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Effect of Wind Speed on Distribution Uniformity and Uniformity Coefficient of Sprinkler Irrigation System in Western Haryana

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ABSTRACT

An experiment was conducted to study the effect of wind speed (0-4 km/h, 4-8 km/h and 8-12 km/h) with lateral spacing (6 m × 9 m) on distribution uniformity of sprinkler irrigation system at the field of the village Luhana located in Western Haryana, India, during 2019-20. The basic principle used in this experiment was using the catch-cans to estimate applied water depth over the field under varying wind conditions. The distribution uniformity of the sprinkler irrigation system was determined using a low-pressure portable rotating sprinkler system. The results shows that for spacing 6 m × 9 m was used, the average distribution uniformity was highest (75.42%) at a range of wind speed 0-4 km/h followed by at ranges of wind speed 4-8 km/h and 8-12 km/h, the average distribution uniformity was 75% and 74.16% respectively and similarly the average uniformity coefficient was highest (86.33%) at a range of wind speed 0-4 km/h followed by at ranges of wind speed 4-8 km/h and 8-12 km/h, the average distribution uniformity was 84.04% and 82.05% respectively. At wind speed range 0-4 km/h, variation of uniform water distribution was less prominent. But it was observed that a range of wind speed 8-12 km/h, significant deviation from the uniformity distribution of water was observed.

Keywords Sprinkler irrigation system, Distribution uniformity, Wind speed, Lateral spacing, Water distribution.

INTRODUCTION

Sprinkler irrigation is a technique that involves applying water to crops in a manner that resembles like rainfall. However, uneven distribution of water by sprinklers can potentially decrease crop yields. Therefore, performance evaluation of irrigation system is very important for limited water resources in agriculture (Subramani and Prabakaran 2015). Sprinkler irrigation is an advanced irrigation technique for water saving and fertigation accurately, controlling

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irrigation time and water quantity (Saroch *et al*. 2015). At present, about 22% of the world's total irrigated area (52.6 million ha) is equipped with sprinkler and micro-irrigation methods, 16% (38 million ha) of which uses sprinkler irrigation. In India, about 8% of the total irrigated area (5 million ha) is equipped with sprinkler and micro-irrigation methods, 5% (3 million ha) of which uses sprinkler irrigation (Anonymous 2018). The sprinkler system has higher efficiency than the traditional flood irrigation methods by saving water more than 30% (Hashim *et al*. 2016). In a comparison between fields irrigated using sprinkler and surface irrigation methods, the crop yield and water use efficiency of wheat were found to be higher in the sprinkler-irrigated field (Sharma *et al*. 2018).

A sprinkler irrigation system in a field is composed of several components, such as pipes, couplers and fittings. As water flows through the system, each of these components contributes to head loss. The effectiveness of water distribution, in terms of uniformity, is dependent on the style and characteristics of the sprinkler nozzles. The primary objective of these nozzles is to distribute water evenly, while avoiding surface runoff and excessive drainage from the root zone. Studies have indicated that wind is the primary environmental factor that influences the pattern of sprinkler irrigation systems. For a sprinkler system to be considered acceptable, it must satisfy a minimum uniformity requirement. The uniformity of water dispersion is depends upon the spacing between the nozzles of the sprinkler and overlapping of sprinklers. The uniformity of distribution tends to decrease as the inter-nozzle distance and wind velocity increase. To optimize distribution uniformity, closer nozzle spacing is required under windy conditions. Lateral and sprinkler spacing should be determined based on the various wind velocities and directions and nozzle pressures. In order to increase distribution uniformity under windy conditions, an increase in the degree of overlapping between the sprinklers is necessary. It is generally recommended that irrigation practices be conducted only when wind speeds are below 8 km/h (Mohamed *et al.* 2019).

The objective of the present research is to study the effect of different wind speeds and various sprinkler spacing on the distribution uniformity and uniformity coefficient of a sprinkler irrigation system.

MATERIALS AND METHODS

A field experiment was conducted at Luhana village in district Rewari, Haryana (lat. 28°12'36.39"N, long76°31'27.32"E) and at an elevation of 246 m above mean sea level during June and July 2019. The area broadly forms part of Indo-Gangetic alluvial plain of Yamuna sub-basin. The annual rainfall in this region is 569.6 mm. The ranges of relative humidity include 36–45% in winter and 78–84% in the summer and monsoon seasons. The texture of the soil was sandy-loam. The sprinkler system used was solid set semi-permanent hand-move type.

Water source

The available resource in the area was ground water. The ground water of the district was alkaline in nature. The depth of water level ranges from 6.67 m to 26.31 m during pre-monsoon period 6.79 m to 25.14 m during post-monsoon period. The submersible pump of 15 HP installed in the bore well was being used to lift and supply water to sprinkler irrigation system through a set of mains and sub mains of 6 m long aluminium pipe of 75 mm diameter. The measured discharge in main line was 4.5 l/sec.

Sprinkler nozzle

Sprinkler nozzle distributes water uniformly over the field without runoff or excessive loss due to deep percolation. Different types of sprinklers are available, but the rotating type was used in this experiment. The rotating type can be adapted for a wide range of application rates and spacing. The sprinkler nozzles were connected to risers and covers at an angle of 360º. Nozzle size of sprinkler was 4.5 mm with coverage diameter of 12 m.

Instruments

A digital Anemometer was used for measuring the wind velocity during the experiment. It measures wind speed between 1.4-180 km/h. The pressure gauge was used for measuring the pressure. The discharge of sprinkler was measured with a bucket

Table 1. Treatment details to study the effect of sprinkler spacing and average wind speed on distribution uniformity.

Sl. No.	Treatment	Abbreviation
1	6 m × 9 m sprinkler spacing with the range of 0-4 km/h wind speed	T_1
2	6 m × 9 m sprinkler spacing with the range of 4-8 km/h wind speed	T_2
3	6 m × 9 m sprinkler spacing with the range of 8-12 km/h wind speed	T_3

and stopwatch. The sprinkler was run for 30 min and discharge collected in catch-cans was measured with measuring cylinder. The details of the different treatments are presented in Table 1.

Distribution uniformity (DU)

DU = 100 * (Avg. low quarter depth of application/ Overall avg depth of application)…(1)

Uniformity coefficient (UC)

Christiansen equation (Michael 2010) was used.
UC = 100 * {1-(ΣX/mn)} ... (2)

Where,

m = Average value of all observation (average application rate), mm
n = Total number of observation points
X = Numerical deviation of individual observation from the average application rate, mm

Methodology

The detailed step by step procedure adopted for conducting the experiments is described below:

A proper location was chosen for the layout of the test area. The location was free from obstacles that could block the free distribution of water. There were no obstructions present in the field. The test area where the catch cans were positioned was leveled evenly in a horizontal plane.

The laterals were laid in the test area according to the required spacing. The risers were kept vertical.

The rotating sprinkler heads were mounted on the risers with a diameter compatible with the connecting thread on the sprinkler.

The catch cans were set out on a grid having a spacing of 1 m × 1 m for testing water distribution patterns for 6 m × 9 m spacing.

Water was supplied to the sprinklers through 75 mm aluminium lateral pipes by a 15 HP submersible pump.

All the catch-cans were made empty before starting the test.

The test was started by operating all the sprinklers surrounding the test site at the same time and the starting time was noted.

The wind velocity and direction were noted during the test with the help of Anemometer at an interval of 5 minutes. Ambient temperature was also noted.

The sprinklers were run for duration of 30 minutes.

The discharge of the nozzles was measured by collecting the water into the bucket. The duration of water collected was noted by using a digital stopwatch.

The test was terminated by stopping the sprinklers. The finishing time of the test was noted.

The volume of water collected in the catch-cans was measured carefully by means of a measuring cylinder. The readings were noted.

RESULTS AND DISCUSSION

Distribution uniformity for 0-4 km/h wind speed with spacing 6 m × 9 m (T_1)

The table represents the results of an experiment where the average wind speed, DU (%) and CU (%) were measured for three different trials (Experiment no. 1, 2, and 3) in the NW direction for 0-4 km/h wind speed and lateral spacing of 6 m × 9 m. The minimum and maximum wind speeds were observed as 2.46 km/h and 3.83 km/h respectively, with an average

Table 2. Distribution uniformity and average wind speed in different directions calculated from observing data of treatment T_1.

Experiment no.	Avg wind speed (km/h)	DU(%)	CU(%)
	NW	NW	NW
1	2.46	78.05	87.10
2	2.86	74.79	86.31
3	3.83	73.43	85.59
Average	**3.0**	**75.42**	**86.33**

value of 3.0 km/h. The distribution uniformity varied from 73.43% to 78.05% with an average value of 75.42% in NW direction. The details of the distribution uniformity of water as influenced by the wind speed in the range 0-4 km/h are presented in Table 2.

Distribution uniformity for 4-8 km/h wind speed with spacing 6 m × 9 m (T_2)

The table represents the results of an experiment where the average wind speed, DU (%) and CU (%) were measured for three different trials (Experiment no. 1, 2 and 3) in the NW direction for 4-8 km/h wind speed and lateral spacing of 6 m × 9 m. The minimum and maximum wind speeds were observed as 4.6 km/h and 7.73 km/h respectively, with an average value of 6.47 km/h. The distribution uniformity varied from 73.07% and 77.04% with an average value of 75% in NW direction. The details of the distribution uniformity of water as influenced by the wind speed in the range 4-8 km/h are presented in Table 3.

Distribution uniformity 8-12 km/h wind speed with spacing 6 m × 9 m (T_3)

The table represents the results of an experiment

Table 3. Distribution uniformity and average wind speed in different directions calculated from observing data of treatment T_2..

Experiment no.	Avg wind speed (km/h)	DU (%)	CU(%)
	NW	NW	NW
1	4.67	77.04	84.80
2	6.81	74.88	83.91
3	7.73	73.07	83.41
Average	**6.4**	**75**	**84.04**

Table 4. Distribution uniformity and average wind speed in different directions calculated from observing data of treatments T_3.

Experiment no.	Avg wind speed (km/h)	DU (%)	CU (%)
	NW	NW	NW
1	9.74	75.54	82.91
2	10.93	74.29	81.84
3	11.91	72.67	81.41
Average	**10.8**	**74.16**	**82.05**

where the average wind speed, DU (%) and CU (%) were measured for three different trials (Experiment no. 1, 2 and 3) in the NW direction for 8-12 km/h wind speed and lateral spacing of 6 m × 9 m. The minimum and maximum wind speeds were observed as 9.74 km/h and 11.91 km/h respectively, with an average value of 10.8 km/h. The distribution uniformity varied from 72.67% and 75.54% with an average value of 74.16% in NW direction. The details of the distribution uniformity of water as influenced by the wind speed in the range 8-12 km/h are presented in Table 4. To further support these results, previous research has also reported similar trends regarding the effect of wind on distribution uniformity in sprinkler irrigation systems. Abedinpour (2017) studied that effect of variation of speed produced CU values of 80.3, 82.7 and 86% for S_1, S_2 and S_3 speed, respectively. Furthermore, DU standard value was obtained at S3 speed of 82%. Also Mohamed *et al*. (2019) conduct a experiment which showed that the highest CU% and DU% values of 84% and 78%, respectively, were obtained under the operating pressure of 2.0 bar and riser height of 1.0 m. Higher efficiencies were obtained at low wind speeds, high relative humidity

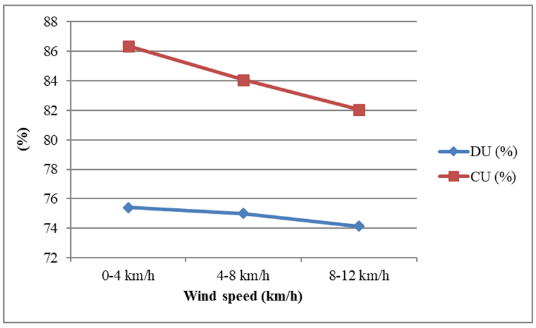

Fig. 1. Effect of wind speed on average distribution uniformity and uniformity coefficient.

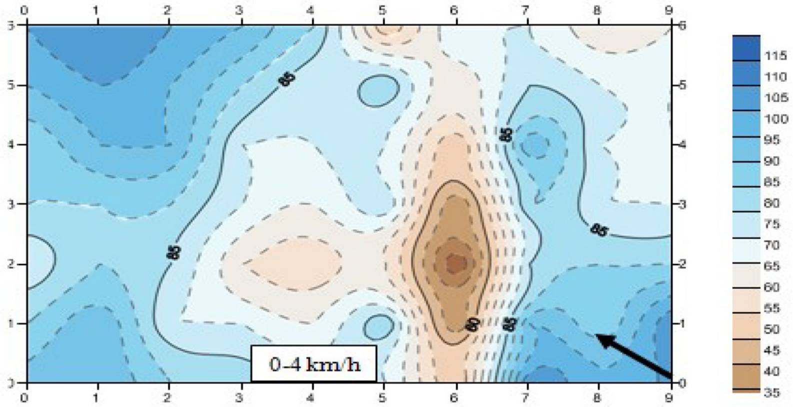

Fig. 2. Effect of wind movement on water distribution at treatment combination T_1.

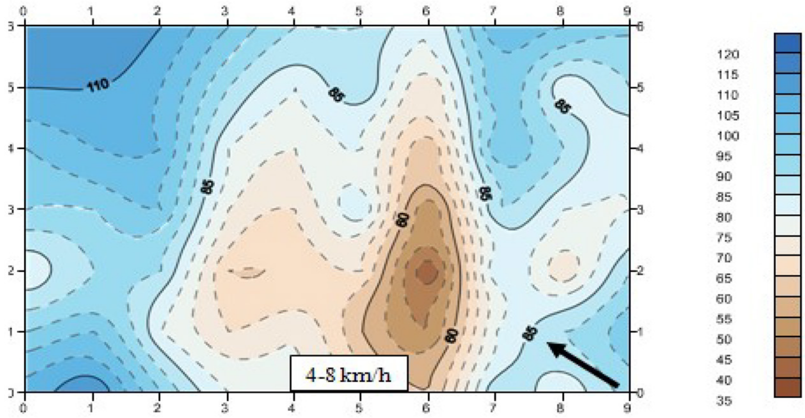

Fig. 3. Effect of wind movement on water distribution at treatment combination T_2.

and low temperatures.

Effect of wind speed on average distribution uniformity and uniformity coefficient

Based on the Fig. 1, it appears that as wind speed increases from 0-4 km/h to 8-12 km/h, both the distribution uniformity and coefficient of uniformity decrease. This means that at higher wind speeds, the water applied to a particular area is distributed less uniformly, and the degree of uniformity is lower. For example, at wind speeds of 0-4 km/h, the distribution uniformity is around 75.42%, whereas at wind speeds of 8-12 km/h, the distribution uniformity is around 74.16%. A similar trend can be observed for the coefficient of uniformity as well.

Effect of different wind speeds on water distribution

On comparing treatment combinations (T_1, T_2 and T_3) under varying wind speeds (0-4 km/h, 4-8 km/h, and 8-12 km/h) with a sprinkler spacing of 6 m × 9 m, it was observed that T_1 provided the best water distribution pattern due to the significant overlap between sprinklers. Wind speed caused minor deflection of the spray towards the middle of the field, likely due to low volume reach at the field's sides and corners, which could be reduced by placing wind breaks in the windward direction. In contrast, T_2 and T_3 showed

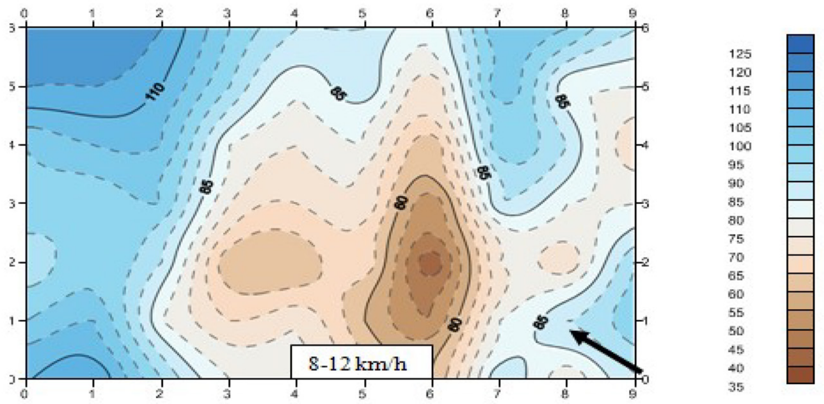

Fig. 4. Effect of wind movement on water distribution at treatment combination T_3.

more deflection in water distribution pattern due to an increase in wind speed and multi-directional access, leading to uneven overlap.

Comparison of Figs. 2-4 revealed that water intensity increased towards the sprinkler in the north-west direction. T_1 showed a higher amount of water collected than the other combinations, with the highest distribution uniformity and coefficient uniformity of 75.42% and 86.33%, respectively, compared to the other treatments.

CONCLUSION

Most imperative conclusions based on the results obtained from the experiment are given in a brief summary:

This suggests that at higher wind speeds, the distribution of particles in the air becomes less uniform, and the distribution uniformity and coefficient of uniformity decreases. This can be due to the turbulent nature of the wind at higher speeds, which causes uneven mixing of particles in the air.

To achieve a distribution uniformity of 75% for sprinkler systems under wind speeds between 4-8 km/h, a spacing of 6 m x 9 m is considered appropriate. Similarly, to maintain a coefficient uniformity of 85% under wind speeds between 0-4 km/h, a spacing of 6 m x 9 m is acceptable.

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