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HYDRAULIC PERFORMANCE EVALUATION OF DOUBLE NOZZLE FULL CIRCLE MICRO-SPRINKLER IRRIGATION SYSTEM UNDER SEMI-ARID CONDITIONS

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ABSTRACT

Assessment of the performance of micro irrigation system is essential before using as they are performing below their capacity and resulted in water loss. Therefore, hydraulic performance of double nozzle full circle micro sprinkler with different spacing and operating pressures was evaluated. It was found that discharge rates and effective radius of throw increased as the operating pressure increased. Wind drift and evaporation losses (WDEL) were found in the range of 0.85 to 19.60% respectively. Sprinkler overlapping was varied from 47.56 to 125.00 %, while mean application rate was ranged from 3.41 to 11.45 mm/h. Distribution uniformity and uniformity coefficient were found in the range of 75.63 to 90.40 % and 81.17 to 92.93%, respectively. The fixed and annual cost were found lower in 5 m × 5 m spacing (1.5 kg/cm^2) and 4 m × 4 m spacing (2.0 kg/cm^2) but these treatment combinations reported poor performance. Hence, economical and performance point of view, 4 m × 4 m spacing (2.5 kg/cm^2) may be preferred for micro sprinkler irrigation.

Keywords: Micro sprinkler, distribution uniformity, sprinkler discharge, mean application rate, uniformity coefficient, sprinkler design, economics.

I. INTRODUCTION

Water being a limited resource, its efficient use is basic to the survival of the ever increases population of the world. Rainwater is the main source to feed the demand that is either for ground water recharge or filling the surface water bodies. It is required to make every effort for the best use of water in order to increase the level of agricultural production per unit volume of water by using micro irrigation technology (Sadatiya *et al.,* 2019). Saurashtra region of Gujarat state depends on groundwater for irrigating all the crops in winter season (Patel *et al.,* 2014) as surface water is limited. Due to intensive agriculture and excess irrigation, tube wells and reservoirs are drying and started to failure resulted in massive water scarcity (Vadar *et al.,* 2016). Application of excess water to crop either due to rainfall or due to surface irrigation resulted in reduction of yield (Arjun Prakash *et al.,* 2017). Therefore, adaptation of efficient irrigation methods is important in view of increasing irrigation as well as water use efficiency. The use of soil moisture sensors along with micro irrigation system plays an important role to increase the irrigation water use efficiency (Patel and Rank, 2016 and Vora *et al.,* 2016). However, there is no need to irrigate the crop to its entire root zone depth as maximum root density is available within the upper half of the total root zone depth (Rank *et al.,* 2016). The micro irrigation system includes drip irrigation, sprinkler irrigation, micro sprinkler irrigation, porous pipe irrigation etc. All of these offer high water savings and additional benefits. It is emphasized here on micro sprinkler irrigation system because of its greater discharge rates and greater coverage than especially drip emitters and conventional sprinklers in dense field crops. Micro sprinkler applies less water per unit area then drip emitters because they spread water over a larger area. These devices have orifices which reduce the need for filtration to control clogging. It irrigates the crop in shorter time and provides the capacity of protecting the crop from frost. As compared to conventional sprinkler, it has even distribution of water since droplet size is small and less evaporation losses due to low height. The droplet sizes were larger for non-circular nozzles, which produced the largest average droplet size at the outer perimeter of their pattern (Chen and Wallender, 1985). Micro sprinklers are suitable in dense cropping, orchards or in the soil with low permeability and having low soil water storage capacity, or on extreme slopes where high runoff might occur. Flow rate of micro sprinkler ranges from 30 to 200 lph (Dwivedi *et al.,* 2015). Micro sprinklers normally required to be operated at 1.5 to 2.5 kg/cm^2 for having wetted diameters. Micro sprinkler irrigation system saves up to 50% of water compared to surface irrigation method and increases productivity by about 15-25%. (NABARD, 2013). Nearly all crops are suitable for sprinkler irrigation system except crops like paddy, jute, etc. Sprinklers working at low pressure cover smaller area, but the water application rate is high for the given lateral spacing. Christiansen's uniformity coefficient (C_U) (Christiansen, 1942) is widely used by researches on the global scale and has been applied as a proven criterion to define water distribution uniformity. Merriam and Keller (1978) gave method and parameters like effective radius, average application rate, distribution characteristics etc. to evaluate performance of sprinklers. Watson and Sluggett (1984) evaluated sprinklers using either the distribution uniformity or co-efficient of uniformity with the sprinkler in overlapping pattern by taking catch cans at 0.5 m grid and interval in two to four radiuses for each sprinkler and with the assumption that the application rate for a given distance from head was uniform around the head. The average flow variation and the emission uniformity of micro sprinkler at 2.0 kg/cm^2 operating pressure is to be 15.81 and 80.1 %, respectively as well as discharge pressure equation for micro sprinkler is a power function (Singh *et al.,* 1990). The water distribution uniformity depends on design parameters of micro sprinkler nozzles, which is responsible for uniform distribution of water without runoff and deep percolation losses. Therefore, the design parameters of micro sprinkler nozzle is an important element of entire system. Singh *et al*. (2001) reported more than 90% emission uniformity for micro jet sprinkler at different operating pressures ranging from 0.5 to 1.7 kg/cm^2. Additionally, row to row and plant to plan distance (density) plays a major role on the size and yield of the produce (Dudhat *et al.,* 2010). However, in the sub surface study, Vadar *et al.* (2019) suggested the optimum depth of drip emitter placement to be 0.15 m to get maximum efficiency. Many irrigation systems perform below their capacity leading to non-uniformity and water loss and therefore performance assessment becomes necessary to evaluate the irrigation system before its use (Dwivedi and Pandya, 216). The impact of lateral and sprinkler spacing on the performance is needed to be revealed. The main objective of the micro sprinkler system to minimize the water loss by applying water uniformly throughout the field. The uniformity in water distribution depends on the distance between the sprinkler nozzles (Wilcox and Swailes, 1947). As sprinklers are spaced further apart from optimum spacing, uniformities usually decrease (Tarjuelo *et al*., 1999). Anon. (1988) reported that on operating the micro sprinkler at 1.5 kg/cm^2 pressure with the spacing of 3 m × 3 m and of 0.30 m stake height of micro sprinkler, the diameter of wetted soil was 5 m. Only use of micro irrigation system is not beneficial but uniform water distribution is also very important. Keeping this in view, a study has been undertaken to evaluate the hydraulic performance of double nozzle full circle micro sprinkler irrigation system in field condition for the betterment of production and to achieve the more crop per drop concept.

II. MATERIALS AND METHODS

The study for evaluating hydraulic performance of double nozzle full circle micro sprinkler irrigation system was carried out at instructional farm of Junagadh Agricultural University having semi-arid conditions and the location is geographically located at 21 31' N latitude and 70 33' E longitudes with an elevation of 82.92 m. The wind velocity was measured during experiment by placing anemometer at 2 m height from the ground which was found in the range of 0.7 to 8.5 kmph with an average of 3.1 kmph and was flowing in N-E direction. The existing 200 mm diameter bore well of 45 m depth and submersible pump of 12.5 HP was used to supply water to micro sprinkler. To remove impurities in irrigation water hydro cyclone and disc filters were used. The bypass valve was used to regulate the pressure of the system and digital manometer was used to measure the pressure. In experimental system, 90 and 63 mm class II rigid PVC pipes were used as main and submain, respectively as well as 16 mm LLDPE lateral was used. To measure the pressure over experimental site manometer was installed at just beginning of the submain and reading of that manometer was considered for evaluation of micro sprinkler. In the study, double nozzle full circle orange coloured rotating type micro sprinkler of 1.5 mm nozzle diameter mounted on an installation stake of 30 cm was used.

Experimental Detail:

Treatment details: The experiment comprises 9 treatment combinations and 3 replications.

First factor: Pressure (P), (1) 1.5 kg/cm^2 (2) 2.0 kg/cm^2 (3) 2.5 kg/cm^2

Second factor: Spacing (S), (1) 3 m × 3 m (2) 4 m × 4 m (3) 5 m × 5 m

For statistical analysis of the investigation completely randomized design (CRD) was adopted.

Hydraulic Performance:

The system was installed at square geometry of lateral to lateral and sprinkler to sprinkler spacing as 3 m × 3 m, 4 m × 4 m and 5 m × 5 m. The experiment was performed using a flexible setup of nine (9) micro sprinklers. For the determination of sprinkler discharge, wind drift and evaporation losses (WDEL), effective radius, water spread area, sprinkler overlap, mean application rate, distribution uniformity and Christiansen's uniformity coefficient the micro sprinklers were operated at three different pressures of 1.5, 2.0 and 2.5 kg/cm^2. Metrological factors cannot be controlled in the field, but we sought low wind condition during the study. To catch the sprinkling water plastic cans of cylindrical shape with diameter 50 mm and depth 50 mm were used. The experimental area was divided in 1 m × 1 m grid to evaluate hydraulic performance of the system and catch cans were placed at ground level at grid points of each grid that cover the experimental area of the four central sprinklers. A measuring cylinder was used for measuring the volume of the water caught in every catch can. Each set of experiment were replicated 3 times to minimize the experimental error.

Sprinkler discharge

The water discharging from sprinkler was collected in a bucket and the discharge was calculated thrice for each operating pressure. Pressure-discharge relationship for micro sprinkler at various operating pressures was formulated. Micro sprinkler discharge can be expressed as a function of pressure in the following manner:

$$Q = C_D \times A \times (2gP)^n$$

Where, Q is micro sprinkler discharge, lph

C_D is emitter constant or flow or discharge coefficient

A is sum of areas of the nozzle orifices, mm^2

P is operating pressure (pressure head), kg/cm^2

g is gravity acceleration, m/s^2

n is emitter discharge exponent which characterize flow regime

The value of 'C_D' and 'n' was determined for micro sprinkler from regression analysis of power plot of the measured discharge against operating pressure.

Wind drift and evaporation losses (WDEL)

Wind drift and evaporation losses was estimated as the percentage of the water emitted by the sprinkler (ID_e) but not collected inside the catch cans according to the following formula (Holker, 2012):

$$WDEL = \frac{ID_e - ID}{ID_e} \times 100$$

$$ID_e = \frac{Q \times t}{S_s \times S_L}$$

Where, Q is sprinkler discharge, lph

t is operating time, h

S_S is sprinkler to sprinkler distance, m

S_L is lateral to lateral distance, m

ID_e is irrigation depth emitted by the sprinkler, mm

ID is average irrigation depth observed using the catch can, mm

Effective radius (r) and overlapping (O_S)

The micro sprinklers were operated at definite operating pressures and the covered radius of nine sprinklers was measured, and an average was taken as an effective radius. Water spread area was computed by using the effective radius of the micro sprinkler at the respective pressure. Proper degree of overlapping is necessary for uniformity of application of water in the field. If sprinkler overlapping is not proper there may remain dry patches in the field. Sprinkler overlapping was found by using the following formula:

$$O_S = \left(2 - \frac{D_S}{r}\right) \times 100$$

Where, O_S is overlapping of micro sprinklers, %

D_s is distance between micro sprinklers, m

r is effective radius of micro sprinkler, m

Application rate (I)

Mean application rate (I), the depth of water applied by the sprinkler on the soil surface per unit time, was found by dividing the volume of water collected per unit time in catch can by cross-sectional area of the catch can. It was calculated using following formula:

$$I = \frac{\sum X}{n \times t}$$

Where, I is mean application rate, mm/h

ΣX is total depth of water collected in the catch cans, mm

n is total number of catch cans

t is time of operation, h

Distribution uniformity (D_U)

The distribution uniformity (D_U) or pattern efficiency (P_e) indicates the uniformity of water application throughout the field and is computed by,

$$D_U = \frac{Minimum\ depth\ (mm)}{Average\ depth\ (mm)} \times 100$$

Where, minimum depth is calculated by taking the average of the lowest $1/4^{th}$ of the can used in a particular test. The DU is useful for calculating the average depth to be applied for certain minimum depth; for example if minimum depth of 8 cm is to be applied and the distribution efficiency is 80%, then average depth of 10 cm should be applied.

Christiansen's uniformity (C_U)

This is the parameter developed by Christiansen (1942), which is widely used to evaluate sprinkler irrigation uniformity. A measurable index of degree of uniformity obtained from any size of sprinkle operating under given condition is known as uniformity coefficient (C_U). The better the uniformity, the smaller the deviation and the value will approach 100%. A uniformity coefficient of about 85% or more is considered to be satisfactory.

The average precipitation rate of three replications in each case was used to determine the uniformity coefficient by applying the Christiansen's formula:

$$C_U = \left[1 - \frac{\sum\left|X - \overline{X}\right|}{n \times \overline{X}}\right] \times 100$$

Where, C_U is Christiansen's uniformity

$\overline{X}$ is the mean water depth collected in the catch can, mm

$\sum|X- \overline{X}|$ is cumulative of numerical deviation of individual observation from the mean water depth, mm

n is total number of catch cans

Design of micro sprinkler system

For the economizing cost of the micro sprinkler irrigation, sound design of the system must be needed. In this study, the system was tested for different spacing arrangement of sprinklers at various operating pressures and designed with adopting following assumptions and equations.

- Area of the field is one hectare i. e. 100 m × 100 m with water source is in a corner of the field
- Availability of electricity is 8 h/day.
- Peak water requirement of the crop is 6 mm/day.
- Efficiency of motor and pump are 70 and 60 %, respectively and total head of 45 m.

The head loss in the main line may be determined by following equation (Williams and Hazen Equation, 1905)

$$H_f = \frac{15.27 \times Q^{1.852} \times L}{D^{4.871}}$$

Where, H_f is head loss over a length of pipe (m) (meter of water)

L is length of pipe (m)

D is inside pipe diameter (cm)

Q is volumetric flow rate (lps)

With the help of above equation, the energy drop of the main line can be calculated.

The total head loss in the submain or lateral can be determined by following equation (Williams and Hazen Equation, 1905)

$$H_f = \frac{5.35 \times Q^{1.852} \times L}{D^{4.871}}$$

Where, H_f is head loss over a length of pipe (m) (pressure head)

L is length of pipe (m)

D is inside pipe diameter (cm)

Q is volumetric flow rate (lps)

Cost analysis of micro sprinkler system

Micro sprinkler irrigation systems were designed for one hectare field at various discharges and operating pressure. The cost of the design system was determined. The rates of components were considered as per GGRCL price list. The cost is estimated considering 10 year's life of the system and 2 seasons in a year at an interest rate of 10% per annum. The cost of instalment can be determined by following equation.

$$Ai = \frac{P \times [i \times (1+i)^n]}{(1+i)^n - 1}$$

Where, i is interest rate (%)

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n is expected life of system (years)

P is present cost of the system (Rs.)

Ai is annual instalment cost (Rs.)

Annual cost = annual instalment + variable cost (10% of the annual instalment) + repair and maintenance cost (5% of the annual instalment)

III. RESULTS AND DISCUSSION

Sprinkler discharge variation with pressure

The micro sprinkler having 1.77 mm² area of nozzle orifice was operated at 1.5, 2.0 and 2.5 kg/cm² pressure and the corresponding volume of water and time were recorded by keeping the micro sprinkler upside down in a bucket for measurement of discharge. An average discharge of three replications for micro sprinkler were determined and presented in Table 1. The plot of discharge against operating pressure revealed that the micro sprinkler discharge increases with the operating pressure and increase exponentially (Figure 1). The values of C_D and n was obtained respectively as 0.98 and 0.545 while equated the graph with the power series. The power function fitted best for pressure discharge relationship with drip emitters (Sadatiya *et al.* 2019).

Table-1: Discharge rate at various operating pressure for micro sprinkler

Sr. No.	Operating pressure (Kg/cm²)	Discharge (lph)			Average discharge (lph)
		R_1	R_2	R_3	
1.	1.5	86.00	82.00	89.00	85.66
2.	2.0	105.00	99.00	102.00	102.00
3.	2.5	116.00	109.00	113.00	113.00

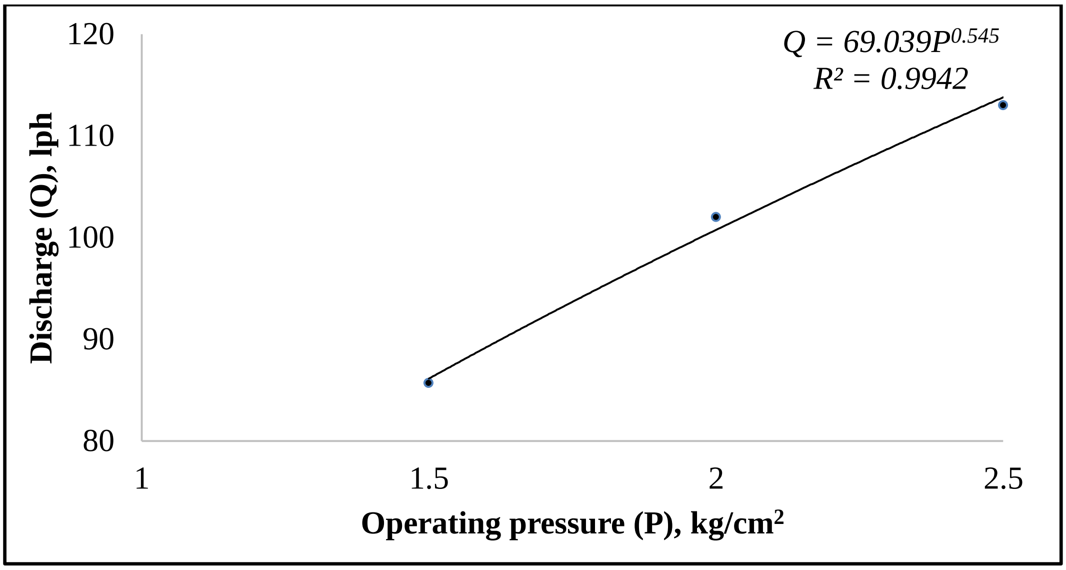

Fig.-1: Relationship between operating pressure and discharge of micro sprinkler

Wind drift and evaporation losses (WDEL)

Wind drift and evaporation losses were determined for the different arrangement of sprinkler systems using the tests conducted with catch cans are presented in Table 2. It is indicated that the wind drift and evaporation losses are increasing with the sprinkler spacing while it was found independent in respect to operating pressure. It remained in the range of 0.85% to 19.60% for studied arrangements of the sprinkler system.

Table-2: Wind drift and evaporation losses of micro sprinkler various operating pressures

Sprinkler spacing	Operating pressure (kg/cm^2)	Wind drift and evaporation losses (%)
3 m × 3 m	1.5	1.47
	2.0	2.83
	2.5	0.85
4 m × 4 m	1.5	2.53
	2.0	9.69
	2.5	4.40
5 m × 5 m	1.5	13.72
	2.0	19.60
	2.5	14.91

Effective radius and water spread area

Water spread area of the micro sprinkler is calculated using the average effective radius of the micro sprinkler corresponding to operating pressure of the system (Table 3). It is revealed that the effective radius of the micro sprinkler increases with increase in the operating pressure of the system.

Table-3: Effective radius and water spread area of micro sprinkler at various operating pressures

Sprinkler	Operating pressure (kg/cm^2)		
	1.5	**2.0**	**2.5**
1	3.24	3.52	4.20
2	3.75	3.74	4.00
3	3.10	3.50	3.90
4	3.15	4.10	4.10
5	3.40	3.66	4.20
6	3.50	3.15	4.18
7	3.32	3.76	4.15
8	3.30	3.90	3.80
9	3.28	3.89	4.12
Average effective radius (m)	**3.33**	**3.78**	**4.07**
Water spread area (m^2)	**34.82**	**44.87**	**52.01**

Sprinkler overlapping

Sprinkler overlapping is important for good distribution of water in the field. If overlapping is not good dry patches may remain in the field. The sprinkler overlapping for different combination of sprinkler spacing and operating pressure is given in Table 4, which is resulted that the sprinkler overlapping was found higher at lower sprinkler spacing.

Table-4: Overlapping (%) of micro sprinkler at various operating pressures

Sprinkler spacing	Operating pressure (kg/cm^2)		
	1.5	**2.0**	**2.5**
3 m × 3 m	107.40	119.78	125.00
4 m × 4 m	79.51	85.71	103.61
5 m × 5 m	47.56	63.38	71.79

Mean application rate

The mean application rate obtained is presented in the Table 5 and it is revealed that the effect of sprinkler spacing and pressure head was significantly influenced the mean application rate. It was found that as the pressure increases mean application rate increases and with the increase in sprinkler spacing mean application rate decreases. It can be said that the mean application rate of the sprinkler is directly proportional to the operating pressure of the sprinkler and inversely proportional to the spacing between the sprinklers. Thus highest mean application rate is observed when system was operated at 2.5 kg/cm^2 pressure at a spacing of 3 m × 3 m. Similarly, the lowest mean application rate was noticed when system was operated at 1.5 kg/cm^2 pressure at a spacing of 5 m × 5 m.

Table-5: Mean application rate (mm/h) of micro sprinkler at various operating pressures

Sprinkler spacing	**Operating pressure (kg/cm^2)**		
	1.5	**2.0**	**2.5**
3 m × 3 m	8.23	10.15	11.45
4 m × 4 m	5.10	5.70	6.63
5 m × 5 m	3.41	3.63	4.29
S.Em.			0.28
CD at 5%			0.85
C.V. %			5.69

Distribution uniformity

Distribution uniformity of any sprinkler system is dependent upon the sprinkler overlapping. If the overlapping is not proper, the water distribution will be non-uniform which may render the system ineffective for proper irrigation. The results found on distribution uniformity are shown in Table 6 and it is revealed that the effect of sprinkler spacing and pressure head was significantly influenced the distribution uniformity. Though the highest distribution efficiency observed with 3 m × 3 m spacing and 2.5 kg/cm^2 operating pressure, the treatment combination of with 4 m × 4 m spacing and 2.5 kg/cm^2 operating pressure gave at par results. It is observed that the distribution uniformity is directly related to the overlapping of the sprinklers. For the sprinkler overlapping of 125.00% the distribution uniformity is 90.40% whereas when the overlapping is 47.56% the distribution uniformity attains a value of 75.63%. Dwivedi and Pandya (2016) reported the similar results as the distribution uniformity is higher while the sprinkler spacing is narrower with higher operating pressure.

Table-6: Distribution uniformity (%) of micro sprinkler at various operating pressures

Sprinkler spacing	**Operating pressure (kg/cm^2)**		
	1.5	**2.0**	**2.5**
3 m × 3 m	80.75	86.20	90.40
4 m × 4 m	78.12	81.47	88.14
5 m × 5 m	75.63	77.97	79.30
S. Em.			3.02
CD at 5%			9.21
C.V. %			7.70

Christiansen's uniformity coefficient

This calculation is based on determining the average amount of water in the container and deviation from this amount. Uniformity coefficient characterizes the uniformity and efficiency of irrigation. Its value helps to assess the efficiency of the system. The values of Christiansen's uniformity coefficient are shown in Table 7 and it is revealed that the effect of sprinkler spacing and pressure head was significantly influenced the Christiansen's uniformity coefficient. Though the highest uniformity coefficient observed with 3 m × 3 m spacing and 2.5 kg/cm^2 operating pressure, the treatment combination of with 4 m × 4 m spacing and 2.5 kg/cm^2 operating pressure gave at par results with closer value. It is observed that the uniformity coefficient has a direct relation with operating pressure and an inverse relation with sprinkler spacing. The similar trend was also followed by distribution uniformity.

Table-7: Christiansen's Uniformity coefficient (%) of micro sprinkler at various operating pressure

Sprinkler spacing	Operating pressure (kg/cm^2)		
	1.5	**2.0**	**2.5**
3 m × 3 m	87.94	90.20	92.93
4 m × 4 m	85.00	89.63	91.19
5 m × 5 m	81.17	83.41	87.91
S. Em.			0.94
CD at 5%			2.80
C.V. %			1.87

Design of micro sprinkler system

From the results obtained, it was found that the treatment combination of 4 m × 4 m spacing and 2.5 kg/cm^2 operating pressure gave best results with at par value of both distribution uniformity and uniformity coefficient. So the design for selecting main, submain and lateral was made for this treatment combination and design parameters of micro sprinkler system is shown in Table 8 and the design is shown in Figure 2.

Table-8: Design parameters of micro sprinkler system (4 m × 4 m spacing and 2.5 kg/cm^2 operating pressure)

Available motor flow	:	24.44 m^3/hr	**Sub main line design**		
Application rate	:	7.06 lph/m^2	Max length	:	100 m
Required flow	:	70.62 m^3/hr/ha	Total length	:	200 m
Irrigation time	:	0.85 h	Discharge	:	6.54 lps
No of sprinkler	:	625	Diameter selected	:	75 mm
No of shifts possible	:	3	Friction head (H_f)	:	0.95 m
Lateral design			**Main line design**		
Permissible length	:	33.33 m	Total length	:	116.66 m
Total length	:	2600 m	Discharge	:	6.54 lps
Discharge	:	0.26 lps	Diameter selected	:	90 mm
Dia. Selected	:	20 mm	Friction head (H_f)	:	1.29 m
Friction head (H_f)	:	0.50 m	**Filter capacity**	:	23.54 i.e 25 m^3/hr

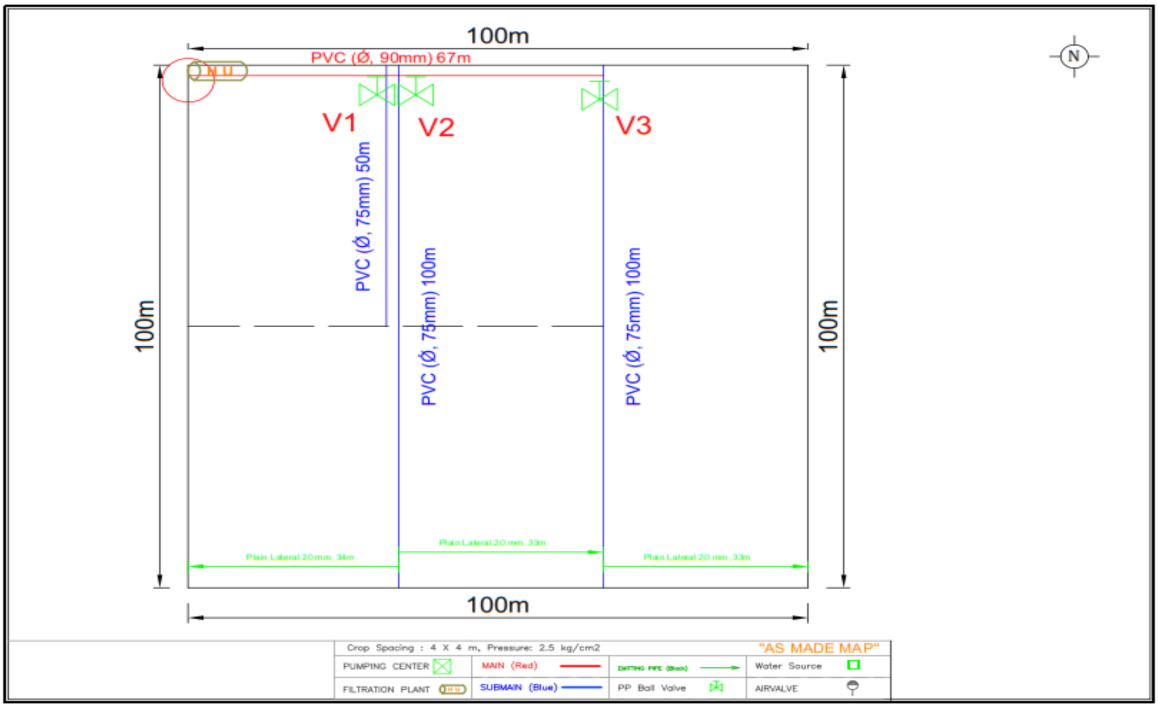

Fig.-2: Design of micro sprinkler system (4 m × 4 m spacing and 2.5 kg/cm^2 operating pressure)

Cost analysis

Total nine systems were designed with varying sprinkler spacing in the range of 3 m × 3 m, 4 m × 4 m and 5 m × 5 m for different operating pressure of 1.5, 2.0 and 2.5 kg/cm^2. The systems were designed for one hectare (i.e. 100 m × 100 m) field considering 10 years life of the system and two seasons in a year at an interest rate of 10% per annum. The cost of all the system were determined and presented in the Table 9. It can be seen that the fixed and annual cost of best treatment combination (i.e 4 m × 4 m spacing and 2.5 kg/cm^2 operating pressure) in respect to distribution uniformity and Christiansen's uniformity has fixed and annual cost were found Rs. 86925.26 and 16268.69 per hectare per season. The fixed and annual cost were lower in 5 m × 5 m spacing and 1.5 kg/cm^2 operating pressure and they were same in 4 m × 4 m spacing and 2.0 kg/cm^2 operating pressure but the performance of the system at those treatment combinations were found poor, so as per the economics point of view and on the basis of performance of the system 4 m × 4 m spacing at an operating pressure of 2.5 kg/cm^2 may be preferred.

Table-9: Summary of fixed and annual cost (Rs/ha/season) of micro sprinkler system

Sprinkler spacing	Cost	Operating pressure (kg/cm^2)		
		1.5	**2.0**	**2.5**
3 m × 3 m	Fixed	114158.96	12261.98	124347.26
	Annual	21365.67	22947.53	23272.49
4 m × 4 m	Fixed	108685.12	86925.26	86925.26
	Annual	20341.20	16268.69	16268.69
5 m × 5 m	Fixed	65619.67	91014.67	91014.67
	Annual	12337.37	17034.05	17034.05

IV. CONCLUSIONS

In the present study, a system comprising of nine double nozzle micro sprinkler were arranged at different sprinkler spacing of 3 m × 3 m, 4 m × 4 m and 5 m × 5 m and run for 30 minutes at various operating pressures viz., 1.5, 2.0 and 2.5 kg/cm^2 to collect the precipitation in catch cans placed between four central sprinklers. It was found that discharge rates and effective radius of throw were varied, respectively from 85.66 lph to 113.00 lph and 3.10 m to 4.20 m as operating pressure increases from 1.5 to 2.5 kg/cm^2. Wind drift and evaporation losses (WDEL) were found to be in the range of 0.85 to 19.60%. Water spread area was highest when the operating pressure was 2.5 kg/cm^2 with a value of 55.39 m^2 while it was minimum as 30.17 m^2 at an operating pressure of 1.5 kg/cm^2. Sprinkler overlapping was in the range of 47.56 to 125.00 %. Mean application rate was in the range of 3.41 to 11.45 mm/h. Distribution uniformity and uniformity coefficient were found, respectively in the range of 75.63 to 90.40 % and 81.17% to 92.93%. The fixed and annual cost of best treatment combination (i.e 4 m × 4 m spacing and 2.5 kg/cm^2 operating pressure) on the basis of performance of system, has fixed and annual cost were found Rs. 86925.26 and 16268.69 per hectare per season, respectively. The fixed and annual cost were lower in 5 m × 5 m spacing and 1.5 kg/cm^2 operating pressure and they were same in 4 m × 4 m spacing and 2.0 kg/cm^2 operating pressure but the performance of the system at those treatment combinations were found poor, so as per the economics point of view and on the basis of performance of the system 4 m × 4 m spacing at an operating pressure of 2.5 kg/cm^2 may be preferred.

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