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Wind speed's impact on the distribution uniformity of sprinkler irrigation system in Haryana

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***Abstract*— *This study investigated the impact of varying wind speeds on water distribution uniformity using a 6 m × 6 m lateral spacing configuration with rotating sprinklers at the field of the village Luhana located in Western Haryana, India, during 2019-20. Three replications were conducted under different wind conditions: 0-4 km/h, 4-8 km/h, and 8-12 km/h. For wind speeds ranging from 0 to 4 km/h, observed speeds averaged 3.0 km/h, with distribution uniformity ranging from 79.17% to 86.33% in the northwest direction (average 82.46%). Wind speeds between 4 and 8 km/h yielded an average of 6.4 km/h, with distribution uniformity varying from 81.42% to 84.22% (average 82.88%). At wind speeds of 8-12 km/h (average 10.8 km/h), distribution uniformity ranged from 79.73% to 83.57% (average 81.42%). Variations in the uniform distribution of water were less prominant at wind speeds between 0-4 km/h. 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*— Distribution uniformity, Irrigation, Sprinkler, Sprinkler spacing, Wind speed**

I. INTRODUCTION

The Green Revolution in India, which significantly transformed agricultural productivity post-independence, was largely driven by the development and expansion of irrigation systems. Unirrigated regions in India, barring a few exceptions, did not experience the same agricultural advancements, underscoring the critical role of irrigation [1]. Despite having only 4% of the world's water resources, India supports 17% of the global population, highlighting the country's intense water resource management challenge [2]. Out of the annual 3700 BCM of water resources derived from precipitation, approximately 850 BCM are used for evapotranspiration, and 1850 BCM are lost to runoff [3].

Pressurized irrigation techniques, such as drip, sprinkler, center-pivot, and traveler irrigation systems, offer high water application efficiency [3], [4]. These methods enhance soil health, provide precise irrigation, and mitigate issues related to water scarcity, salinization, labor shortages, and waterlogging. This is particularly crucial in arid and semi-arid regions where best management practices are essential for optimal results [5].The primary objective of sprinkler irrigation systems is to achieve high distribution uniformity (DU). Several factors, including design parameters, environmental conditions and management practices, influence the uniformity of sprinklers [6]. Sprinkler irrigation disperses water in the form of tiny droplets over the irrigated surface using pressurized systems. The goal is to maintain high water uniformity and achieve a good crop yield. The system includes numerous laterals that are easily disassembled and reassembled, making it suitable for irrigating large areas efficiently. Unlike traditional irrigation methods, sprinkler systems minimize water losses due to seepage, evaporation, and evapotranspiration, leading to improved crop productivity.

The design of the sprinkler irrigation system significantly impacts crop yield. An ideal system ensures even water distribution across the entire irrigated area. Enhanced water productivity is achieved when optimal water supplies result in higher crop yields. Conversely, excess water can reduce yields by leaching plant nutrients, increasing disease prevalence, and failing to promote the growth of commercially valuable plant parts. Insufficient water leads to weaker plants and lower crop yields [7].

II. MATERIAL AND METHODS

An experiment was conducted on a low-pressure portable rotating sprinkler system installed in the village of Luhana, located in Western Haryana at 28° 15' 33.84" N latitude and 76° 24' 4.68" E longitude, with an elevation of 246 meters above mean sea level. The field was leveled and free from obstacles to ensure accurate measurement of water distribution. The region experiences an annual rainfall of 569.6 mm. Relative humidity ranges from 36-45% in winter to 78-84% during the summer and monsoon seasons. The sprinkler system utilized was a solid set, semi-permanent hand-move type. The soil texture is sandy loam. Wind speed was measured using an anemometer, and water distribution was collected using catch cans placed uniformly across the irrigated area.

Table 1: Different treatments combinations to study the effect of sprinkler spacing and average wind speed on distribution uniformity

S. No.	Treatment	Abbreviation
1	6 m × 6 m sprinkler spacing with the range of 0-4 km/h wind speed	T1
2	6 m × 6 m sprinkler spacing with the range of 4-8 km/h wind speed	T2
3	6 m × 6 m sprinkler spacing with the range of 8-12 km/h wind speed	T3

The primary water resource in the area was alkaline groundwater, with levels ranging from 6.67 m to 26.31 m during the pre-monsoon period and from 6.79 m to 25.14 m during the post-monsoon period. To lift and supply this water to the sprinkler irrigation system, a 15 HP submersible pump was installed in the bore well. The water was conveyed through a network of mains and sub-mains consisting of 6 m long aluminum pipes with a diameter of 75 mm, achieving a measured discharge of 4.5 l/sec in the main line. The sprinkler system was designed to distribute water uniformly across the field, preventing runoff and significant deep percolation losses.

For this experiment, rotating sprinklers were selected due to their adaptability to a wide range of application rates and spacing configurations. Each sprinkler nozzle, with a size of 4.5 mm and a coverage diameter of 12 m, was connected to risers and positioned to cover a 360º angle. To measure wind velocity during the experiment, a digital anemometer was employed, capable of recording wind speeds from 1.4 to 180 km/h. Additionally, a pressure gauge was used to monitor the system's water pressure. The discharge of the sprinklers was measured using a bucket and stopwatch method. The sprinklers were operated for 30 minutes, and the water collected in catch-cans was measured with a measuring cylinder to determine the discharge rate.

2.1 Distribution Uniformity (DU)

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

2.2 Uniformity Coefficient (UC)

Christiansen equation [8] was used.

$$UC = 100 * \{1-(\Sigma X/mn)\} \quad (2)$$

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

2.3 Methodology

A suitable location was chosen for the test area layout, ensuring it was free from obstacles that could hinder the even distribution of water. The field was clear of obstructions, and the area where catch cans were positioned was leveled evenly in a horizontal plane. The laterals were laid out in the test area according to the required spacing, with the risers kept vertical. Rotating sprinkler heads were mounted on the risers, ensuring compatibility with the connecting thread on the sprinklers.

Catch cans were arranged on a grid with a 1 m × 1 m spacing to test water distribution patterns for different sprinkler spacings (6 m × 6 m, 6 m × 9 m, and 9 m × 12 m). Water was supplied to the sprinklers through 75 mm aluminum lateral pipes by a 15 HP submersible pump. Before starting the test, all catch cans were emptied.

The test commenced by simultaneously operating all the sprinklers surrounding the test site, with the start time recorded. Wind velocity and direction were noted every 5 minutes using an anemometer, along with the ambient temperature. The sprinklers ran for 30 minutes before the test was terminated by stopping the sprinklers, and the end time was noted. The volume of water collected in the catch cans was measured with a measuring cylinder, and the readings were recorded. Additionally, the discharge of the nozzles was measured by collecting water in a bucket, with the duration noted using a digital stopwatch.

III. RESULTS AND DISCUSSION

3.1 Distribution uniformity for range 0-4 km/h wind speed with spacing 6 m × 6 m in different directions (T_1)

Three replications were conducted for lateral spacing of 6 m × 6 m under wind speeds ranging from 0 to 4 km/h. The observed wind speeds ranged from 2.46 km/h to 3.83 km/h, with an average speed of 3.0 km/h. In the northwest direction, distribution uniformity ranged from 79.17% to 86.33%, averaging 82.46%. Table 2 presents detailed data on the distribution uniformity of water influenced by wind speeds within the 0-4 km/h range.

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

Experiment no.	Avg. wind speed (km/h)	DU (%)	CU (%)
1	2.46	86.33	91.79
2	2.86	81.89	90.85
3	3.83	79.17	90.20
Average	**3.0**	**82.46**	**90.94**

3.2 Distribution uniformityfor range 4-8 km/h wind speed with spacing 6 m × 6m in different directions (T_2)

Three replicates were carried out for a lateral spacing of 6 m × 6 m under wind speeds ranging from 4 to 8 km/h. Throughout these trials, wind speeds ranged from a minimum of 4.67 km/h to a maximum of 7.73 km/h, with an average of 6.4 km/h recorded. In the northwest direction, the distribution uniformity of water varied between 81.42% and 84.22%, with an average value of 82.88%. Detailed results depicting the impact of wind speeds within the 4-8 km/h range on water distribution uniformity are provided in Table 3.

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

Experiment no.	Avg. wind speed (km/h)	DU (%)	CU(%)
1	4.67	84.22	89.49
2	6.81	83.02	88.93
3	7.73	81.42	87.88
Average	6.4	82.88	88.76

3.3 Distribution uniformityfor range 8-12 km/h wind speed with spacing 6 m × 6 min different directions (T_3)

Three replicates were performed for a lateral spacing of 6 m × 6 m under wind speeds ranging from 8 to 12 km/h. During the experiments, wind speeds ranged from a minimum of 9.74 km/h to a maximum of 11.91 km/h, averaging 10.8 km/h. In the northwest direction, the distribution uniformity of water varied between 79.73% and 83.57%, with an average of 81.42%. Table 4 provides detailed findings on how wind speeds in the 8-12 km/h range influenced the distribution uniformity of water.

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 (%)
1	9.74	83.57	87.36
2	10.93	80.98	86.94
3	11.91	79.73	86.17
Average	**10.8**	**81.42**	**86.82**

3.4 Effect of different Wind Speed at Spacing 6 m * 6 m on Water Distribution

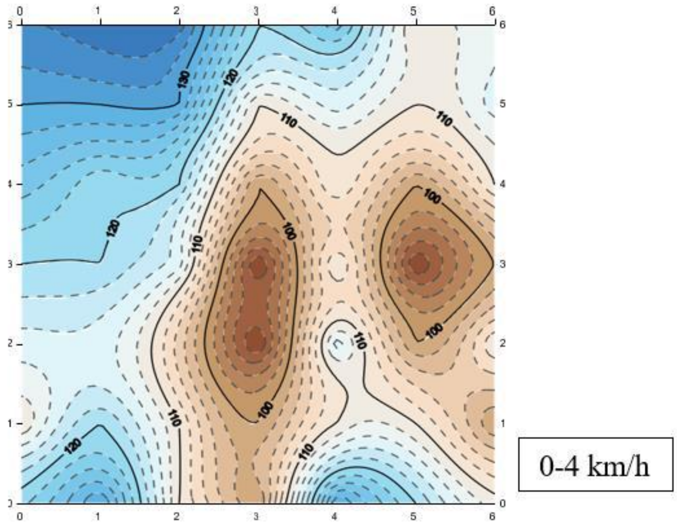

Fig.1: Effect of wind movement *on water distribution at treatment combination T_1*

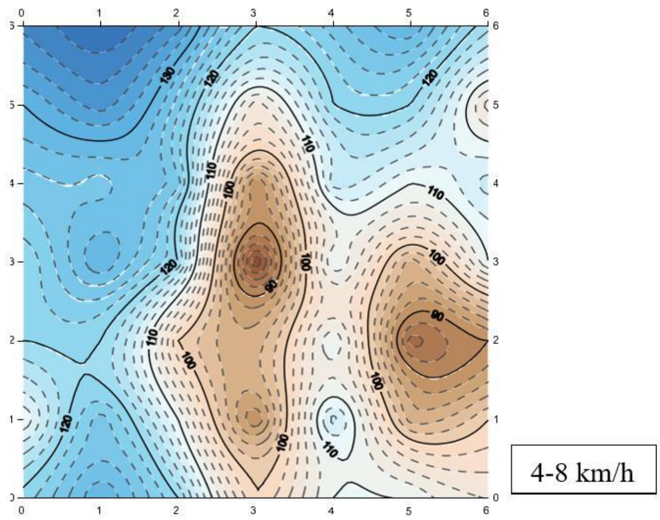

Fig.2: Effect of wind movement on water distribution at treatment combination T_2

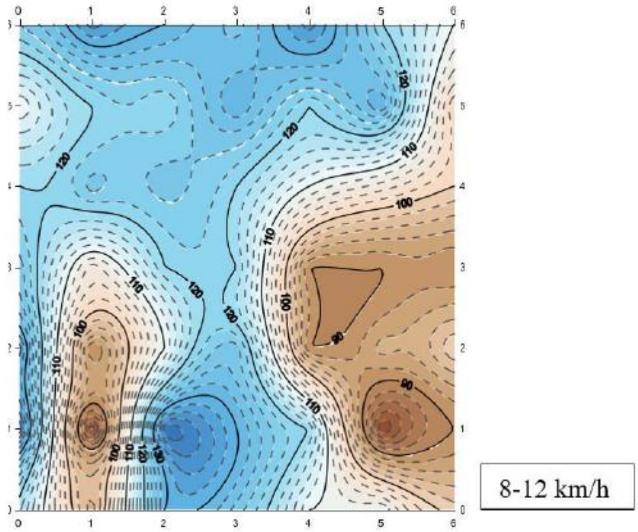

Fig.3: Effect of wind movement on water distribution at treatment combination T_3

Comparing treatment combinations (T_1, T_2, and T_3) across 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 revealed that T_1 exhibited the most effective water distribution pattern. This was attributed to significant overlap between sprinklers, ensuring uniform water coverage. However, higher wind speeds, particularly in T_2, and T_3, caused minor deflection of spray towards the field's center, potentially reducing water reach at the sides and corners. Implementing wind breaks in the windward direction could mitigate this issue.

In contrast, treatments T_2, and T_3demonstrated more pronounced deflection in water distribution patterns as wind speed increased. The multi-directional impact of wind led to uneven water coverage and reduced overlap between sprinklers. These observations underscore the importance of considering wind effects in optimizing sprinkler system performance and uniformity of water application.

3.5 Impact of Wind Speed on Average Distribution Uniformity and Uniformity Coefficient

Based on the findings presented in Fig. 1, it is evident that as wind speed increases from 0-4 km/h to 8-12 km/h, both distribution uniformity and uniformity coefficient decrease. This indicates that higher wind speeds result in less uniform distribution of applied water across the field, leading to lower overall uniformity. For instance, distribution uniformity decreases from approximately 82.46% at wind speeds of 0-4 km/h to about 81.42% at wind speeds of 8-12 km/h. A similar trend is observed for the uniformity coefficient, illustrating a reduced consistency in water application with increasing wind speeds. These results highlight the significant influence of wind speed on the performance of sprinkler irrigation systems. Higher wind speeds disrupt the trajectory of water droplets from sprinkler nozzles, causing them to drift and resulting in uneven water distribution. This can potentially impact crop growth and yield, as certain areas may receive more water than others, leading to water stress or nutrient leaching in some parts of the field.

In conclusion, managing wind effects is crucial for optimizing the efficiency of sprinkler irrigation systems. Strategies such as adjusting sprinkler design, spacing, or operating schedules based on prevailing wind conditions can help mitigate the negative impact of wind on distribution uniformity.

IV. CONCLUSION

As wind speeds increase, the uniformity of airborne particle distribution decreases, resulting in lower distribution uniformity and coefficient of uniformity. This phenomenon is likely due to the turbulent nature of wind at higher velocities, which disrupts the consistent distribution of particles.

For sprinkler systems operating under wind speeds of 8-12 km/h, a spacing of 6 m × 6 m appears suitable to achieve a distribution uniformity of 75%. Similarly, this spacing maintains a coefficient of uniformity of 85%. These findings underscore the importance of considering wind conditions in optimizing sprinkler system performance to ensure uniform water application and effective agricultural irrigation practices. Adjusting sprinkler spacing and other system parameters according to prevailing wind speeds can mitigate the adverse effects of wind turbulence on water distribution uniformity.

REFERENCES

[1] Jhorar, R.K. (2002). Estimation of effective soil hydraulic parameters for water management studies in semi-arid zones: integral use of modelling, remote sensing and parameter estimation. Doctoral Thesis, Wageningen University. The Netherlands.

[2] Dhawan, V. (2017). Water and agriculture in India, *OAV German Asia-Pacific business association.* 1-28.

[3] Bhagyawant, R.G., Digrase, L.N., Jadhav, S.B., Khodke, U.M. &Rautmare, L.V. (2007). Hydraulic studies of raingun irrigation. *Karnataka Journal of Agricultural Science*, **20**(2), 446–447.

[4] Ahaneku, I.E. (2010). Performance evaluation of portable sprinkler irrigation system in Ilorin, Nigeria. *Indian Journal of Science and Technology*, **3**(7), 853–857.

[5] Acar, B., Topak, R. &Direk, M. (2010). Impacts of pressurized irrigation technologies on efficient water resources uses in semi-arid climate of Konya Basin of Turkey. *International Journal of Sustainable Water &*

Environmental Systems, **1**(1), 1–4.

[6] Okasha, E.M. &Pibaras, S.K. (2016). Investigation of riser height and operating pressure on sprinkler irrigation performance under different wind condition. *International Journal of ChemTech Research,* **9**(7), 292-298.

[7] Darko, R.O., Yuan, S., Sam-Amoah, L., Liu, J. &Issaka, Z. (2018). Field evaluation of tomato yield affected by uniformity of sprinkler-applied water. *Acta Scientific Agriculture,* **2**(8), 54-61.

[8] Christiansen, J.E. (1941). The uniformity of application of water by sprinkler systems. *Agricultural Engineering,* **22**(3), 89–92.