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The hydraulic performance of rain pipe irrigation system under lateritic soils of Konkan region

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Abstract
The rain pipe irrigation system is emerging technology in the field of pressurized irrigation the system has both sprinkler and micro irrigation system benefits with optimum operating pressure. The rain pipe irrigation system is suitable for growing agronomical as well as nursery crops, vegetables crops. In this system water is applied through micro-openings in the form of spray over the crop canopy with high coverage area and uniform distribution. The coverage area of the rain pipe irrigation system is more and has less investment as compared to sprinkler, micro jets and other pressurized irrigation systems and need less energy. By knowing the advantages of rain pipe irrigation system (RPIS) and its prospective, the system tested for different hydraulic parameters such as uniform coefficients, pressure discharge relationship, mean application rate, distribution pattern, coverage width and percent coverage area.
To test the hydraulic parameters the system was run with 3 replications for different pressures (0.8, 1.0, 1.2 kg/cm^2), lengths (10 m, 20 m, 30 m) and spacing (2 m, 3 m, 4 m) respectively.
Based upon the field hydraulic study, it found that rain pipe irrigation system (RPIS) operated at 0.8kg/ cm^2 with lateral spacing of 3m with 20m lateral length found suitable in terms of distribution efficiency (72.40%) in good category, uniformity coefficients (82.50%) in good category. The mean application rate and coverage area found (21.38 mm/hr) and 73 percent respectively. The system also found suitable for uniform moisture distribution under lateritic soil conditions. Similarly, the system tested for foxtail millets crop found that the plant growth was better than surface irrigation.
Based on these results it was found that rain irrigation system is suitable under lateritic soil in terms of better distribution uniformity, uniformity coefficient and mean application rate, and coverage area.

Keywords: Rain pipe irrigation system, distribution uniformity, uniformity coefficient, mean application rate, coverage width, Konkan region

1. Introduction

Rain pipe irrigation system is combination of sprinkler and drip irrigation system. The Rain pipe systems irrigates the crop intensely under optimum pressure with large coverage area. The rain pipe irrigation system consists of a micro-opening over a flexible pipe with specific intervals and having specific discharge capacity. The system works under low operating pressure. The system is easy to install simple to maintain, low cost and low operating pressure. The system is suitable for loamy soil having high infiltration rate. It helps in conserving water by providing moisture nearly to plant roots with fined droplets. The other advantage of rain pipe irrigation is its flexibility and adaptability to different types of crops and field conditions. The system easily customized and installed and allowing for efficient irrigation in various agricultural cropping system. The same layout of rain pipe irrigation system (RPIS) can be used for different crop geometry and crop type.

For precision application of irrigation water the selection of proper irrigation system is essential component of irrigation management. The proper irrigation method provides favourable conditions for plant growth as well enhances the output and system efficiency. The design of irrigation method is depending upon the hydraulic performance of the method and its response to crop growth.

The different irrigation method was tested in terms of hydraulic parameters by many researchers. The different reviews indicated that drip irrigation system is suitable for most of the crops but needs more number of emitters for uniformity in application.

The greater number of emitters also increase the cost of the system. The overhead sprinkler or mini sprinkler system needs more pressure and other fitting accessories which results in increasing the cost. By knowing the advantages and disadvantages of micro irrigation system the rain pipe irrigation system (RPIS) is the combination of drip and sprinkler system and have the advantages of both systems.

Many researchers studied the hydraulic performance of micro irrigation system (Kadam et al. 2008; Patil et al. 2011; Patel et al. 2021) [7, 14, 15] the rain pipe irrigation system also tested by (Kathiriya et al. 2021; Bhadarka et al. 2023) [2, 8] and found that system is very useful for uniform application and distribution of water and also helps in water saving and reduce the conveyance losses.

According to Kadam et al. (2006) [6] the performance of micro-sprinkler system observed that if the spacing of laterals increased and operating pressure decreased, the uniformity reduced and results in decrease in yield. Sahoo et al. (2007) [16] observed that for low pressure rotating sprinkler the effect of wind velocity on uniformity is less, when wind speed is below 4 km/hr to 7 km/hr. Similar, results also stated by Kursad & Senser (2009) [11]. Moazed et al. (2010) [13] stated that the spacing between the sprinklers is increased results in decrease in uniformity. According to Kadam et al. (2008) [7] for micro-sprinkler operated of 1 kg/cm^2 with spacing of 1.5 m x 1.5 m gave higher uniformity of application. Similar results were also reported by Dwivedi and Pandya (2016) [4], Kathiriya et al. (2021) [8] operated the rain pipe irrigation system using solar photovoltaic system (SPVS) and found that, the system operated at 0.75 kg/cm^2 gave excellent performance in terms of distribution efficiency, uniformity coefficient. Bhadarka et al. (2023) [2] stated that the rain pipe irrigation system found excellent performance in terms of distribution uniformity, coefficient variation, mean application rate and the maximum width coverage of 10.20 m with length of 30 m operated of 1.5 kg/cm^2.

Based on the above reviews, it was found that very fewer works has been under taken lateritic soils of Konkan region, therefore the presents study have been taken to test the hydraulic performance of rain pipe irrigation system (RPIS) in terms of uniformity coefficients, distribution uniformity, mean application rate, coverage area, operated at different spacing, length and pressures.

2. Materials and Methods

2.1 Study Area

The field trial conducted at Central Experimental Station (CES), Gavtale Block, Wakawali, Dapoli Dist. Ratnagiri (Maharashtra). The study area lies between 17.48° N Latitude and 73.78° E Longitudes and situated at Altitude of 250m from mean sea level. The location map of study area is shown in Fig 1.

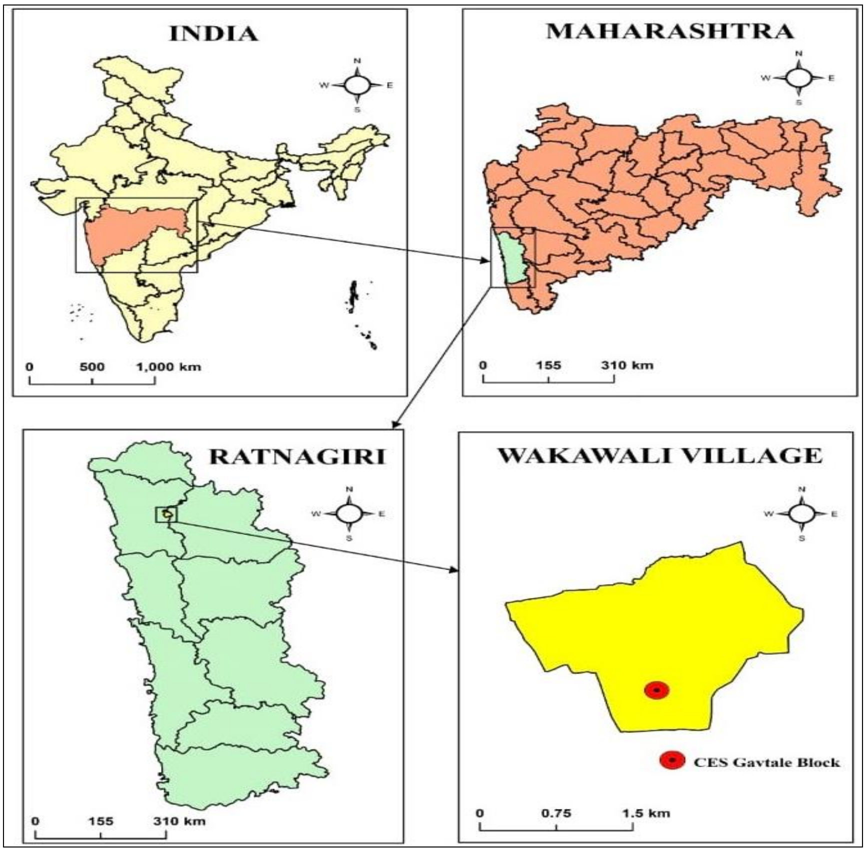

Fig 1: Location map of study area.

2.2 Methodology

The study of hydraulic performance of rain pipe irrigation system was conducted under following specification. The rain pipe with three spacing (2m, 3m, 4m) and three lengths (10 m, 20 m, 30 m) and three operating pressures of (0.8, 1.0, 1.2) kg/cm^2 respectively. The catch can place in grid with spacing of 60 cm x 60 cm rain pipe irrigation system (RPIS). The system was operated for 30 minutes and discharge is collected in catch cans. The pressure gauge was installed to maintain the constant pressure. The necessary observations required for pressure discharge relationship, uniformity coefficient, distribution uniformity, mean application rate, coverage area was recorded for different spacing (2 m,3 m, 4 m), lengths (10 m, 20 m,30 m) at different operating pressures (0.8 kg/cm^2, 1.0 kg/cm^2, 1.2

kg/cm^2). To get less error three replications for each combination were taken and mean observation were used for analysis. The adopted hydraulic parameters are described below.

1. Pressure Discharge relationship

The Pressure discharge relationship was established by using the equation given by Keller and Karmeli (1974) [9] by equation.

$$q = K_d H^x \quad \dots (1)$$

Where,
q = Discharge flow lit/hr,
K_d = Discharge coefficient dimensionless
H = Operating pressure, m,
x = Discharge exponent.
To determine the exponent "x" the equation is given as

$$x = \frac{\log\left(\frac{q2}{q_1}\right)}{\log\left(\frac{H2}{H1}\right)} \quad \dots (2)$$

2. Uniformity coefficient

The uniformity coefficient procedure developed by Christiansen (1942), was used. In this method, a measurable index of degree of uniformity obtained from any size of sprinkler or rain pipe irrigation system operating under given condition. The equation of uniformity coefficient is

$$C_u = 100\left(1.0 - \frac{\sum |X|}{mn}\right) \quad \dots (3)$$

C_u = Uniformity coefficient (%)
X = Numerical deviation of individual observations from the average application rate, mm
m = Average value of all observations, mm
n = Total number of observations.

3. Distribution uniformity

The distribution uniformity suggested by Merriam and Keller (1978) [10] was used. The distribution uniformity coefficient is given by equation .The minimum depth is calculated by taking the average of the lowest 1/4th of the can used in a particular test .

$$Du = \frac{Average\ depth(mm)}{Minimum\ depth(mm)} \quad \dots (4)$$

4. Mean application rate

Mean application rate is the water applied by the rain pipe on the soil surface per unit time. It was be estimated according the following formula (Hansen et al. 1980).

$$I = \frac{\sum X}{n \times t} \quad \dots (5)$$

Where,
I = Application rate, mm/hr
∑X = Total depth of water collected in the catch cans (volume/ area of can), mm
n = Number of catch cans
t = Time of operation, hr

5. Coverage area

The water spread area were calculated by using the coverage area of the rain pipe at different length and spacing.

$$A = L \times B \quad \dots (6)$$

Where,
A= Area of spread or coverage, m^2
L= Length of coverage along the lateral, m,
B= Width of coverage across the lateral, m

The**%** coverage area computed on the basis on spacing allocated and actual area covered under different operating pressures. Based upon the above hydraulic parameters the rain pipe irrigation system (RPIS) was tested for different operating pressures. The field observations were recorded analysed and summarized in following sections.

3. Results and Discussion

1. Measurement of pressure discharge relationship (H-Q)

An average discharge of three replications was obtained at various operating pressure for rain pipe irrigation system (RPIS) was measured and presented in the Table No.1.

Table 1: Discharge rate at various operating pressures

Sr. No	Operating pressure (kg/cm^2)	Average Discharge (lph)	% Deviations with recommended discharge
1.	0.8	38.0	-2%
2.	1.0	39.7	-0.3%
3.	1.2	43.6	+3.6%

The rain pipe irrigation system (RPIS) was tested for discharge at various operating pressure between 0.8 kg/cm^2, 1.0 kg/cm^2, 1.2 kg/cm^2 . From Table No. 1, the average discharge for rain pipe irrigation system (RPIS) and found that it varies from 43.6 lph to 38.0 lph. The% deviation in discharge varied from -0.3% to 3.6% with recommended discharge which is less than 5 percent and acceptable for length of 30m. Similarly, the pressure discharge relationship was developed to find out the relationship of discharge variation with respect to change in pressure. The discharge constant (K_d) for rain pipe irrigation system was observed k_d = 0.5, which indicated that, the flow is fully turbulent in nature. Similarly, the discharge exponent was x = 0.35. Based upon the above constants the pressure discharge relationship equation was developed which is very useful to find the pressure variation on discharge i.e. q =0.514 $H^{0.38}$. The pressure discharge relationship is also deplicated in Fig 2.

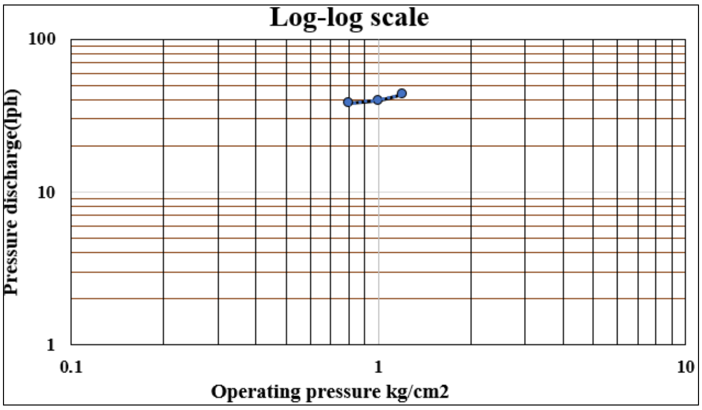

Fig 2: Pressure discharge relationship (H-Q)

2. Uniformity Coefficient

The Uniformity coefficient for rain pipe irrigation system operated at different pressure, length of laterals and spacing between the laterals is given in Fig No 3, 4, & 5. Based upon they field observation, it seen that for operating pressure of 0.8 kg/cm^2 the uniformity coefficients more than 80%, i.e. good for the spacing of 3 m and lateral length of 30 m. This indicated that at lower operating pressure the rain pipe irrigation system irrigates upto length of 30 m with 3 m spacing. The field observation of uniformity coefficient indicated that for low operating pressure (0.8 kg/cm^2) for wider spacing the emission uniformity is less than the desirable i.e., ≤ 80% and categorized as poor. It means for 30 m length and spacing of 3 m and operating pressure of 0.8 kg/cm^2 achieved uniformity coefficient more than 80 percent.

The rain pipe irrigation system operated at 1.0 kg/cm^2 for different lengths of lateral i.e. 10 m, 20 m and 30 m for 2 m spacing and 3 m spacing gave very good uniformity coefficients. For 4 m spacing and 30 m length of lateral, the uniformity coefficients is slightly less than 80%, i.e., very near to good category i.e., 79.67%. Therefore, it resulted that rain pipe irrigation system operated at 1.0 kg/cm^2 pressure can irrigated upto 4m spacing and upto 30 m length. It also observed that for better uniformity coefficients the rain pipe irrigation system can be operated 1.0 kg/cm^2 pressure for the spacing 4 m with the laterals of 30 m.

The rain pipe irrigation system operated at 1.2 kg/cm^2 operating pressure covered 4 m spacing and lateral length of 30 m gave higher uniformity coefficient. From Fig 3,4,5 it observed that for the spacing of 2 m and lateral length of 20 m operated at 0.8 to 1.2 kg/cm^2 operating pressure the uniformity coefficients were more than 85%.

From these results, it concluded that for low operating pressure (0.8kg/cm^2), the lateral spacing of 3m and length upto 30 m achieved higher uniformity coverage. For operating pressure of 1.0 kg/cm^2 laterals spacing of 4m and lateral length of 30m found suitable in terms of good uniformity coverage (greater than 80%). Similar, results were also observed by (Kadam 2008, Patel et al. 2021, Dwivedi et al. 2021) [7, 14].

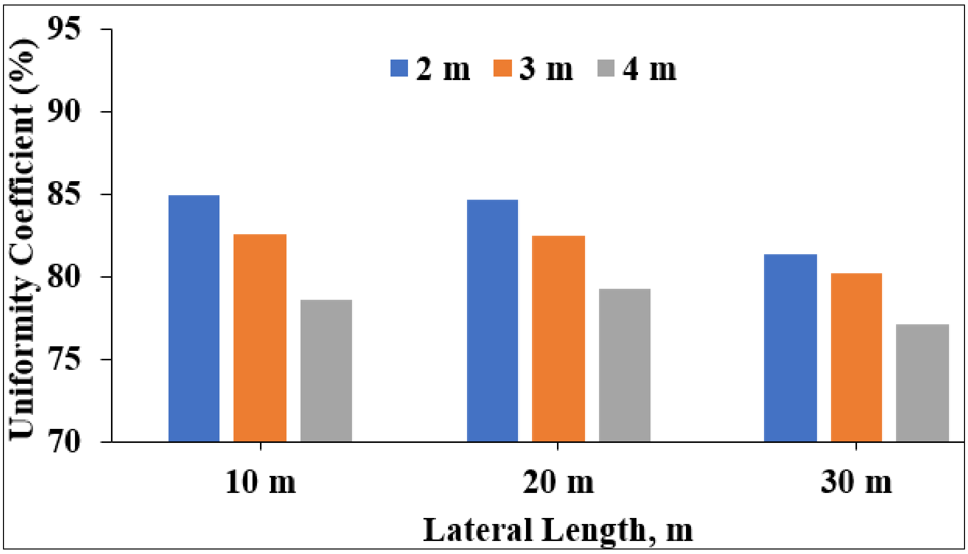

Fig 3: Uniformity coefficients at 0.8 kg/cm^2 operating pressure

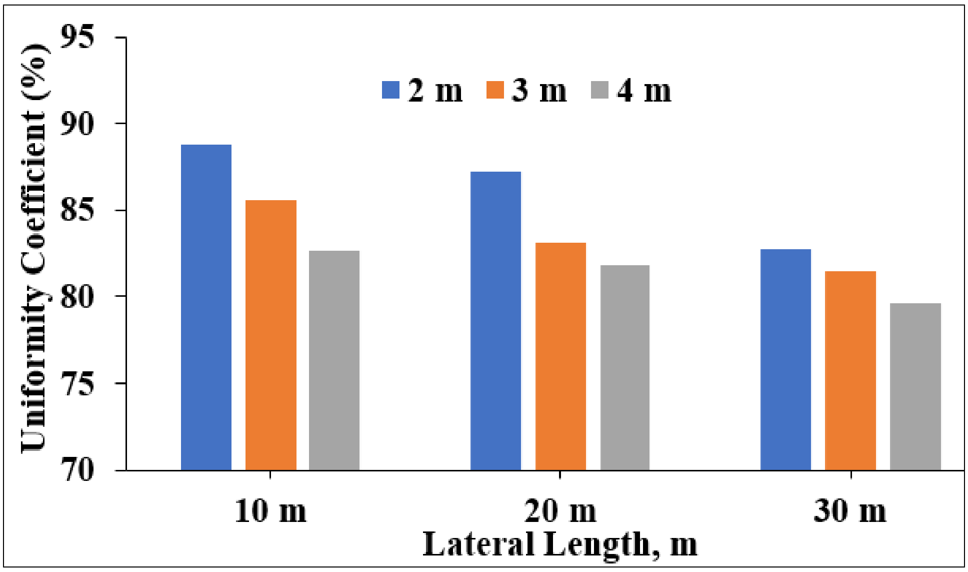

Fig 4: Uniformity coefficients at 1.0 kg/cm^2 operating pressure

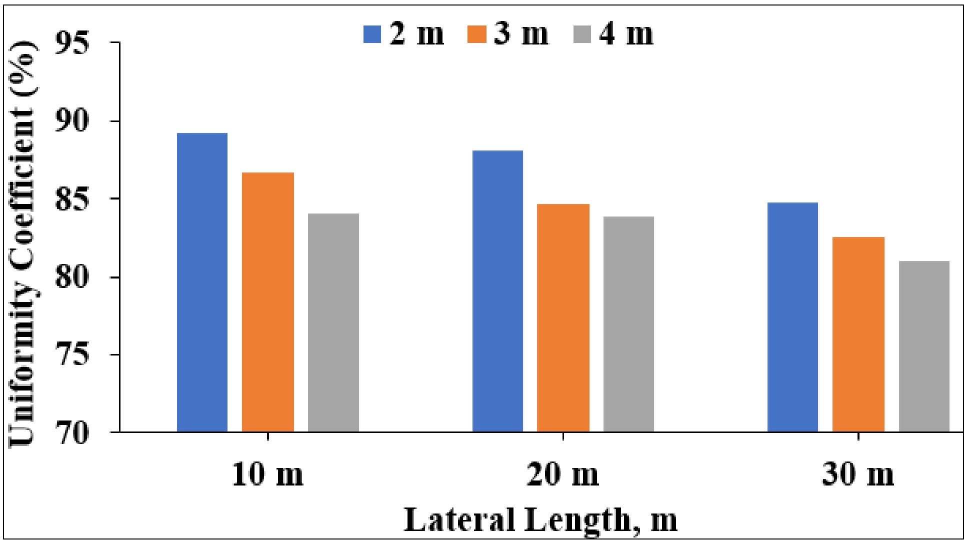

Fig 5: Uniformity coefficients at 1.2 kg/cm^2 operating pressure

3. Distribution Uniformity

The Distribution Uniformity for rain pipe irrigation system operated at different pressure, length of laterals and spacing is given in Table No 2. Based upon field observations it seen that for operating pressure of 0.8 kg/cm^2 the distribution uniformity more than 70% i.e., that is good for the spacing of 3m and lateral length of 30 m. This indicated that at lower operating pressure the rain pipe irrigation system irrigates upto length of 30 m with spacing of 3m. The field observations of distribution uniformity indicated that for low operating pressure (0.8 kg/cm^2) for more than 3m spacing, the distribution uniformity is less than 70% and falls in category as poor. For 30 m length and spacing of 3m operated at pressure of 0.8 kg/cm^2 achieved distribution uniformity more than 70%.

The rain pipe irrigation system operated at 1.0 kg/cm^2 for different length of laterals i.e 10 m, 20 m, 30 m, for 2 m and 3m spacing gave very good distribution uniformity upto 30 m lateral length. For 4 m spacing and 20 m length of laterals, the distribution uniformity is 69.47% and very near to good category. Based upon the results, it seen that rain pipe irrigation system operated at 1.0 kg/cm^2 pressure irrigates upto 3 m spacing with 30 m length. It also observed that for better distribution uniformity the rain pipe irrigation system operated at 1.0 kg/cm^2 pressure for the spacing 3 m with lateral length of 30 m.

Based upon the distribution uniformity, it concluded that for low operating pressure (0.8 kg/cm^2) pressure, the lateral spacing of 3 m with length upto 20 m gave better distribution uniformity (more than 70%.). Similarly for operating pressure of 1.0 kg/cm^2 with spacing of 4 m and length of 10 m found suitable in terms of good distribution uniformity (greater than 70%). these, results were also observed by (Moazed et al; 2010, Pardo 2016; Dwivedi et al. 2016) [13, 4].

Table 2: Distribution uniformity RPIS for different operating pressure, length and spacing

Operating pressure, kg/cm^2	Length, m	Distribution Uniformity,%		
		2 m	3 m	4 m
0.8	10	78.96	72.41	69.76
	20	74.63	72.40	68.50
	30	72.76	71.33	65.85
1.0	10	82.21	73.17	71.11
	20	75.24	73.11	69.47
	30	73.31	72.06	66.12
1.2	10	83.24	74.05	72.34
	20	76.04	74.22	70.29
	30	74.06	73.59	67.09

5. Mean application rate

The Mean application rate for different lateral spacing and length and operating pressure is given in Fig 6, 7 & 8. The mean application rate indicated that for operating pressure 0.8 kg/cm^2 was ranged from 32.11 to 24.81 mm/hr for different operating pressure for the spacing of 2m. The mean rate in reduced as operating pressure decreased and increase in lateral length. For operating pressure of 1.0 kg/cm^2 for different length of laterals and spacing the mean application rate ranged from 18.34 to 33.50 respectively.

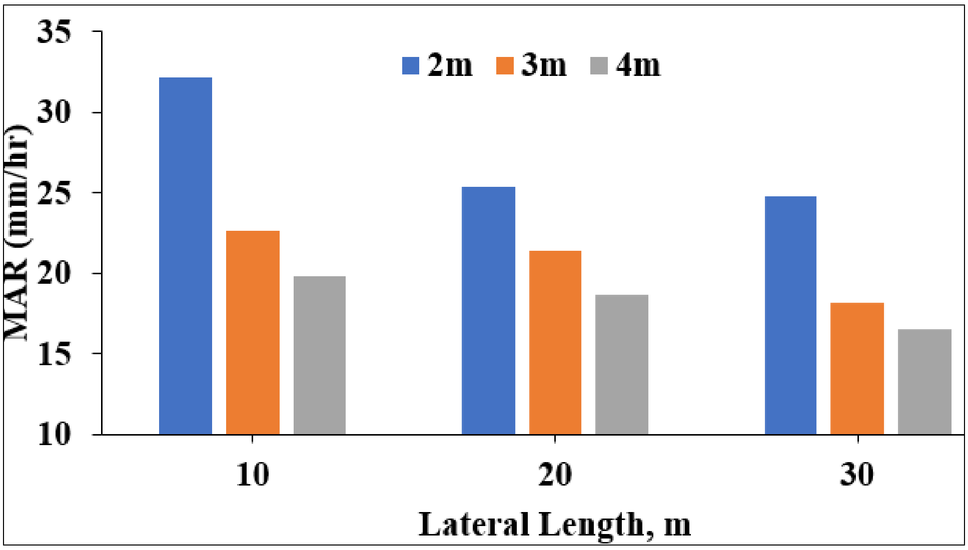

Fig 6: Mean application rate at 0.8kg/cm^2 operating pressure

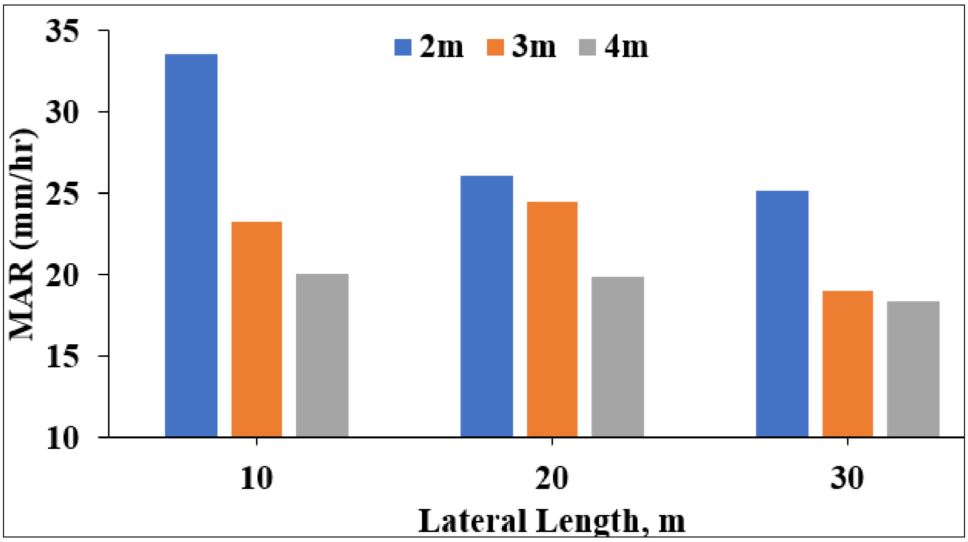

Fig 7: Mean application rate at 1.0 kg/cm^2 operating pressure

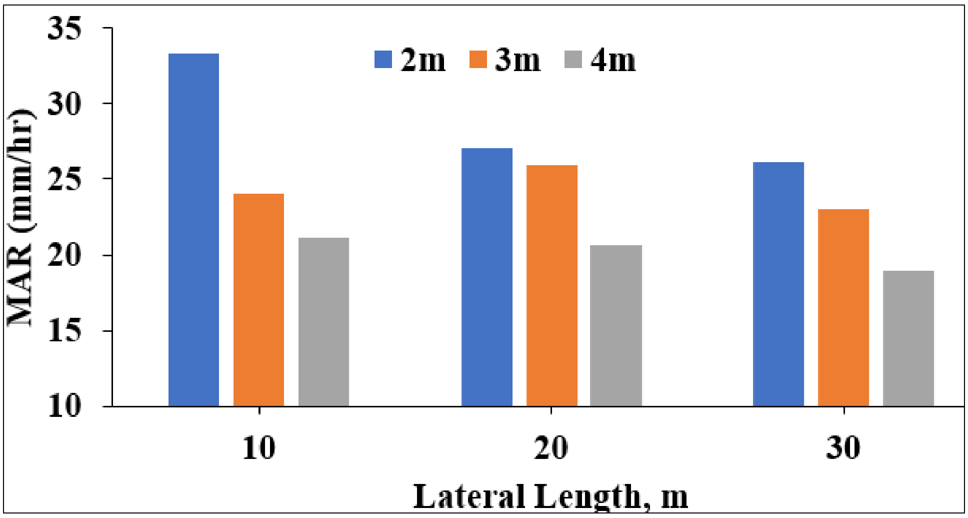

Fig 8: Mean application rate at 1.2 kg/cm^2 operating pressure

5. Coverage area

The coverage width and percent coverage area under different lengths, spacing and operating pressure was recorded and given in Table 3. From Table no 3, it observed that for all operating pressure for 10 m to 30 m length and spacing of 2 m, the coverage width is more than 2 m and percent coverage area was more than 100% . This indicated that there was 10% to 60% more area overlapped for small spacing i.e., for 2 m spacing. For 3 m length the percent coverage area was less by 10 to 20%, but this area covered by water front i.e. (wetting pattern) and

covered nearly 100% coverage area upto 20 m lateral length. If the lateral length more than 20 m. i.e., for 30 m lateral length with 3 m spacing 30% coverage area was less at different operating pressure. This indicated that for 20 m length with 3 m spacing provided maximum coverage area. From Table no. 3, it also observed that for 4 m spacing with different lateral lengths and operating pressure and the coverage width was less by 40 to 60%. This indicated that the spacing of 4 m will not covered entire coverage width for the different spacing and operating pressures. The percentage coverage area is also shown in fig. 9,10 & 11 for different operating pressures and length of laterals.
From these results, it observed that for 20 m lateral length with 3 m spacing covered 90 to 100 percent coverage area at different operating pressures. Similar results were also reported by (Bhadarka et al. 2023, Kathiriya et al. 2021) [2, 8].

Table 3: Coverage width of RPIS, coverage area under different different spacing, different length and operating pressure

Operating pressure, (kg/cm^2)	Length, m	Coverage width, m		
		2 m	3 m	4 m
0.8	10	2.5	2.4	2.1
	20	2.3	2.2	1.8
	30	2.2	2.1	1.6
1.0	10	2.8	2.6	2.3
	20	2.6	2.5	2.2
	30	2.3	2.2	1.7
1.2	10	3.2	2.9	2.5
	20	2.8	2.6	2.3
	30	2.4	2.3	1.8

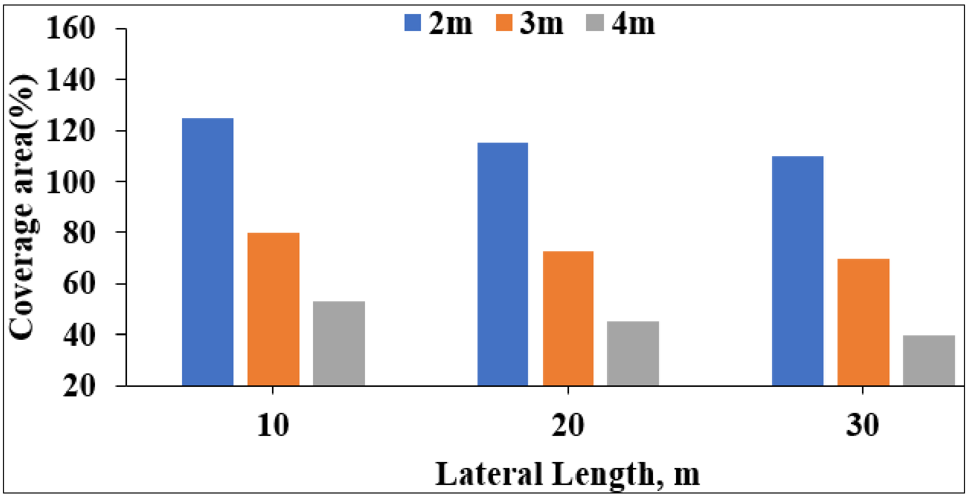

Fig 9: Percent coverage area at 0.8 kg/cm^2 operating pressure

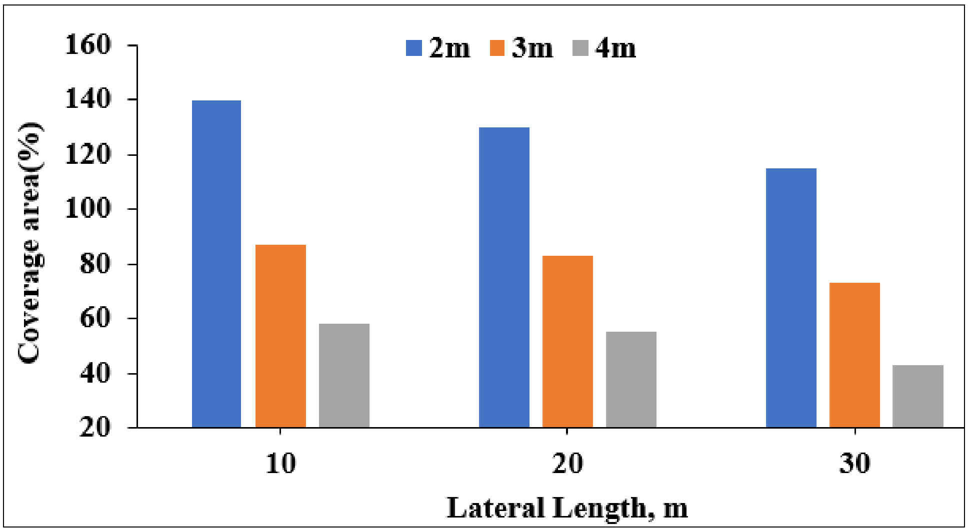

Fig 10: Percent coverage area at 1.0 kg/cm^2 operating pressure

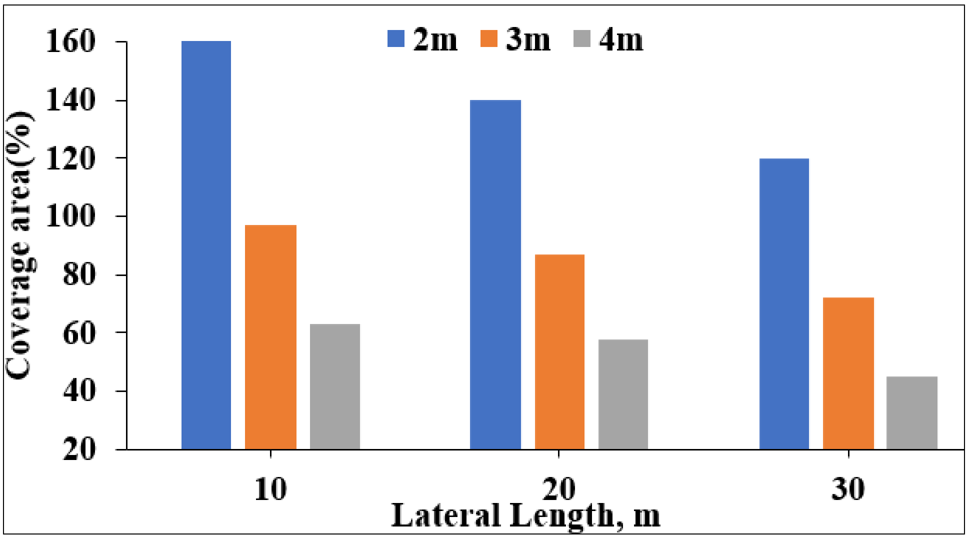

Fig 11: Percent coverage area at 1.2 kg/cm^2 operating pressure

Conclusion

Based upon pressure discharge relationship, uniformity coefficient, distribution uniformity, mean application rate and% coverage area, it observed that rain pipe irrigation system operated at 0.8 kg/cm^2 with 20 m lateral length and 3 m spacing and for 1 kg/cm^2 pressure, 30 m length width 3m spacing found suitable under lateritic soil conditions of Konkan region.

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