water is projected into the air. The higher the water is projected, the wider the reach of the sprinkler. However, this subjects the spray to higher wind speeds and larger pattern distortion than water is ejected closer to the ground surface. The best angle for a sprinkler jet under ideal conditions is 32° above the horizontal. However under windy conditions, a lower angle must be used to reduce the affect of wind. Most medium size sprinklers are about 25 to 26 degrees, whereas larger sprinklers are between 23 to 24 degrees. The selection of the spray angle depends on the crop to be irrigated and the prevailing winds.

5.6 Sprinkler Rotation

A constant sprinkler rotation speed will give a good distribution. An average of 2 rotations per minute or an optimum speed between 2,1 to 2,5 m/s on the outer circumference is recommended.

5.7 Diameter of Coverage

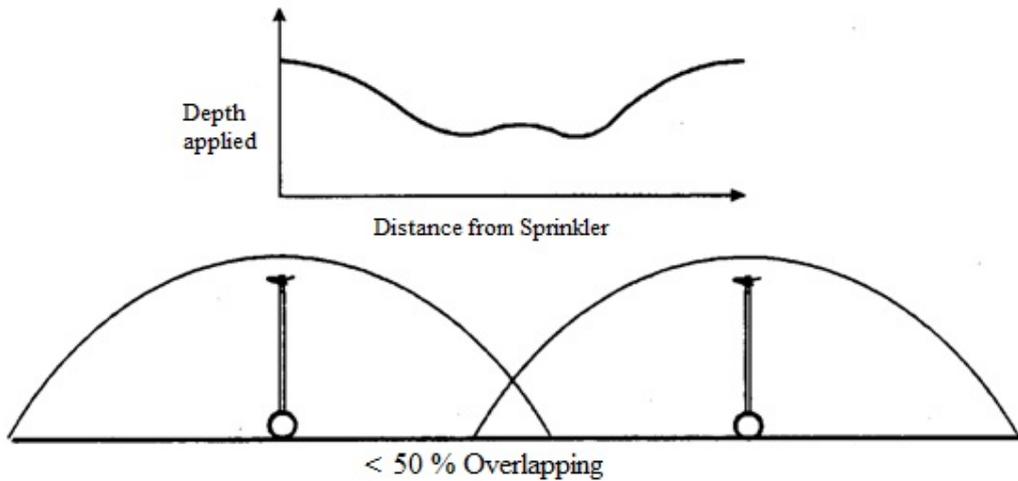
Diameter of Coverage is a maximum diameter wetted by the sprinkler. It depends on various factors like operating pressure at nozzle, sprinkler and nozzle design including inner diameter, trajectory angle etc. Discharge (gpm) for straight bore nozzles of various sizes operating for a range of nozzle pressures is shown in Table 3.

Nozzle Size		NOZZLE PRESSURE, psi															
inches	/64"	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
3/32	6	64	66	68	69	70	71	72									
7/64	7	65	67	69	70	71	72	73									
1/8	8	78	79	80	81	82	83	84	85	86	86	87	87				
9/64	9	80	81	82	83	84	85	86	87	88	89	90	91				
5/32	10	82	85	87	88	89	90	91	92	93	94	95	96				
11/64	11	83	88	90	92	93	95	96	97	98	99	100	101				
3/16	12	85	91	94	96	98	100	101	102	103	104	105	106				
13/64	13	91	97	100	103	105	107	109	111	113	114	116	117				
7/32	14	92	99	102	105	108	110	113	115	117	118	120	122				
15/64	15	93	100	104	107	110	112	115	117	119	121	123	125				
1/4	16	94	102	105	109	112	115	118	120	122	124	127	129				
17/64	17	95	103	107	110	114	117	119	122	125	127	129	131				
9/32	18	96	104	108	112	116	119	122	125	127	130	132	134				
5/16	20	121	124	127	130	133	136	140	143	145	147	149	151				
11/32	22	122	128	134	138	142	146	150	154	158	162	164	166	170	172	174	176
3/8	24	124	130	136	142	146	150	154	158	162	166	168	172	174	178	180	182
13/32	26	128	136	144	150	154	158	162	166	168	172	174	178	180	184	186	188
7/16	28	132	138	158	154	158	162	166	172	174	178	180	184	186	190	192	194
15/32	30	132	144	154	160	164	168	172	176	180	182	186	188	192	194	196	198
1/2	32	132	146	156	166	170	174	178	182	186	188	192	194	198	200	202	204
17/32	34	132	146	158	166	176	180	184	188	192	196	198	202	204	208	210	212
9/16	36	132	146	158	172	180	188	192	194	198	202	204	208	210	212	216	218
5/8	40	132	146	158	172	184	190	198	202	204	208	210	214	216	220	222	224
11/16	44	132	146	158	172	184	194	200	208	212	216	218	220	224	226	230	232

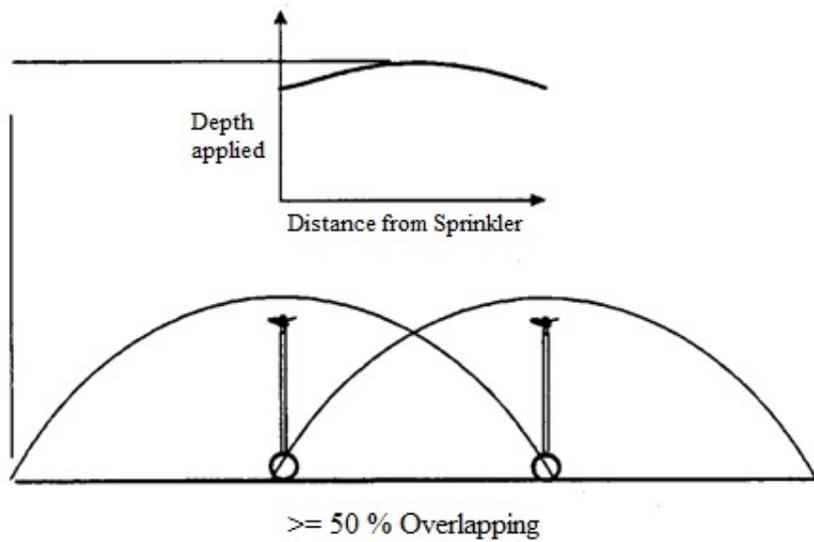
Table 3 : Variation in Diameter of Coverage as per varied nozzle diameter and nozzle pressure

5.8 Sprinkler Overlapping

To get the uniform application of water sprinkler must be overlapped in such manner that depth applied is maintained at each and every place. Overlapping is done on basis of diameter of coverage of sprinklers. If the overlapping is less than 50 % of diameter of coverage, it leads to Non-Uniform Application. See figure 13(a). If the overlapping is more than or equals to 50 % of diameter of coverage, it leads to Uniform Application. See figure 13(b).



(a)



(b)

Fig. 13 : Overlapping of Sprinklers

5.9 Operating Pressure

Operating Pressure at nozzle is very important factor in determining diameter of coverage, nozzle discharge, spacing between sprinklers and laterals etc. For different operating pressures water drops distribution changes as per Figure 14.

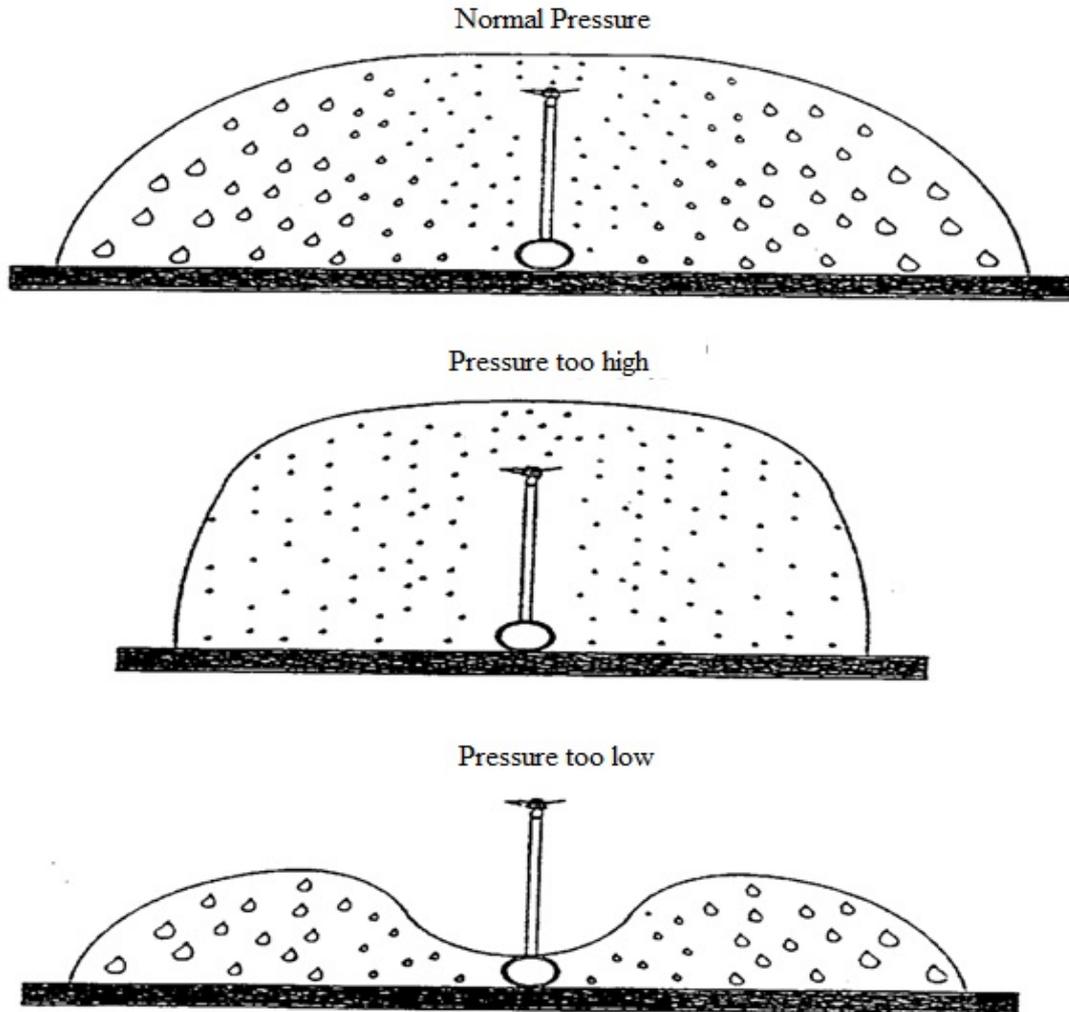


Fig. 14 : Sprinkler Distribution at different operating pressures

Discharge from nozzle and diameter of coverage increase when operating pressure increases which can be seen from table 2 and 3. Here unit of pressure is taken as psi i.e. pounds per square inch. It is also noted that from smaller diameter of nozzle we can get more pressure than that of bigger diameter.

5.10 Hydraulics of Laterals

The equation $q = k P^{0.5}$ indicates that nozzle discharge is a function of the square root of the nozzle operating pressure. Previous relationships for uniformity, gross application rate, and net application rate all assumed that each nozzle was discharging at same flow rate. In all but the rarest conditions, it is not possible to have the same operating

pressure available for every nozzle on a lateral. The concept of lateral design is therefore based on limiting pressure differences along a lateral so the variation of nozzle discharge is within acceptable range.

The usual criterion applied for the design of laterals is that the difference in nozzle discharge along a single lateral is less than $\pm 10\%$. To accomplish this goal, the difference in nozzle operating pressure is typically constrained to a variation of less than $\pm 20\%$ along the lateral.

The procedure for lateral design requires that a balance be developed between the length of the lateral, the head loss due to friction in the lateral, and the change in elevation head due to topographic effects

The governing equation for the maximum allowable head loss due to friction between the two critical sprinklers is given by

$$H_L = \frac{q \cdot H_a - H_e}{l}$$

Where,

H_L = maximum allowable head loss due to friction, m/m

q = maximum allowable pressure difference, fraction

H_a = nozzle design pressure expressed as head, m

H_e = increase in elevation in direction of water flow between the two critical Sprinklers, m

l = distance between the two critical sprinkler, m

5.11 Pressure Variation along a Lateral

As per general trends, pressure is maximum at inlet end and minimum at distal end. One thing should be noted that there is no linear variation between inlet and distal ends.

For a Leveled Lateral,

$$\text{Inlet pressure, } P_i = P_a + \frac{3}{4} P_l$$

$$\text{Distal pressure, } P_d = P_a - \frac{1}{4} P_l$$

Where, $P_a = \text{Avg. pressure}$

$P_l = \text{Pressure loss}$

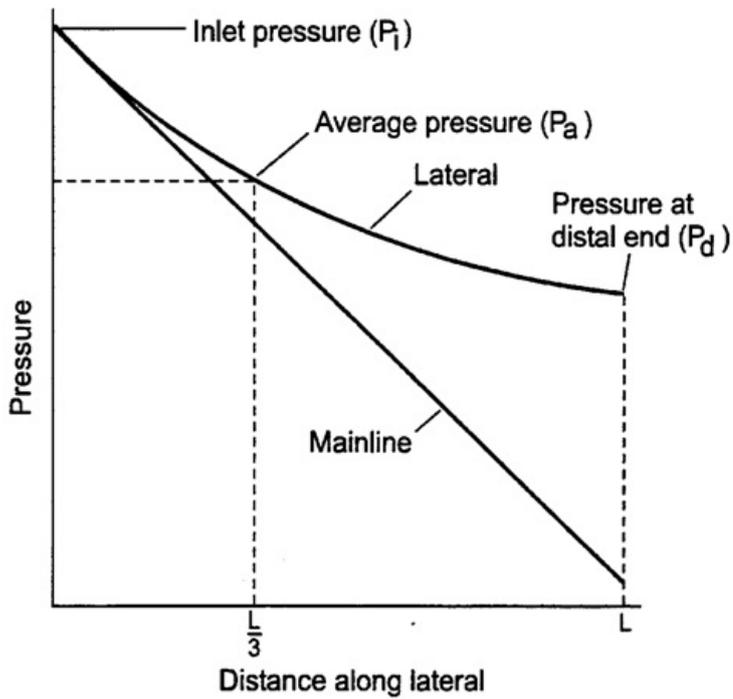


Fig. 15 : Pressure distribution along a lateral placed on a levelled surface

For a Slopy Lateral,

$$\text{Inlet pressure, } P_i = P_a + \frac{3}{4} P_l - \frac{1}{2}$$

$$\text{Distal pressure, } P_d = P_a + \frac{3}{4} P_l + \frac{1}{2}$$

Here E_s are elevations of the ends of the lateral (in feet) .

Above equations assume half the elevation change occurs upstream of the average pressure point, and half occurs downstream of that point (even if that assumption is not quite true, equations still work pretty well) .

5.12 Key Points

Key points in designing an irrigation system include:

- The irrigation system must be able to deliver and apply the amount of water needed to meet the crop-water requirement.
- Application rates must not exceed the maximum allowable infiltration rate for the soil type. Excess application rates will result in water loss, soil erosion, and possible surface sealing. As a result, there may be inadequate moisture in the root zone after irrigation, and the crop could be damaged.
- Flow rates must be known for proper design and management.
- Soil textures, available soil water holding capacity, and crop rooting depth must be known for planning and designing system application rates, irrigation water management, and scheduling irrigations so that water applied is beneficially used by the crop.
- The water supply, capacity, and quality need to be determined and recorded.
- Climatic data - precipitation, wind velocity, temperature, and humidity must be addressed.
- Topography and field layout must be recorded.
- Farmer's preferences in irrigation methods, available operation time, farm labour, cultural practices, and management skills must be noted for selecting and planning the type and method of irrigation.

Chapter 6 : METHODOLOGY

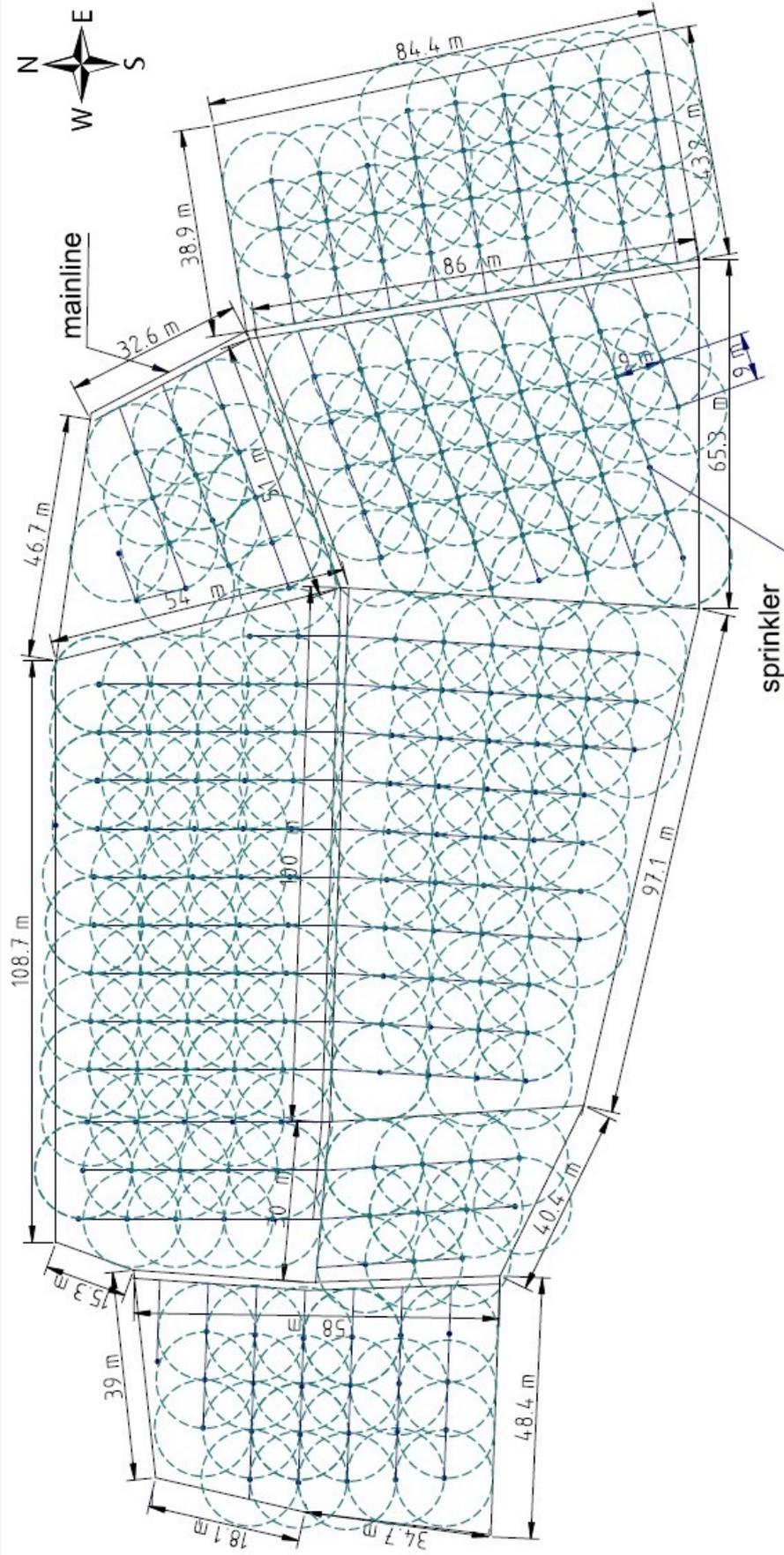
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6.1 Project Methodology



Chapter 7 : DESIGN OF SPRINKLER SYSTEM
MADE FOR A FARM IN KODARAM VILLAGE

-



Layout plan of laterals spread in 2.49 Ha area

Fig. 16 : Design Made for Groundnut crop at 9 mt.

7.1 Introduction

Here we are considering a farm of 2.49 Ha. In Kodram Village of Vadgam Taluka Dist. Banaskantha which is considered as arid area of Gujarat. Due to low water table and less irrigation water availability, Sprinkler and Drip irrigation are used most. Due to less crop variety available if drip irrigation is used, Sprinkler irrigation become popular. In these areas many crops like groundnut, wheat, millet can be grown successfully by sprinkler irrigation.



Fig. 17 : Location of farm on a map

As per typical use square layout of sprinklers is chosen having equal lateral width and same width between two sprinklers on one lateral. All mains of having 90mm diameter PVC pipe.



Fig. 18 : Sprinklers installed in a farm

For pumping of water, bore well is used and 25 hp motor is installed which draw water from upto 137,17 m. depth. Available flow is 29.52 m³/hr. Design data for irrigating 2.49 ha is given in table 4.

7.2 Irrigation Data

AREA (Ha)	2.49
CROP	Groundnut
Crop Spacing	0.76 × 0.4
Irrigation System	Mini Sprinkler
Lateral Spacing (m)	9.00
Emitter Spacing (m)	9.00
Nozzle Discharge (lph)	450
Water requirement (mm)	4.00
Irrigation Rate (mm/hr)	5.55
No. of Shift	5
Operating Time (Hrs)	0.72
Max. Flow (lps)	7.70
Available Flow (lps)	8.2

Pumpset size (HP)	25
Outlet Size (mm)	90
Discharge Variation	10 %

Table 4 : Irrigation data for Groundnut at 9 mt.

Wetting pattern and lateral spacing is as per Fig. 19.

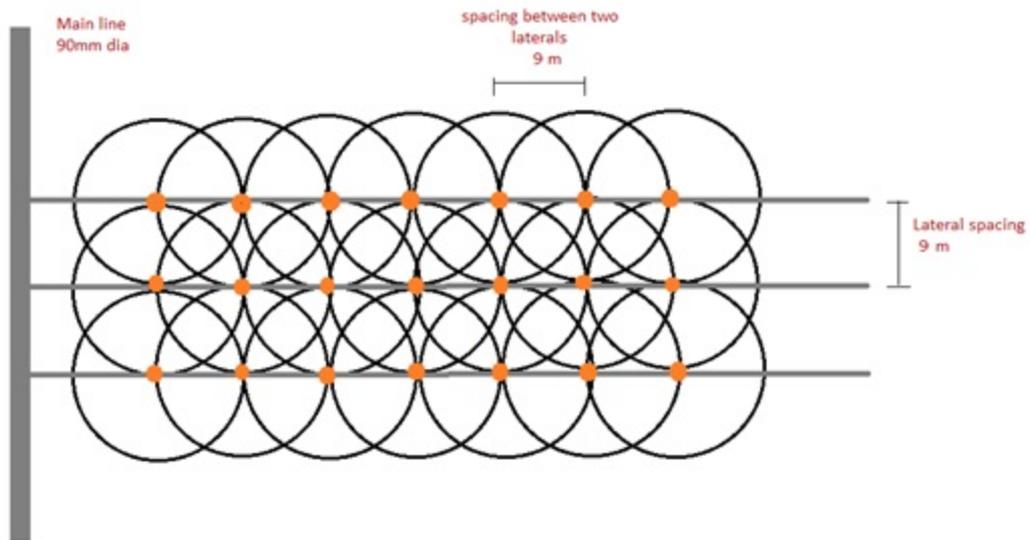


Fig. 19 : Spacings between laterals and two adjacent sprinklers.

Here, No. of Shifts are 5. Scheme of operation of 5 shifts is shown in table 5.

Shift	AREA (Ha)	TOTAL FLOW (LPS)	PEAK OPERATING TIME (Hr.)
1	0.500	7.70	0.72
2	0.500	7.70	0.72
3	0.500	7.70	0.72
4	0.500	7.70	0.72
5	0.490	7.55	0.72

Table 5 : Scheme of Operation

Here all laterals are LLDPE plain lateral 32MM class II having wall thickness 2 mm. We can select appropriate lateral out of many pipes having various diameter pipe and

wall thickness. See Table 6 for LLDPE pipe sizes.

Nominal Diameter (mm)	Outside Diameter (mm)	Class 1 wall thickness (mm)	Class 2 wall thickness (mm)	Class 3 wall thickness (mm)
12	12.2	0.6-0.8	0.9-1.1	1.2-1.4
16	16.2	0.8-1.0	1.1-1.3	1.4-1.6
20	20.2	0.9-1.1	1.2-1.4	1.5-1.7
25	25.2	1.2-1.6	1.7-2.0	2.1-2.4
32	32.2	1.5-1.9	2.0-2.4	2.5-2.9

Table 6 : Lateral pipe Sizes

Here Riser pipe of length 1330 mm is used having 12 mm dia.

Even though proper design is made as per the specifications, due to many reasons water efficiency and uniformity is not achieved in sprinkler system. Therefore various tests to find uniformity co-efficient, nozzle pressure, wind effect etc, are discussed in detail in further chapters considering a single farm of 0.53 ha having 50 sprinklers. See fig. 20.

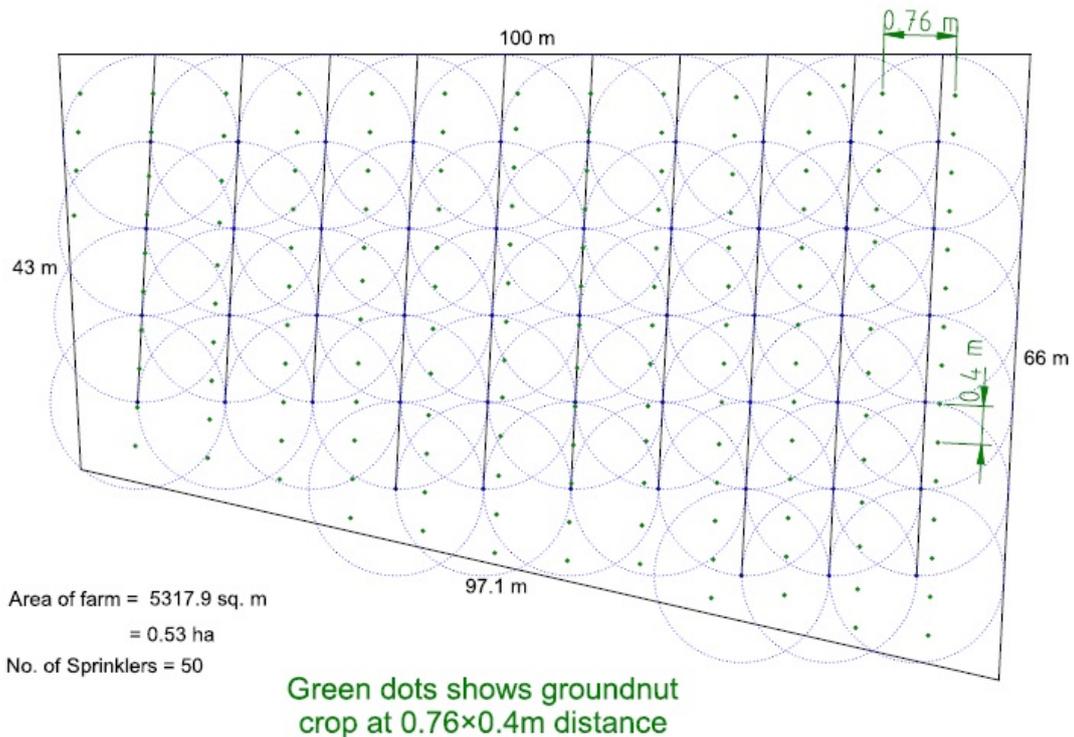


Fig. 20 : Sprinkler layout for groundnut

Here area under irrigation is shown in fig. 21.

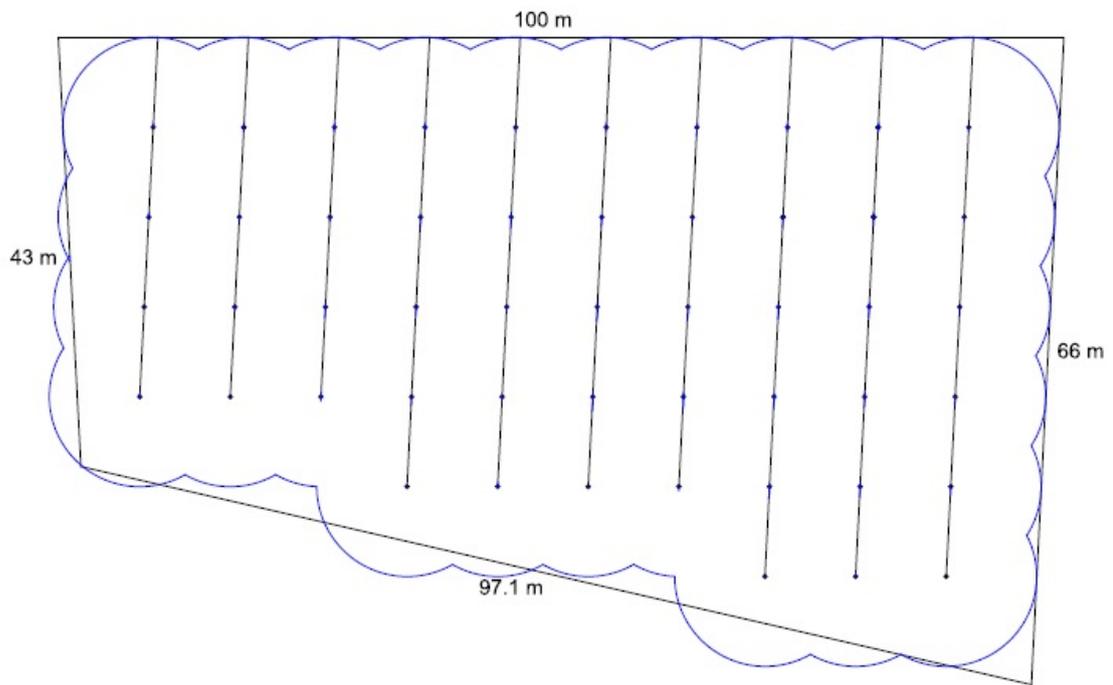


Fig. 21 : Area under Irrigation

Chapter 8 : UNIFORMITY COEFFICIENT OF
SPRINKLER SYSTEM

-

8.1 Review of Literature

One of the main advantages of sprinkler irrigation is its ability to distribute irrigation water fairly uniformly over the area to be irrigated. Crop response is better under uniform distribution conditions (*Jacobson. W. L.*). Uneven distribution produces drought areas in some parts of the irrigated field that can only be overcome by the application of excess water, which results in waste of water.

Sprinkler evaluation tests with respect to water distribution uniformity and water application efficiency were reported by some investigators, probably starting with *Wadsworth*, who proposed, in 1926, that test cans of uniform cross-section be placed at equidistant points along one radius of a circle to be covered. He stated that at the end of a given period, absolute equality of distribution was reflected by equal depths of water in the cans. Furthermore, the tests were to be run for several hours in a day, with little or no wind disturbance, before reliable conclusions could be reached. *Wadsworth* also suggested the use of equal diameter funnels which would drain into glass test tubes as a refinement of the test method. This refinement would allow a reduction of evaporation losses from the cans and the detection of minor inequalities of distribution.

Staebner ran extensive tests on both American-made and German-made sprinklers. A lack of standard procedure for analysing and reporting the data was one of his main difficulties. *Staebner* judged the sprinklers tested on their ability to distribute water so that the maximum depth was not more than twice the minimum (except near the edge of the area covered). The optimum spacing of sprinklers for the best performance as well as overlap were not discussed.

Christiansen conducted a series of extensive and detailed experiments on sprinkler irrigation between 1935 and 1940 at the University of California at Davis. He presented the results of the research in a detailed form in 1942. About 200 sprinkler tests were made on sprinklers of the types used on portable sprinkler systems to determine the uniformity of distribution for various spacing and to determine the most desirable geometrical patterns and their relation to spacing. *Christiansen* introduced a numerical expression, which is called the uniformity coefficient, C_u for the purpose of comparing sprinkler

patterns and determining the effect of various spacing on water distribution. The uniformity coefficient expressed as a percentage is defined by the equation,

$$C_u = 100$$

Where, m = avg. value of all observations

n = total no. of observation points

X = numerical deviation of individual observations from the avg. application rate

A uniformity coefficient of 100 % will represent an absolutely uniform application; a lower percentage will represent a less uniform application. *Christiansen* defined six general cross-sectional patterns for water distribution. The patterns were designated by the letters shown in Figure 22. These designations will be used in this study for defining the distribution patterns of the sprinklers.

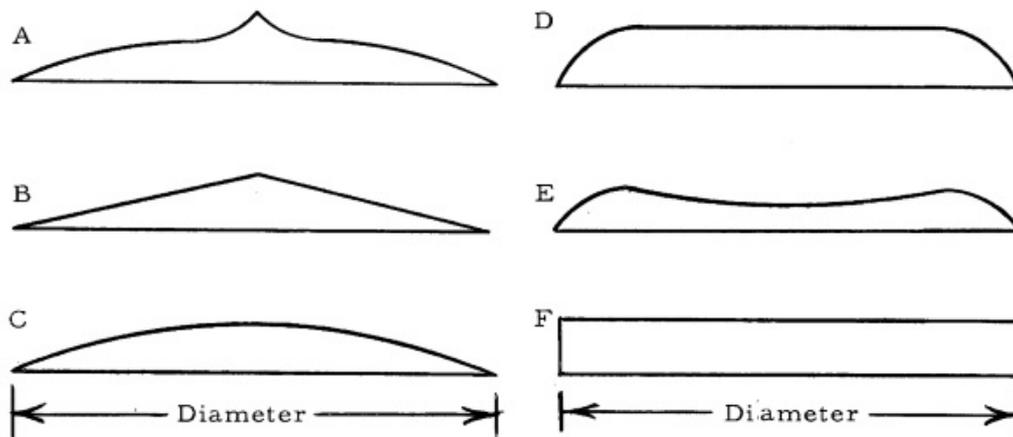


Fig. 22 : Geometric sprinklers pattern defined by Christiansen

The patterns shown can be divided into two general groups: A, B and C, for which the application decreases gradually toward the edge of the area wetted; and D, E, and F, for which the application is fairly uniform over most of the area covered.

In 1944, *Shoenleber* reported the results of many tests on several types of individual sprinklers to determine their characteristics. No overlap was taken into

consideration. One of his interesting findings was that the oscillating sprinkler line equipped with small nozzles consistently showed the highest uniformity coefficient for pressures used. His index of uniformity was Christiansen's coefficient of uniformity.

In 1947, *Wilcox and Swailes* used a modified procedure for determining the uniformity coefficient as follows:

$$U = 100 - \frac{100 \cdot SD}{M}$$

Where, U = modified uniformity coefficient

SD = standard deviation of depths of water in cans

M = mean of depths of water

This numerical expression was used in evaluating the effects of pressure, wind, spacing, and nozzle size on the uniformity of distribution. They suggest that a value of at least 70 per cent for this modified uniformity coefficient would be desirable. The author has adopted this modified uniformity coefficient as one of the expressions to be studied.

In 1949, the *U. S. Soil Conservation Service* suggested a distribution curve with a steadily decreasing rate of water application from the sprinkler outward as being the most satisfactory type.

In 1951, the *American Society of Agricultural Engineers* proposed a set of recommendations for the minimum requirements for the design, installation, and performance of sprinkler irrigation equipment. Section 4 of the recommendations reads as follows:

4. Uniformity of water application

"Since uniformity of water application is affected by both pressure in the line and spacing of sprinklers, recommendations for desirable operating pressures and spacing for different types of sprinklers and nozzle sizes shall be obtained from the sprinkler manufacturer. Differences in pressures at the sprinklers shall be kept to a minimum to assure reasonable uniform distribution of water over the entire design area. A common rule, which should be adhered to as closely as practicable, is to limit pressure differences along a sprinkler lateral to 20 percent of

the higher pressure.”

Wiersma reported his study on factors affecting sprinkler patterns and application uniformity in thesis form in 1952. He investigated the influences of wind velocity, type of sprinkler head, head of sprinkler above ground, pressure at sprinkler, and sprinkler spacing on the uniformity of distribution. The main conclusion of his study was that the uniformity of distribution is greatly affected by pressure and wind velocity according to derived linear equations.

Korven reported in 1952, investigations concerning the influence of wind on uniformity of application from different makes of rotary sprinklers at various spacing and pressures. He used the modified uniformity coefficient suggested by *Wilcox* and *Swailes* as an index of application uniformity.

In 1954, *Molenaar and his associates* reported the results of their study on the water distribution patterns experienced with sprinklers and the factors which influence these patterns under actual field conditions. They used a uniformity coefficient, U , to compare the relative distribution performance for the sprinklers, expressed by the equation:

$$U = 100$$

Where, \bar{x} = a mean value of x_i

x_i = the value of individual volumes of water accounted for in cans at the grid points within a sprinkler spacing area

n = the number of grid points within the wetted area

This coefficient is the same as that proposed by *Wilcox and Swailes* and the author's statistical uniformity coefficient. One of the important conclusions drawn from this study was that the pronounced effect of wind on the coefficient of uniformity could be largely overcome by correct spacing of sprinklers. What constituted correct spacing was

not specified.

McDougald and Wilcox presented in 1955 the results of their studies instituted to determine the relationship between the type of water distribution curve and the uniformity of water distribution when sprinkler sprays overlap. They found that the best type of distribution curve for general application was one showing a steady decrease in rate of water application from the sprinkler out toward the outer circumference of water throw. They suggested a range coefficient, R, and a spacing coefficient, S, for the evaluation of the uniformity of distribution. The range coefficients represented by the formula:

$$R = \frac{200}{H+L}$$

Where, H = the highest value of can catch

L = the lowest value of can catch

When R = 200 the lowest value is zero and the range is at its maximum.

When R = 0 there is perfect uniformity of distribution.

The spacing coefficient, S, is expressed by the formula:

$$S = \frac{100 \text{ area included in spacing}}{\text{diameter of throw}}$$

In 1960, *Hansen* proposed a numerical expression similar to *Christiansen's* uniformity coefficient that he called water distribution efficiency and defined by the expression:

$$E_d = 100$$

Where, E_d = water distribution efficiency

y = average numerical deviation in depth of water stored from average depth stored during the irrigation

d = average depth of water stored during the irrigation.

W. E. Hart studied the distribution characteristics of small sprinklers and the methods used in their evaluation. He suggested that the distribution of the can-catch in an

overlapped sprinkler pattern follows a normal distribution function. *Hart* proposes that theoretically the interrelationship existing between *Christiansen's* uniformity coefficient and the uniformity coefficient of a normally distributed population (identical to that proposed by *Molenaar, Wilcox and Swailes* and the author's statistical uniformity coefficient) to be as follows:

$$U C_h = 1 - 0.798 \frac{s}{x}$$

Where, $U C_h$ = HSPA uniformity coefficient
 s = standard deviation of sample
 x = average of observations

Keller and associates stated that higher application efficiencies can be obtained through alternate sets than through standard sets. They determined that for single-alternate sets, the uniformity coefficient after two irrigations becomes:

$$C_{u'} = 10 C_u$$

Where, $C_{u'}$ = uniformity coefficient of single-alternate sets
 C_u = uniformity coefficient

Uniformity coefficients, using *Christiansen's* expression, of 85 percent or greater are suggested as being acceptable by *the Soil Conservation Service*.

The U. S. Sprinkler Irrigation Association suggests a uniformity coefficient of 84 per cent, according to the *Christiansen* formula, as the criterion of adequate sprinkler performance.

8.2 Christiansen's uniformity coefficient

Christiansen conducted a series of extensive and detailed experiments on sprinkler irrigation between 1935 and 1940 and presented the results of the research in a detailed form in 1942. *Christiansen* introduced a numerical expression, which is called the uniformity coefficient, C_u for the purpose of comparing sprinkler patterns and determining the effect of various spacing on water distribution. The uniformity coefficient is affected by the pressure-nozzle size relations, by sprinkler spacing, and by wind conditions.

The coefficient is computed from the field observations of the depth of water caught in open cans placed at regular intervals within a sprinkled area. The uniformity coefficient expressed as a percentage is defined by the equation,

$$C_u = 100$$

Where, m = avg. value of all observations

n = total no. of observation points

X = numerical deviation of individual observations from the avg. application rate

A uniformity coefficient of 100 per cent (obtained with overlapping sprinklers) is indicative of absolutely uniform application, whereas the water application is less uniform with a lower percentage. A uniformity coefficient of 85 per cent or more is considered to be satisfactory.

Christiansen summarized the results of his important study as follows:

1. The uniformity of distribution of water from sprinklers varies greatly, depending upon pressure, wind, rotation of sprinklers, spacing, and many other factors.
2. A nearly uniform application is possible with proper sprinkler patterns and with proper spacing of sprinklers.
3. Approximately conical sprinkler patterns, where a maximum application occurs near the sprinkler and decreases gradually to the edge of the area covered, produce a uniform application when sprinklers are not farther apart than 55 to 60 per cent of the wetted diameter covered.

4. For wider spacing a pattern in which the application is uniform for some distance from the sprinkler, and then tapers off gradually, is better. However, the maximum uniformity obtainable decreases with the spacing for all spacing greater than 50 per cent of the wetted diameter covered.
5. With a portable system having sprinklers producing desirable patterns, good distribution can be obtained when the lateral is moved not farther than 50 to 70 per cent of the diameter covered by a single sprinkler, and when the sprinkler spacing along the lateral is not more than 35 per cent of the diameter covered.

The data on uniformity coefficient are useful as a basis for selecting the combination of spacings, discharge, nozzle size and operating pressure to obtain high values of irrigation efficiency at specific operation conditions.

8.3 Test Method

The experimental field is located in Kodram Village of Vadgam Taluka Dist. Banaskantha. Almost 0.53 ha of experiment field was chosen and 50 sprinklers were operated in experiment at the pressure 2 bar measured at the pump constantly. The water supply was provided from a well that was almost 85 m distant.

The height of the nozzle was measured 133 cm from the surface. The speed of nozzle rotation was 2.36 rotations/min. Wind speed at that time was 7.11 m/s N/E.





Photographs of Test Method of Uniformity test

In test, to collect water from the sprinkler nozzles, 67 catch cans (tin containers) with a 14.5 cm height and 10 cm diameter were used. Catch cans were placed at half the distance between two sprinklers. Therefore a Grid forming by the catch cans are of 9.0 m which are 4.5 m distal from grid of sprinklers. See the figure 23. The test was carried out for 2 hours at constant 2 bar pressure.

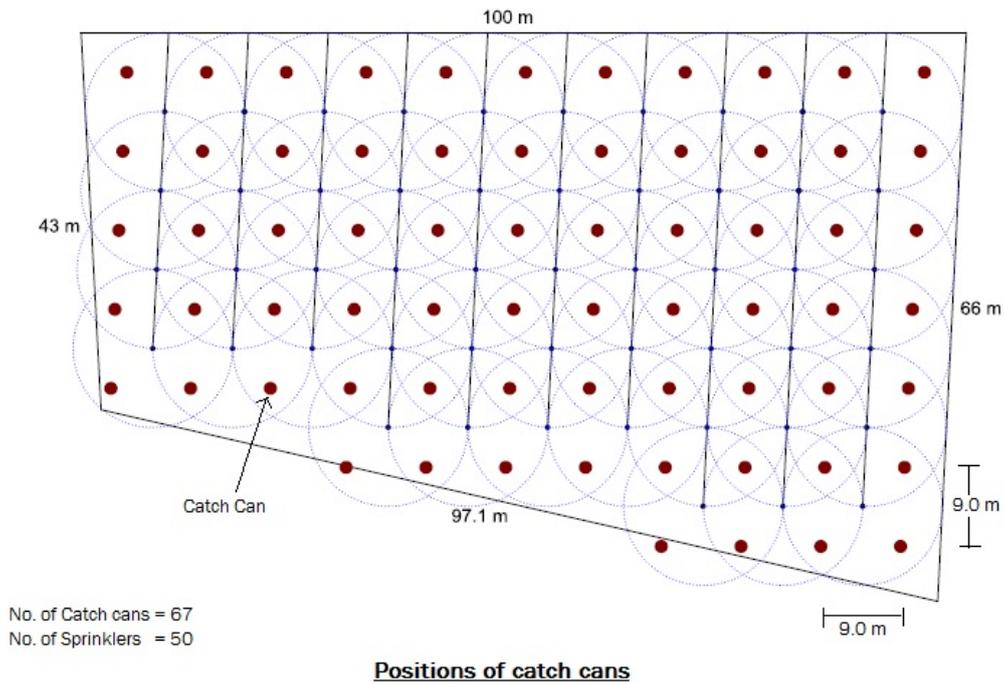
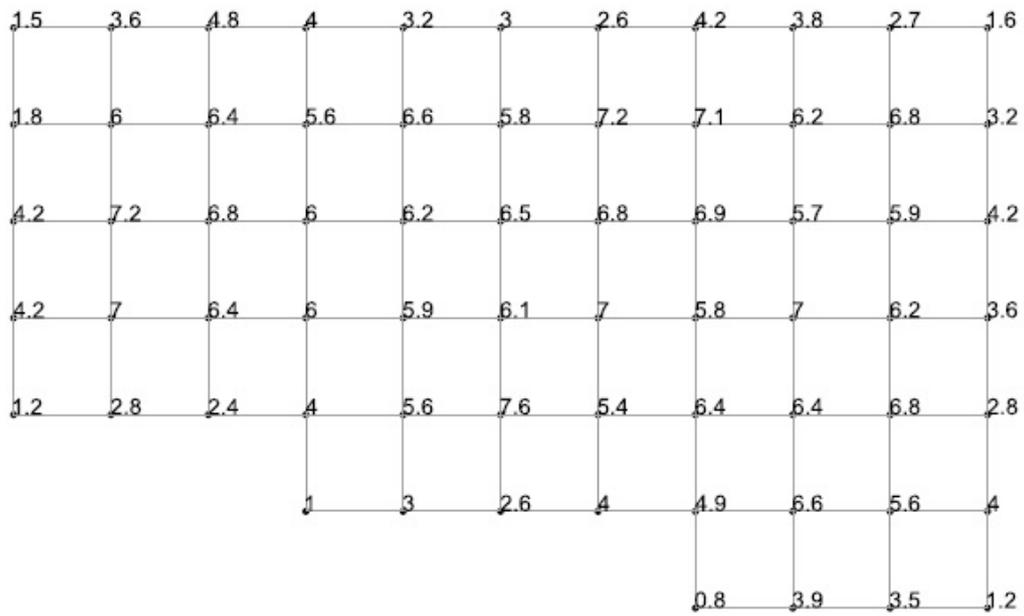


Fig. 23 : Plan showing position of catch cans

After 2 hours water depth in each can is measured. For measuring that measuring cylinder of 100 ml is used. Due to its diameter be 3.6 cm total water in cylinder in ml is same as its height in mm. Water in each catch can was poured in cylinder and from its ml reading total height in mm is noted. Now to know the actual depth of water in can, this reading is multiplied by the ratio of the areas of cylinder to the catch can i.e. 0.13.

The water depth of each catch can in mm are shown at the points of grid in figure 24.



All readings are in mm.

Fig. 24 : Water depth in each catch can

Obs. (O)	Freq. (F)	O×F	Deviation (D)	F×D	Obs. (O)	Freq. (F)	O×F	Deviation (D)	F×D
0.8	1	0.8	4.02	4.02	4.9	1	4.9	0.08	0.08
1	1	1	3.82	3.82	5.4	1	5.4	0.58	0.58
1.2	2	2.4	3.62	7.24	5.6	3	16.8	0.78	2.34
1.5	1	1.5	3.32	3.32	5.7	1	5.7	0.88	0.88
1.6	1	1.6	3.22	3.22	5.8	2	11.6	0.98	1.96
2.4	1	2.4	2.42	2.42	5.9	2	11.8	1.08	2.16
2.6	2	5.2	2.22	4.44	6	3	18	1.18	3.54
2.7	1	2.7	2.12	2.12	6.1	1	6.1	1.28	1.28
2.8	2	5.6	2.02	4.04	6.2	3	18.6	1.38	4.14
3	2	6	1.82	3.64	6.4	4	25.6	1.58	6.32
3.2	2	6.4	1.62	3.24	6.5	1	6.5	1.68	1.68
3.5	1	3.5	1.32	1.32	6.6	2	13.2	1.78	3.56
3.6	2	7.2	1.22	2.44	6.8	4	27.2	1.98	7.92
3.8	2	7.6	1.02	2.04	6.9	1	6.9	2.08	2.08
3.9	1	3.9	0.92	0.92	7	3	21	2.18	6.54
4	4	16	0.82	3.28	7.1	1	7.1	2.28	2.28
4.2	4	16.8	0.62	2.48	7.2	2	14.4	2.38	4.76
4.8	1	4.8	0.02	0.02	7.6	1	7.6	2.78	2.78
						$\Sigma F =$ 67	$mn =$ 323.8		$\Sigma X =$ =

7.6	1	7.6	1.21	1.21
	$\Sigma F = 35$	$mn = 223.5$		$\Sigma X = 16.33$

Table 8 : Observation Table for Coefficient of Uniformity for centre cans

$$Mean = \frac{mn}{\Sigma F} = \frac{223.5}{35} = 6.39$$

Christiansen's uniformity coefficient

$$C_u = 100 \quad = 100$$

$$C_u = 92.7 \%$$

Chapter 9 : WATER CONTOURS AND WETTING
CIRCLE OF SPRINKLER SYSTEM

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9.1 Water contour of single sprinkler

For a single sprinkler, water contour is drawn by measuring water depth in catch cans placed in grid around the sprinkler. For a test, single sprinkler is run about 2 hour at 1.8 bar pressure at pump. And after that readings are taken in mm. Here it is assumed that all sprinklers in a farm perform identically. At a very low wind speed of about 2.5 m/s, a typical water contour is drawn in figure 25.

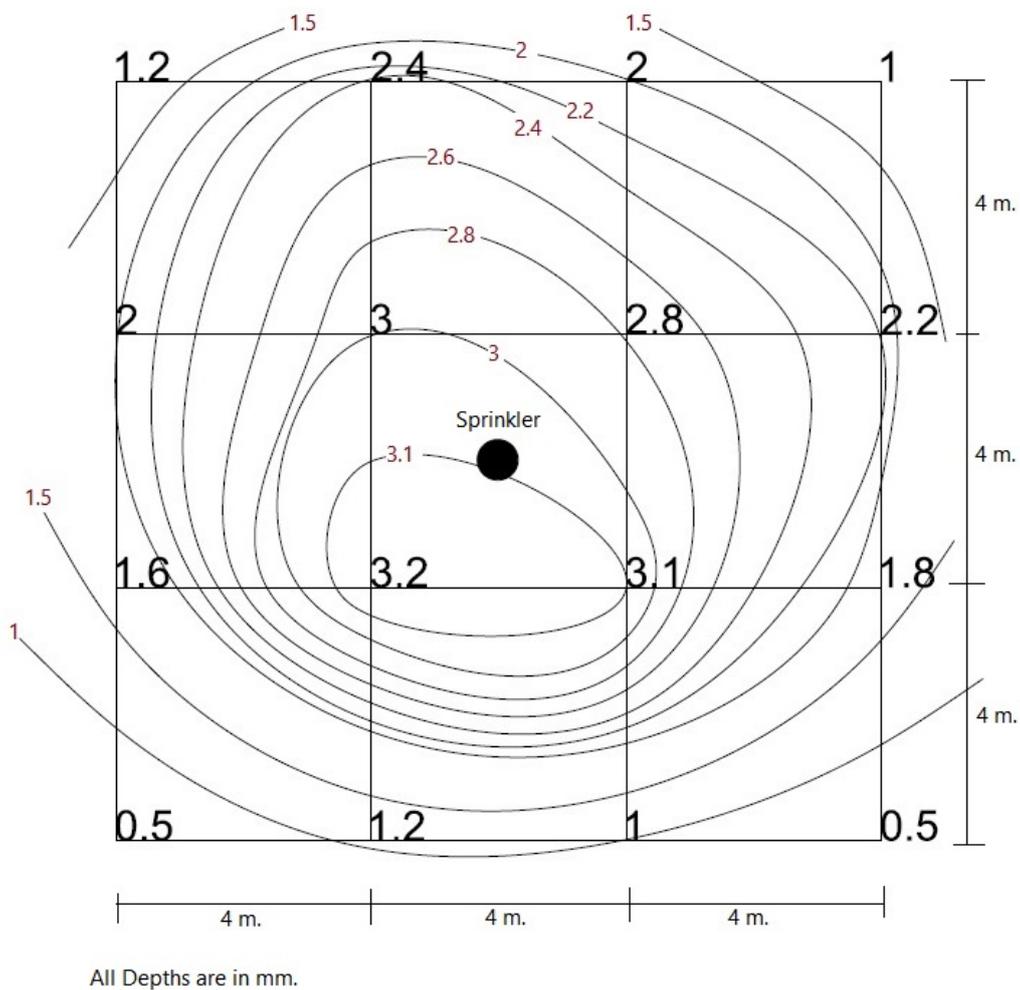


Fig. 25 : Water Contour of individual sprinkler

Since sprinklers are placed at 9 m distance apart, overlapping should be considered while designing sprinkler system. Moisture distribution pattern of these sprinklers at mid

point of sprinkler i.e. 4.5 m apart from sprinklers is shown in figure 26.

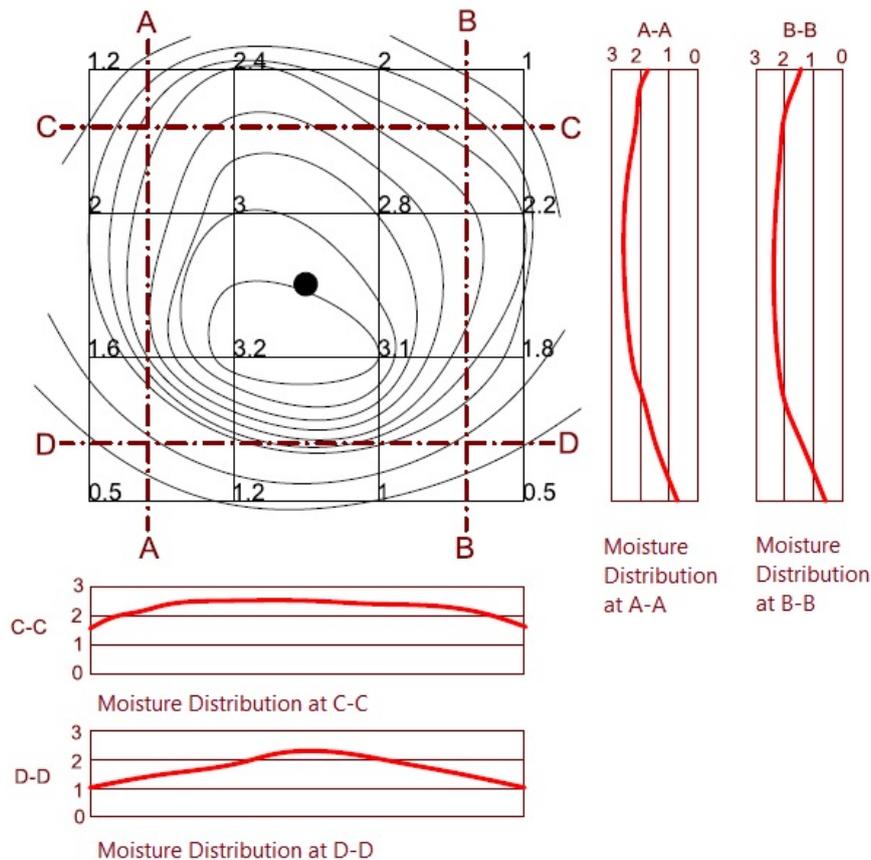


Fig. 26 : Moisture distribution pattern at 4.5 m distance

If we consider identical sprinkler distribution of all sprinkler than we can say that One sprinkler's A-A section and another sprinkler's B-B section overlap which gives additive amount of water at that section. When we move from center part to towards sprinkler, high amount of water from that sprinkler and less amount of water from another sprinkler form the whole area uniformly distributed.

9.2 Water contour of whole area

From the readings obtained from the test to measure uniformity coefficient, water contours are drawn from the water depth at each catch can. 67 catch cans (tin containers) with a 14.5 cm height and 10 cm diameter were used. Catch cans were placed at half the distance between two sprinklers. Therefore a Grid forming by the catch cans are of 9.0 m which are 4.5 m distal from grid of sprinklers. The test was carried out for 2 hours at

constant 2 bar pressure. The contour for the whole farm is drawn in figure 27.

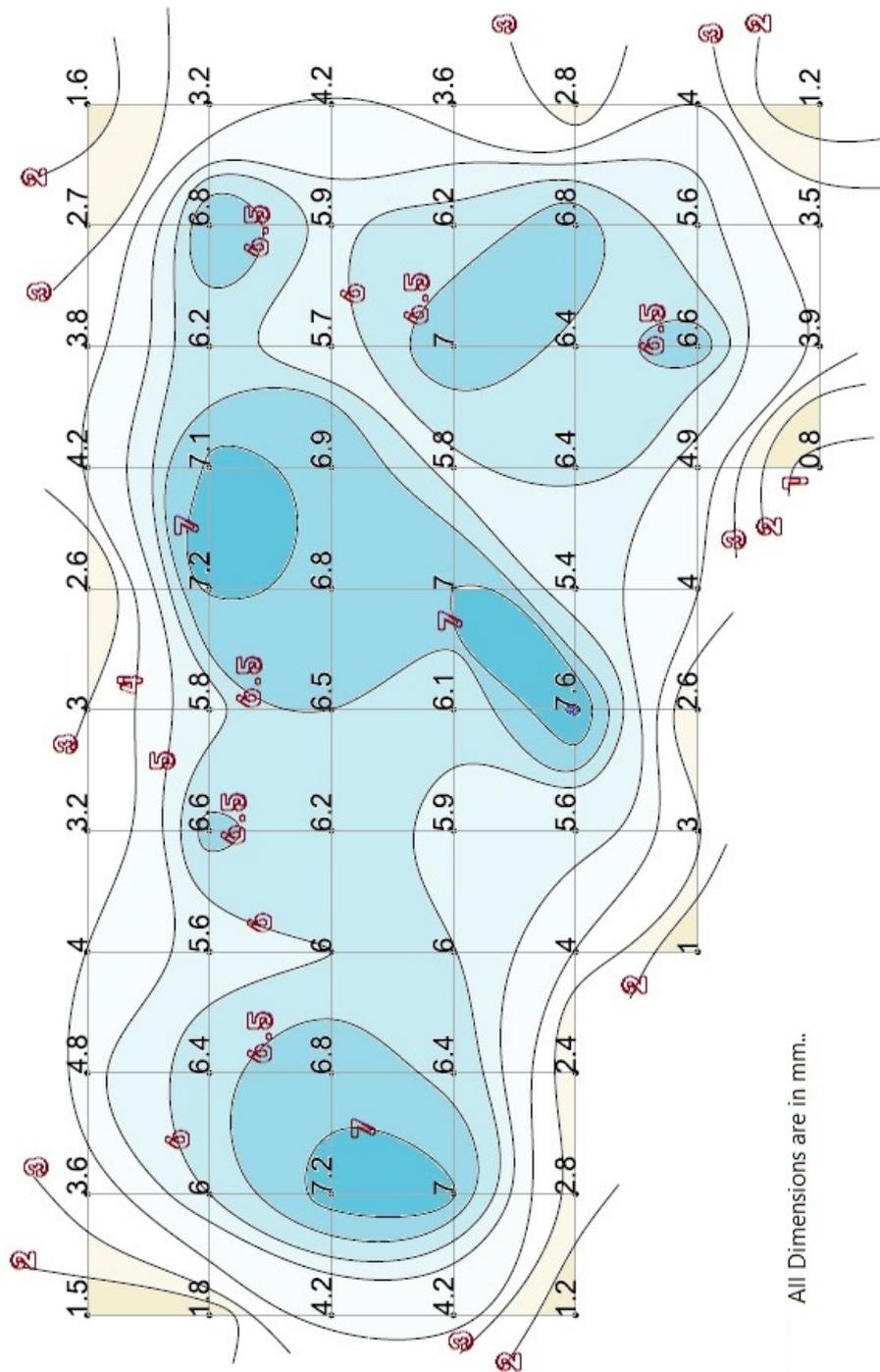


Fig. 27 : Water Contour of whole farm

Water contour of a farm is shown here. Water depths in catch cans are shown at the corners of grid of 9 m × 9 m. Centre part of farm where water of all 4 sprinkler can reach is the most uniform place having higher depth of water. While on borders of farm depth of

water is low because water from only 1 or 2 sprinkler can reach. See figure 26. So due to this overall uniformity of sprinklers is affected. We can get overall picture of uniform application of water from this contour.

9.3 Wetting circle area of individual sprinklers

For each sprinklers wetting radius are measured and compared them to the specifications provided by the supplier. For a farm considered for testing wetting radius as per specification is 9.0 m. But for a stipulated water pressure this radius is different for different sprinklers. See figure 28.

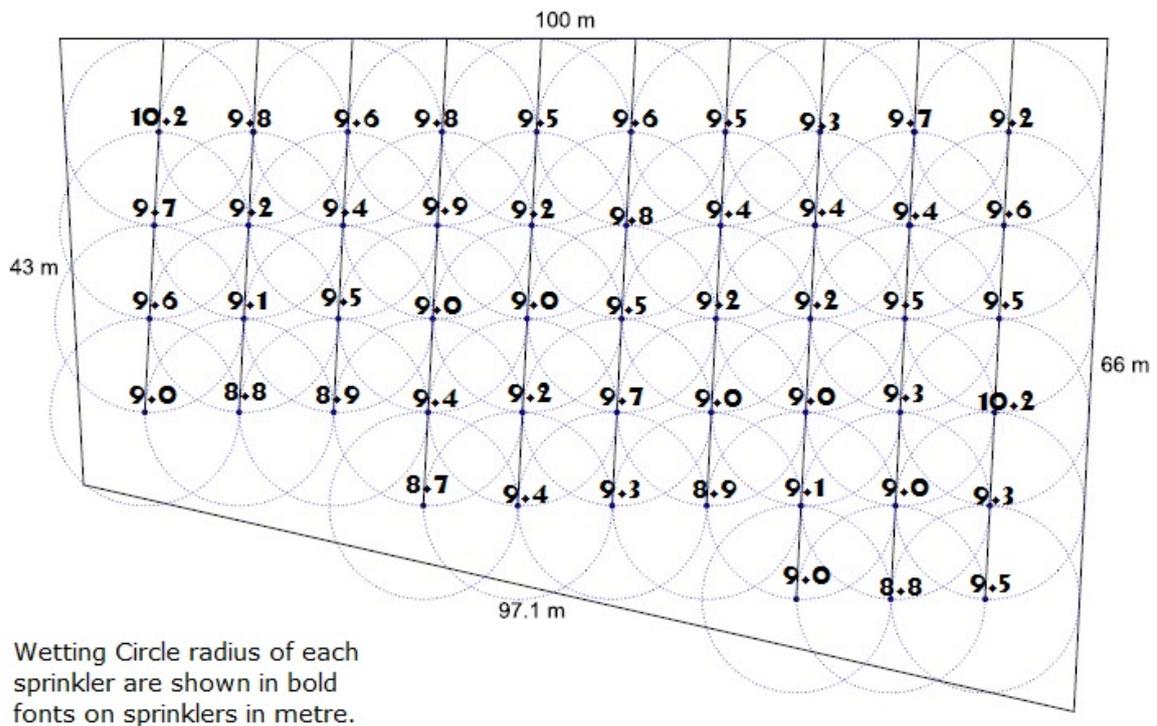


Fig. 28 : Wetting radius of different sprinklers

Wetting circle area mainly depends on nozzle pressure and discharge. Due to various reasons like internal friction in pipes, due to turbulent flow, sand entered in pipes, leakage at various joints etc. water pressure decreases. Thus we cannot get exact same wetting area. In a given lateral the first sprinkler and last sprinkler have different pressure at nozzle and therefore wetting circles decreases as we move from first sprinkler to last

sprinkler. Same effect we can see in mainline. Due to pressure loss, the pressure at very first lateral and last lateral is different. Due to variation on radius of wetting circle, overlapping of sprinklers is disturbed which affects the sprinkler system design.

**Chapter 10 : CROP WATER REQUIREMENT,
DISCHARGE AND NOZZLE PRESSURE**

10.1 Crop water requirement, Discharge and Nozzle pressure

For Millet crop in a considered farm, water requirement is 6.6 mm water depth in each irrigation. Average water depth we have got by test is 4.82 mm for 2 hours of operation. Hence total water depth available for 4 hour is 9.64 mm. Therefor average irrigation rate is 2.41 mm. Thus we can fulfill 6.6 mm depth in operating time of $6.6/2.41 = 2.74$ hrs. i.e.2 hour and 45 minutes.

As general practice, each irrigation is done for 4 hours but from only for 2 hours and 45 minute water is needed. Additional water for next 1 hour and 15 minute will runoff because it is beyond infiltration capacity of the soil.

Nozzle discharge as per sprinkler provider is 450 lph i.e. 0.125 l/s. Therefor total discharge of 50 sprinklers for our considered farm is 22500 lph i.e. 6.25 l/s. But from mean depth in catch cans i.e. 4.82 mm, total volume is Area * mean depth = 25632.28 litre. Thus total discharge actually provided is $25632.28 \text{ litre} / 2 \text{ hr} = 12816.14 \text{ lph}$ i.e. 3.56 l/s.

If we measure discharge from one nozzle, we obtain 10 litres in 2.5 minutes. Thus manually measured discharge for one sprinkler nozzle is 240 lph i.e. 0.06 l/s.



Fig. 29 : Measurement of Nozzle discharge

Nozzle pressure as per sprinkler provider is 2 bar for 450 lph discharge. Since Discharge is proportional to square root of Nozzle pressure, value of nozzle pressure become 0.568 bar for 240 lph discharge which is very less.

Chapter 11 : EFFECT OF WIND SPEED AND
GROUND SLOPE

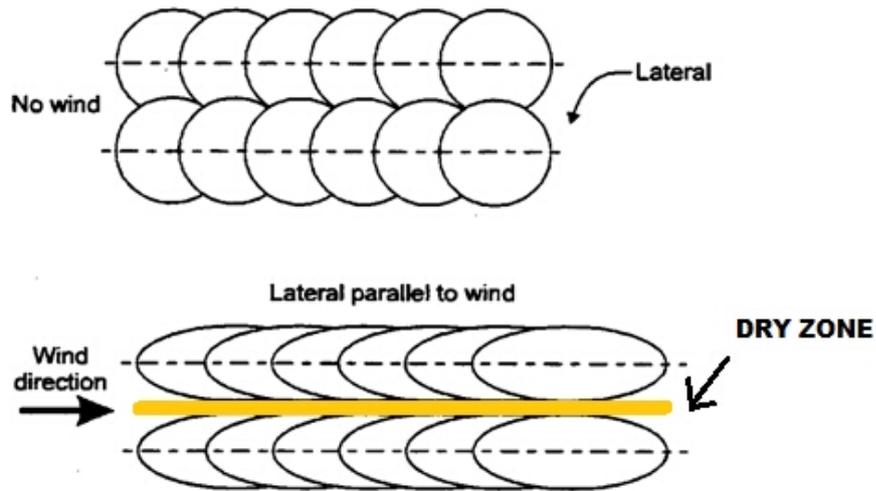


Fig.31 : Dry zone due to wind drift

For areas of high average wind speed, sprinkler system can be designed as per table 8. For higher wind speed sprinkler spacings should be less and lower wind speed spacings can be kept more.

Sr. No	Average wind speed	Spacings
1.	No wind	65% of the diameter of the water spread area of sprinkler
2.	0-6.5 km/hr	60% of the diameter of the water spread area of sprinkler
3.	6.5-13 km/hr	50% of the diameter of the water spread area of sprinkler
4.	Above 13 km/hr	30% of the diameter of the water spread area of sprinkler

Table 9 : Spacings of sprinkler according to wind speed

For our considered farm, wind speed lies between 0 to maximum 13 km/hr hence 50 % of diameter of wetting circle provided in farm is OK.

Ground slope plays an important role even in sprinkler irrigation. Though application of water from sprinkler is uniform, due to difference in elevation, irrigated water tends to move from higher elevation to lower elevation since infiltration rate of soil is less than application rate and hence water logging may occur in lower areas and higher elevated areas remain dry. Water logging may leads to fertilizer leaching and water wastage. Here water infiltration rate of soil is important because quicker the soil infiltrate, less would be the problem of water logging or water deficiency. See fig. 31. Slope also affect the flow of water in laterals and mains laid on a slope. And hence pressure loss increases.

After full irrigation of 4 hours additional water tend to runoff to lower elevation as shown in below figure.

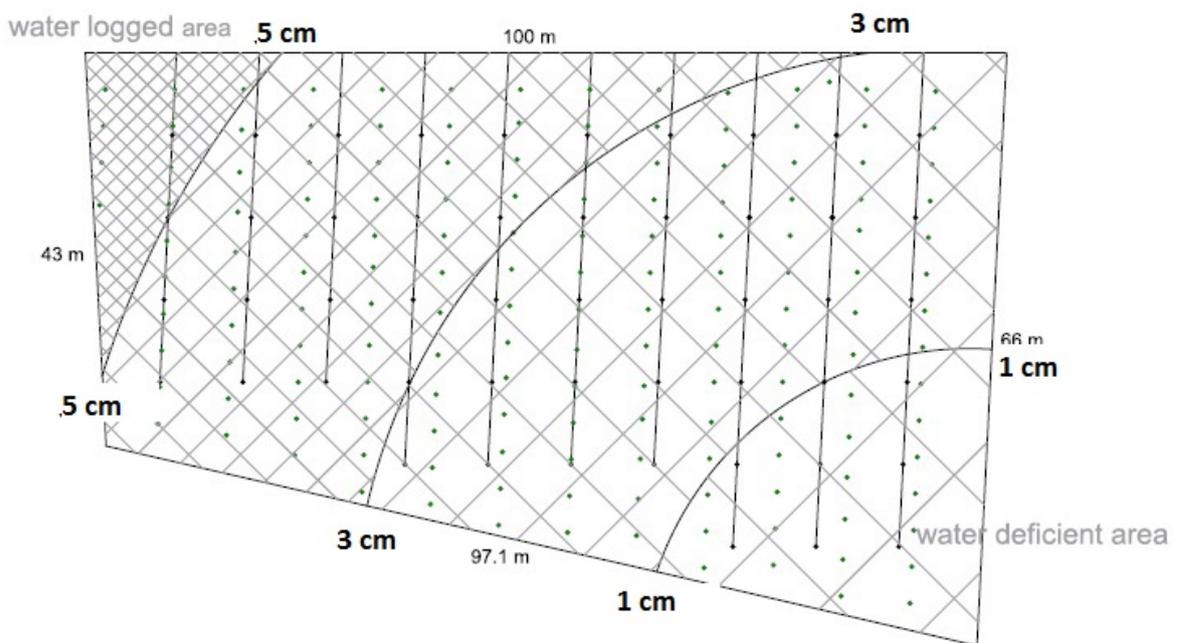


Fig. 32 : Slope on Ground

Chapter 12 : CONCLUSION

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Experiments were carried out to evaluate the specifications of the sprinkler system provided by manufacturer.

- 1) The measured uniformity co-efficient neglecting the edges of the field is 92.7 %. But with inclusion of the sprinklers at the edges of the field it becomes 66.3% which is very less.
- 2) Water contours are drawn for the field to study water distribution of sprinkler system.
- 3) The radius of the spread of the individual sprinkler actually measured in the field is found out to be equal to the specification provided by the manufacturer equal to 9 m.
- 4) The discharge measurement of the field did not match with the specification. The measured discharge is 240 lph and discharge as per specification is 450 lph.
- 5) Irrigation rate from specification is 5.55 m/hr. But from the uniformity test it is found out equal to 2.41 mm/hr.

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