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Discharge and pressure relationship of sprinkler in open field

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■ **ABSTRACT :** Irrigation generally is defined as the application of water to the soil for the purpose of supplying moisture essential for plant growth by making favourable environment for plant growth, to reduce the hazards of soil piping and to soften tillage pans. In India, generally traditional flood irrigation methods (basin, border and furrow) are used to irrigate crops, where in the entire soil surface is almost flooded without considering the actual consumptive requirements of the crops. These practices have created the problems of water logging and salinity and reduction in the overall irrigation efficiency hardly upto 30 per cent. An experiment will conduct on the Instructional Farm of Department of Irrigation and Drainage Engineering, K. K. Wagh College of Agricultural Engineering and Technology Nashik. It is revealed that minimum discharge of 39.6l ph was recorded for green sprinkler for operating pressure of 1.0 kg/cm^{2}and maximum discharge of 248.4l ph was recorded for yellow sprinkler for operating pressure of 2.5 kg/cm^2, the radius of throw increases from 1.85 to 2.33 m, 2.50 to 3.37 m and 3.55 to 4.49 m for green, red and yellow sprinklers, respectively. Co-efficient of uniformity is found to be best for green sprinkler at 87.23 per cent and other having 86.57 per cent and 58.52 per cent for yellow and red, respectively.

■ **KEY WORDS :** Irrigation, Mini sprinkler, Discharge, Radius of throw, Co-efficient of uniformity

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Irrigation generally is defined as the application of water to the soil for the purpose of supplying moisture essential for plant growth, for the purpose of crop production, to dilute salts in the soil, to provide crop insurance against short duration drought, to cool the soil and atmosphere by making favourable environment for plant growth, to reduce the hazards of soil piping and to soften tillage pans. Management of water resources at macro level is quite costly and time taking, even though unavoidable. Irrigation efficiency is an essential component of any irrigation system management due to its relationship with the energy and the labour requirements for implementing a sustainable irrigation scheme. According to Huck (2000), any sprinkler irrigation system with distribution uniformity (DU) of 85 per cent, in the field, is excellent and acceptable. The current stress on water resources, escalating energy cost and threat to groundwater resource and the environment, at large, further accentuate the essence of irrigation efficiency (Osei, 2009).

The system's almost continuous operation at low flow rates and operating pressures allow the grower to irrigate with lower-cost, smaller pumps through smaller, light weight pipes which may deliver as little as 15 or 20 m^3/m. The irrigation pumping requirement drops from the 7 to 4 m^3/m per m^2 at 50 to 40 psi typical for sprinklers to 5 to 2 m^3/m per m^2 at 20 to 6 psi for trickle irrigation systems. So 0.06 m^3/m capacity water well solely dedicated to supplying 3 to 4 sprinklers may be used to trickle irrigate 2 to 4 acres of vegetables or small fruits,

with enough extra capacity to meet normal household needs.

Objectives:

– To study on pressure and discharge of mini sprinkler.

– To study on pressure and radius of throw of mini sprinkler.

– To study the uniformity co-efficient and precipitation rate.

METHODOLOGY

This chapter deals with the information on basic resources, material used and techniques adopted during the course of the investigation.

Location:

An experiment will conduct on the Instructional Farm of Department of Irrigation and Drainage Engineering, K. K. Wagh College of Agricultural Engineering and Technology Nasik. The instructional farm is located at a latitude and longitude 16°52'38"N and 74°15'35"E, respectively altitude 700m. The climate is relatively moderate humid in summer with pleasant winter. The mean annual rainfall is 1040 mm in 68 rainy days.

Experimental setup and material and method required:

Experimental setup consisted of pump, main and sub main pipe, filters, risers, sprinkler head, pressure gauge.

Water source:

An open well was used to supply water for operating sprinkler.

Pump:

A horizontal open well centrifugal pump of 5 HP coupled with an electric mono block motor was used for pumping water from the open well.

Mains and sub mains:

Irrigation water was diverted from the well to the field through PVC pipe of 90 mm class II diameter. Separate HDPE quick coupled pipe of 63 mm diameter

Table A : Details of sprinkler nozzles

Code	Nozzle size mm /colour	Emitter exponent (x)	Flow co-efficient (k)
DJMJGN	1.12 / Green	0.51	44
DJMJRD	1.50 / Red	0.40	69
DJMJYL	2.50 / Yellow	0.40	180

Plate A : Different colour of sprinkler nozzles

with control valves were connected to the main pipe for supply to the sprinkler system.

Filter:

All filter arrangements were done on the delivery side of the pump in the field. Screen filters were installed.

Pressure gauge:

Pressure gauges fitted immediately after the filtration unit and also at the sub main pipe were used to check the operating pressure during irrigation. Pressure was adjusted by operating by pass valve. Pressure gauges were calibrated before their use.

Measuring system pressure and pressure variation:

When checking pressure, first adjust any sub-main or internal valves to the pressure shown on the irrigation plan. Do this at the, start of each irrigation season by carefully adjusting each valve several times until steady, correct pressure is achieved. If the system is working properly, the valves will be adjusted so that the average pressure over the whole unit is as close as possible to the design pressure stated on the irrigation plan. None of the sprinklers or emitters should be operating at more than 10 per cent above or 10 per cent below this average pressure.

Checking pressures:

After the internal pressures are set according to the design, measure the operating measure of at least 10 locations spread across each irrigation unit. These must include the points nearest the valve, at the start and ends of laterals and at points of high and low elevation. The technique for doing this depends upon the type of system.

Anemometer:

The wind velocity was measured by using an anemometer.

Mini sprinklers

Specifications:

– Components manufactured out of revolutionary polymers to achieve wear resistance and longertrouble free performance.

– Colour coded nozzle for different flow rates.

– Gentle precipitation no damage to flowers / plants.

– Detachable nozzle and spinner.

– Uniform distribution.

– Wide flow range, 16-180 lph (4.23 - 47.6 gph) at operating pressure of 1kg/cm² (14.22 psi) 3/8"BSP male threaded inlet.

– Minimum filtration requirement - 100 micron.

– Easy to install with different mounting options. For details please refer to poly fittings and accessories section.

Measurement of discharge:

The experiment will be conducted at four different operating pressures of 1 kg/cm^2, 1.5 kg/cm^2, 2.0 kg/cm^2 and 2.5 kg/cm^2. The required operating pressure at the nozzle was adjusted by the valve and bypass arrangement. To measure the discharge from the nozzle at sprinkler position other end was put in the plastic bucket of 20 liter capacity of each bucket. Time taken to fill the bucket was 1 minute noted by stop watch for each combination and the observations were replicated thrice to get accuracy in results. The water collected in the bucket was measured with the help of graduated cylinder as shown in above plate and then converted in discharge per hour.

Measurement of the radius of throw:

The wetted radius of throw for each sprinkler was measured at different pressures ranging from 1.0 to 2.5 kg/cm^2 with an increment of 0.5 kg/cm^2 by gradually increasing the pressure. It was measured directly by the measuring tape shown in Plate B from the centre of the sprinkler head to the end of water throw.

Plate B: Measurement of radius of throw

Pressure – discharge – radius of throw relationship:

The mathematical relationships (linear, logarithmic, power, polynomial and exponential) between pressure – discharge and pressure – radius of throw were developed from observation data on pressure, discharge and radius of throw. The best fit equation was decided on the basis of regression co-efficient (r_2).

Christiansen's co-efficient of uniformity (CU%):

A measurable index of the degree of uniformity obtainable for any size sprinkler operating under given conditions has been adopted and is known as the uniformity co-efficient (CU). The uniformity co-efficient is measured by following formula:

CU% = 100 (1 – px/mn)

where,

CU = Christiansen co-efficient of uniformity (%).

x = Deviation of individual observations from the mean value.

n = Number of observations.

m = Mean value.

■ RESULTS AND DISCUSSION

The field experiments were conducted to study the of three sprinklers models of different discharge sprinkler. The summarized data and results of the present investigation are presented and discussed in this chapter.

Pressure discharge relationship:

The observations of discharge of three different sprinkler models were recorded for different operating pressures ranging from 1.0 to 2.5 kg/cm^2 with an increment of 0.5 kg/cm^2. The average discharges for all types of sprinkler nozzles are reported are given in following Table 1.

From Table 1 it is revealed that minimum discharge of 39.6 lph was recorded for green sprinkler for operating pressure of 1.0 kg/cm^2 and maximum discharge of 248.4 lph was recorded for yellow sprinkler for operating pressure of 2.5 kg/cm^2. With the pressure range, *i.e.* 1.0 – 2.5 kg/cm^2 the discharge of sprinklers were observed in the range of 39.6 to 248.4 lph. The relationship between the operating pressure and discharge under all three sprinkler models were developed. The best fit relationship between the operating pressure head (H) and discharge (Q) of sprinkler was determined in the form of following polynomial equations.

Sprinkler models	Relationship	Regression co-efficient
Green	$Q_1 = 20.98 + 18.87H$	R = 1.002
Red	$Q_2 = 59.11 + 21.77H$	R = 0.986
Yellow	$Q_3 = 130.76 + 47.17H$	R = 1.008

Where, Q = Discharge, H = Operating pressure

Usually the relationship between the operating pressure and discharge is in the form of power relationship (Vermerien and Jobling 1980 and Mandave and Jadhav, 2014). The polynomial relationship was also found to be better in the present investigation with r^2 values of 1.002, 0.986 and 1.008, respectively which may be due to limited range of operating pressure (1.0 to 3.0 kg/cm^2) in the present investigation. However, there was no significant difference between r^2 values of power and polynomial relationship. Among the sprinkler models

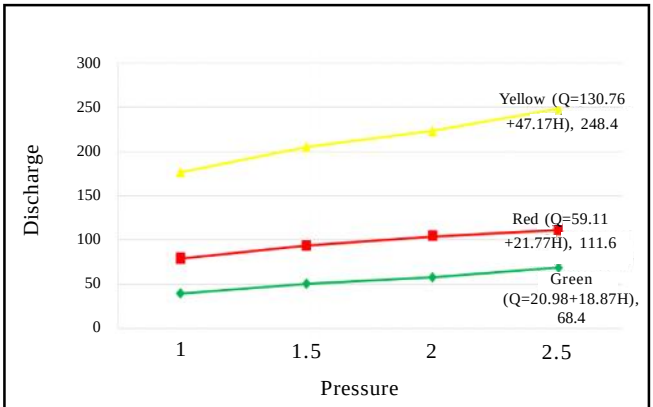

Fig. 1 : Discharge of sprinkler

Table 1 : Discharge of various sprinklers

Sr. No.	Pressure (kg/cm^2)	Discharge (lph.)		
		Green	Red	Yellow
1.	1.0	39.6	79.2	176.4
2.	1.5	50.4	93.6	205.2
3.	2.0	57.6	104.4	223.2
4.	2.5	68.4	111.6	248.4

tested, the yellow produced maximum discharge *i.e.* 2278lph as compared to all sprinkler models and found significantly superior. Further, it is also observed that the discharge of sprinklers increases with an increase in operating pressure.

Pressure – radius of throw relationship:

The observations of the radius of throw of three different sprinkler models were recorded for different operating pressures ranging from 1.0 to 2.5 kg/cm^2 with an increment of 0.5 kg/cm^2. The average radius of throw for all types of sprinkler nozzles is reported in given Table 2. The graphical presentation of pressure to a radius of throw relationship is depicted in Fig. 2. The table gives average values of three observations.

From above it is observed that as the operating pressure increases from 1.0 to 2.5 kg/cm^2, the radius of throw increases from 1.85 to 2.33 m, 2.50 to 3.37 m and 3.55 to 4.49 m for green, red and yellow sprinklers, respectively. From Table 2 it is revealed that the minimum radius of throw of 1.85 m was recorded for green sprinkler for operating pressure of 1.0 kg/cm^2 and a maximum radius of throw of 4.49 m was recorded for yellow sprinkler for operating pressure of 2.5 kg/cm^2. It was

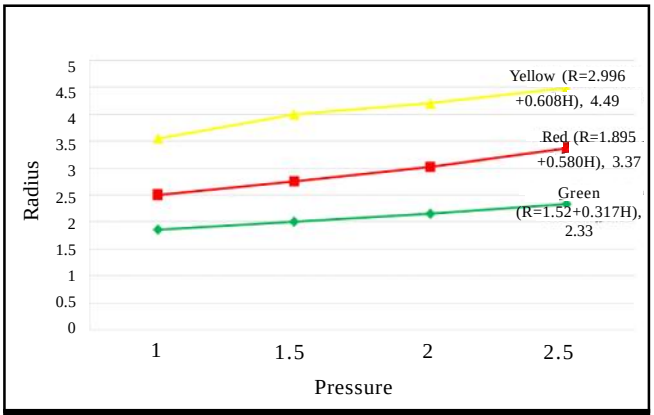

Fig. 2 : Radius of throw of sprinkler

Table 2 : Radius of throw of sprinkler

Sr. No.	Pressure (kg/cm^2)	Radius of throw (m)		
		Green	Red	Yellow
1.	1.0	1.85	2.50	3.55
2.	1.5	2.00	2.75	4.00
3.	2.0	2.15	3.02	4.20
4.	2.5	2.33	3.37	4.49

Table 3 : Water collected in catch can from green sprinkler

S	33	24	S
37	20	26	37
35	27	33	35
S	25	34	S

S = Position of sprinkler

Table 4 : Water collected in catch can from red sprinkler

S	40	42	S
46	38	12	46
44	40	26	44
S	40	42	S

S = position of sprinkler

Table 5 : Water collected in catch can from yellow sprinkler

S	62	54	S
60	40	48	60
68	58	42	68
S	62	54	S

S = Position of sprinkler,

also revealed that the increase in operating pressure increased the radius of throw of all sprinkler models same nozzles. For all types of sprinkler models same nozzles, pressure – radius of throw relationships were established. The best fit relationship between the operating pressure head (H) and radius of throw (R) of sprinkler was determined in the form of following polynomial equations.

Sprinkler models	Relationship	Regression co-efficient
Green	$R_1 = 1.52 + 0.317H$	R = 0.991
Red	$R_2 = 1.895 + 0.580H$	R = 1.0014
Yellow	$R_3 = 2.996 + 0.608H$	R = 0.998

Where, R = Radius of throw, H = Operating pressure

Determination of uniformity co-efficient:

Sprinkler- Green:

Co-efficient of uniformity (Cu) = **(1- 48/376) × 100 = 87.23%**

Sprinkler- Red:

Co-efficient of uniformity (Cu) = **(1-68/460)×100 = 85.52%**

Sprinkler- Yellow:

Co-efficient of uniformity (Cu) = **(1-90/670)×100= 86.57 %**

Summary and conclusion:

This chapter summarizes the present investigation and represents the conclusions of the study.

An experiment was conducted to evaluate performance of three different sprinklers *viz.*, green red, yellow. An experiment was conducted on the Instructional Farm of Department of Irrigation and Drainage Engineering, K.K.Wagh College of Agricultural Engineering. The observations of discharge and radius of throw of Sprinklers of each were taken at different operating pressures ranging from 1 to 2.5 kg/cm^2 with an increment of 0.5 kg/cm^2 to establish pressure, discharge and pressure radius of throw relationship.

The mathematical relationships were developed from observed data on pressure, discharge and radius of throw for three sprinkler models.

The following conclusions can be drawn from the present study.

The discharge obtained at 2.5 kg/cm^2 operating pressure is found to be maximum as 248.4l ph and significantly superior over all other operating pressures. Among the sprinkler tested, the maximum discharge was obtained for yellow sprinkler.

Pressure-discharge relationship for three sprinklers can be very well established by a polynomial equation of the form (Q= a + bH) indicating that discharge increases with an increase in the operating pressure.

The radius of throw obtained at 2.5 kg/cm^2 operating pressure is found to be maximum as 4.49 m and significantly superior over all other operating pressures. Among the sprinkler tested, the maximum radius of throw was obtained for yellow sprinkler.

Pressure-radius of throw relationship for three sprinklers can be very well established by a polynomial equation of the form (R=a + bH) indicating that the radius of throw increases with an increase in the operating pressure.

Co-efficient of uniformity is found to be best for green sprinkler at 87.23 per cent and other having 86.57 per cent and 85.52 per cent for yellow and red, respectively.

Precipitation rate is highest for yellow which is 4.550 mm/hr at operating pressure of 2.0 kg/cm^2 also it is lowest for green which is 3.6830 mm/hr at operating pressure of 1.0 kg/cm^2.

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