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Application Rate of Sprinkler as Influenced by Nozzle Size, Operating Pressure and Nozzle Elevation

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Abstract

Sprinkler irrigation is an advance method of irrigation in which water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. During the field operation of sprinkler irrigation system, sprinkler is associated with some problems like fixation of nozzle size, nozzle elevation and operating pressure to suit the demand of water requirement of crop and other for high water discharge at controlled water application rate and better performance of sprinkler for high yield of crop. The water application rate by sprinklers is limited by the infiltration capacity of the soil. Application with the higher rates than infiltration capacity of the soil results in run-off, with accompanying poor distribution of water, loss of water and soil erosion. Normally, sprinkler irrigation systems are designed such that no runoff occurs. Thus, the rate at which a sprinkler is designed to apply water is less the infiltration capacity of the soil that is the maximum rate at which water can enter the soil at a given time. It is only possible by careful selection of nozzle sizes, operating pressure, nozzle elevation and sprinkler spacing, the amount of water required to refill the crop root zone can be applied nearly uniformly at the rate to suit the infiltration rate of the soil, thereby obtaining efficient irrigation. To obtain a proper solution for above problem, a field test was conducted to study and find out the effect of nozzle size, operating pressure and nozzle elevation on application rate. Application rate from nozzle of sprinkler head was measured with the help of catch can. Application rate was determined at three operating pressures i.e. 2.5, 2.0 and 1.5 kg/cm^2 with three nozzle elevations 150, 110 and 75 cm for 5.6, 4.7 and 3.1 mm nozzle size. It was analyzed from field study that application rate was increased with an increase in nozzle size & operating pressure but decreased with an increase in nozzle elevation.

Key words : Rotary sprinkler, Application rate, Nozzle size, Operating pressure, Nozzle elevation.

The increasing need for crop production for the growing population is causing rapid expansion of irrigation throughout the world. Water being a limited resource, its efficient use is basic to survival of the ever increasing population of the world. This could be possible only by better water management practice in the field and by introducing advance method of irrigation like sprinkler irrigation. Sprinkler irrigation has become quite popular method for irrigating agriculture and horticulture crops in India and world also because of its inherent advantages. The flexibility of sprinkler equipment and its efficient control of water application make this method adaptable to most topographical conditions without excessive land preparations. (1—13). The rate at which sprinkler system irrigates the soil and when a group of them is operating close together is called the application rate. The water application rate by sprinklers is limited by the infiltration capacity of the soil. Application with the higher rates than infiltration capacity of the soil results in run-off, with accompanying poor distribution of water, loss of water and soil erosion. Normally, sprinkler irrigation systems are designed such that the rate at which a sprinkler is designed to apply water is less the infiltration capacity of the soil. The effect of high water application rate than soil infiltration rate or over-watering results runoff from and erosion of soils that tend to seal under sprinkler irrigation continue to be major problems. Excess water application rate may also reduce crop yields below potential levels through mechanisms such as leaching of plant nutrients, increased disease incidence or failure to stimulate growth of the commercially valuable parts of the plant. So, for specific design requirements

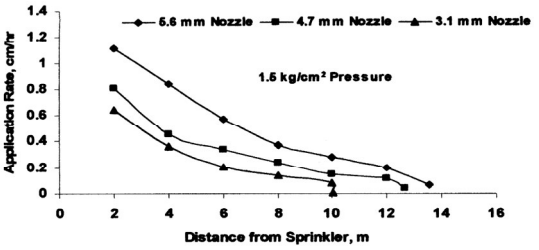

Figure 1. Effect of nozzle size on application rate at 1.5 kg/cm^2 pressure for different nozzle.

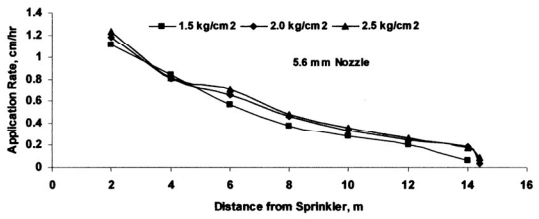

Figure 2. Effect of operating pressure on application rate for 5.6 mm nozzle at different pressure.

of sprinkler irrigation system required the water application rates based on the infiltration for optimum design and efficient operation of sprinkler irrigation system. However, these all processes are associated with the operating characteristics of sprinkler irrigation system but nozzle size, operating pressure and nozzle elevation are three parameters that farmers can change in existing sprinkler system to cope up with field problem caused by high water application rate. With careful selection of nozzle size, nozzle pressure and nozzle elevation, suitable water application rate to be provided will be obtained when in actual field condition. Thus, it is necessary to study the effect of nozzle size, operating pressure and nozzle elevation on water application rate, this may lead for optimum design and efficient operation of irrigation system. As a step to collect the information and to explore these problems, the study was undertaken with specific objectives to obtain the acceptable water application rate.

Methods

The study was conducted in the agricultural field of the instruction farm of College of Technology and Engineering, Udaipur. The variables taken under the study were nozzle size, operating pressure and nozzle elevation. Three-nozzle size of 5.6, 4.7 and 3.1 mm with three nozzle elevations of 150, 110 and 75 cm were tested at three operating pressures i.e. 2.5, 2.0 and 1.5 kg/cm^2. The water application rate was determined using catch can and relation given in equation 1.

*Determination of Application Rate (Ra).*It is an important parameter which express the rate at which sprinkler applies water on the soil surface when a group of them is operating close together and is called the application rate. The required discharge of (an individual) sprinkler to suit the field condition is a function of water application rate and the sprinkler spacing. It was determined using following equation.

$$R_a = \frac{q}{360 \times A} \quad \text{.... 1}$$

Where, Ra = application rate, cm/h, q = rate of dis-

Table 1. Effect of nozzle size on application rate (Ra).

Nozzle size (mm)	Operating pressure (kg/cm^2)	Application rate (cm/h) Radial distance from sprinkler (m) 2	4	6	8	10	12	14
	1.5	1.11	0.84	0.57	0.37	0.27	0.19	
5.6	2.0	1.17	0.80	0.65	0.46	0.33	0.24	0.18
	2.5	1.23	0.81	0.71	0.47	0.35	0.26	0.17
	1.5	0.80	0.45	0.33	0.23	0.14	0.11	
4.7	2.0	0.84	0.49	0.35	0.27	0.18	0.11	
	2.5	0.87	0.52	0.36	0.31	0.21	0.14	
	1.5	0.64	0.35	0.20	0.13	0.08		
3.1	2.0	0.70	0.38	0.22	0.14	0.09		
	2.5	0.73	0.41	0.24	0.16	0.09		

charge of sprinkler, It/sec, A = wetted area of sprinkler, m^2.

Results and Discussion

Effect of Nozzle Size, Pressure and Nozzle Elevation on Application Rate (Ra)

The results of water application rates are shown in Table 1. Table 1 and Figure 1 show that the application rate is increased with an increase in nozzle size. This may be due to the fact that greater nozzle size expected to produce more discharge of water and might have resulted in high application rate. The application rate ranged from 1.11, 0.80 and 0.64 cm/h for 5.6, 4.7 and 3.1 mm nozzle size with 75 cm elevation at 1.5 kg/cm^2 pressure, i.e. an increase of 0.16 cm/h (0.64 to 0.80 cm/h, 24.88%) for 3.1 to 4.7 mm, 0.30 cm/h (0.80 to 1.11 cm/h, 38.23%) for 4.7 to 5.6 mm and 0.46 cm/h (0.64 to 1.11 cm/h, 72.62%) for 3.1 to 5.6 mm nozzle size. Figure 1 shows that application rate is decreased at far distances from the sprinkler with decreasing nozzle size. This may be due to the fact that smaller size drops produced from smaller nozzle size that can travel longer path and fall near to the sprinkler.

Effect of Nozzle Size on Application Rate with Distance from Sprinkler

Table 1 and Figure 1 show that nozzle size had significant effect on application rate near the sprinkler but at farther distance from the sprinkler, the effect of nozzle size was not significant. At 1.5 kg/cm^2 pressure the application rate at 6 m distance from sprinkler ranged from 0.64 cm/h for 3.1 mm nozzle to 1.11 cm/h for 5.6 mm nozzle i.e. an increase of 0.46 cm/h in application rate. But, at 10 m distance from sprinkler, the application rate ranged from 0.14 cm/h for 4.7 mm nozzle to 0.27 cm/h for 5.6 mm nozzle i.e. an increase of 0.13 cm/h in mean droplet diameter. However, overall at given pressure and at given distance from sprinkler, there is decrease in application rate with an increase in nozzle size (Table 1).

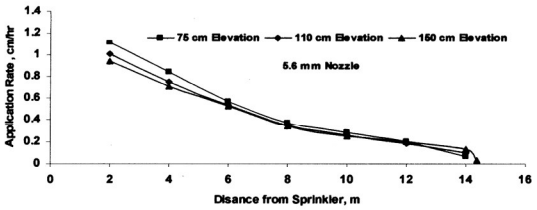

Figure 3. Effect of nozzle elevation on application rate for 5.6 mm nozzle at different nozzle elevation.

The results of effect of pressure on application rate are shown in Table 2 and Figure 1. The application rate is increased with an increase in nozzle size, except application rate of 5.6 mm nozzle at 4 m distance was low than that application rate of 4.7 and 3.1 nozzles at 4 m distance. This may be due to fact that as pressure increases then head and discharge also increases with it that have resulted in more application rate than at lower pressure. The application rate ranged from 1.11 to 1.17 cm/h for 1.5 to 2.0 kg/cm^2, 1.17 to 1.23 cm/h for 2.0 to 2.5 kg/cm^2 and 1.11 to 1.23 cm/h for 1.5 to 2.5 kg/cm^2. The rate of increase of application rate ranged from 0.06 cm/h (1.11 to 1.17 cm/h, 7.09%) for 1.5 to 2.0 kg/cm^2, 0.05 (1.17 to 1.23 cm/h, 4.92%) for 2.0 to 2.5 kg/$cm^2$and 0.126 cm/h (1.11 to 1.23 cm/h, 11.35%) for 1.5 to 2.5 kg/cm^2. Similar

Table 2. Effect of operating pressure on application rate (Ra).

Operating pressure (kg/cm^2)	Nozzle size (mm)	Application rate (cm/h) Radial distance from sprinkler (m) 2	4	6	8	10	12	14
	5.6	1.23	0.81	0.71	0.47	0.35	0.26	0.17
2.5	4.7	0.87	0.52	0.36	0.31	0.21	0.14	
	3.1	0.73	0.41	0.24	0.16	0.09		
	5.6	1.17	0.80	0.65	0.46	0.33	0.24	0.18
2.0	4.7	0.84	0.49	0.35	0.27	0.18	0.11	
	3.1	0.70	0.38	0.22	0.14	0.09		
	5.6	1.11	0.84	0.57	0.37	0.27	0.19	
1.5	4.7	0.80	0.45	0.33	0.23	0.14	0.11	
	3.1	0.64	0.35	0.20	0.13	0.08		

Table 3. Effect of nozzle elevation on application rate (Ra).

Operating pressure (kg/cm^2)	Nozzle elevation (cm)	Application rate (cm/h) Radial distance from sprinkler (m) 2	4	6	8	10	12	14
	75	1.11	0.84	0.57	0.37	0.27	0.19	
1.5	110	1.01	0.74	0.53	0.34	0.25	0.18	
	150	0.94	0.70	0.52	0.33	0.24	0.19	0.13
	75	1.17	0.80	0.65	0.46	0.33	0.24	0.18
2.0	110	1.08	0.70	0.60	0.43	0.31	0.22	0.16
	150	0.92	0.62	0.55	0.41	0.29	0.25	0.15
	75	1.23	0.81	0.71	0.47	0.35	0.26	0.17
2.5	110	1.06	0.72	0.66	0.44	0.33	0.24	0.15
	150	0.91	0.65	0.60	0.40	0.31	0.22	0.14

trend was observed for 4.7 and 3.1 mm nozzle sizes.

Effect of Pressure on Application Rate with Distance from Sprinkler

Table 2 shows that at any distance from the sprinkler for a given nozzle size, there is an increase in application rate with an increase in pressure. It was observed that pressure had a significant effect on the application rate near the sprinkler while at the far distances ; the effect of pressure was not significant. Table 2 and Figure 2 show that for 5.6 mm nozzle size, the application rate at 2 m ranged from 1.23 cm/h at 2.5 kg/cm^2 pressure to 1.11 cm/h at 1.5 kg/cm^2 i.e. a difference of 0.12 cm/h and at 10 m distance application rate ranged from 0.35 cm/h at 2.5 kg/cm^2 to 0.27 cm/h at 1.5 kg/cm^2 i.e. a difference of 0.07 cm/h. Same trend was also found for 4.7 and 3.1 mm nozzle size.

Table 3 shows the results of effects of nozzle elevation on application rate. It is indicated from the Table 3 and Figure 3 show that the application rate decreased with an increase in nozzle elevation. This may be due to the fact that, as the nozzle elevation increases, the friction and head loss also increases which might have resulted into lower application rate of water. The application rate was found to be decreased from 1.11 to 1.01 cm/h for an elevation of 75 to 110 cm, 1.01 to 0.94 cm/h for elevation 110 to 150 cm and 1.11 to 0.94 cm/h for 75 to 150 cm elevation with 5.6 mm nozzle size. The rate of decrease in application rate ranged from 0.03 cm/h (1.11 to 1.01 cm/h, 10.10%) for 75 to 110 cm, 0.06 cm/h (1.01 to 0.94 cm/h, 6.95%) for 110 to 150 cm and 0.16 cm cm/h (1.11 to 0.94 cm/h, 17.77%) for 75 to 150 cm nozzle elevation.

Effect of Nozzle Elevation on Application Rate with Distance from Sprinkler

At any distance from the sprinkler for a given operating pressure, there is a decrease in application rate with an increase in nozzle elevation. Nozzle elevation had significant effect on application rate near the sprinkler and at far distances ; the effect of nozzle elevations was not significant (Table 3, Fig. 3). At 1.5 kg/cm^2 pressure application rate at 4 m ranged from 0.84 cm/h at 75 cm nozzle elevation to 0.70 cm/h at 150 cm nozzle elevation i.e. a difference of 0.13 cm/h and at 10 m distance application rate ranged from 0.27 cm/h at 75 cm nozzle elevation to 0.24 cm/h at 1.50 cm nozzle elevation i.e. a difference of 0.03 cm/h.

Conclusion

Application rate was increased with an increase in nozzle size and pressure but decreased with an increase in nozzle elevation.

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