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Testing of Different Microsprinklers for Uniformity by Wilcox-Swaile's and Merrium and Keller Criteria

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Abstract

Uniform crop growth and subsequent higher production is possible if moisture is equally distributed, timely, in the vicinity of root zone. Several companies manufacture different components of drip and micro sprinkler systems. Farmers purchase those and install the system through technical experts or sometimes themselves. If the system is designed properly and installed correctly, then, the water application losses can be minimized following the time of operation of systems. However, the variation in water application depth should not be more, less than 10-15% for micro irrigation systems. As such it is essential verify the hydraulics, especially uniformity, of emitting devices whether each plant receive the desired discharge/depth of water. In view of this, different micro sprinklers were evaluated for uniformity by Wilcox Swailes uniformity coefficient and distribution uniformity at different microsprinkler spacing and different operating pressures. The experiment was conducted on five different types of microsprinklers (coded for identification as MS-1, MS-11, MS-111, MS-IV and MS-V) at three operating pressures (1.0, 1.5 and 2.0 kg/cm^2) and for micro sprinkler spacings of 3m × 3m, 4m × 4m, 5m × 5m. 6m × 6m, 7m × 7m, 8m × 8m, 9m × 9m and 10m × 10m. The depth distribution data obtained from the experiment was analysed for Wilcox-Swailes uniformity coefficient (UCC) and Merrium and Keller Distribution Uniformity (DU). The decreased values of Uniformity coefficient and distribution uniformity were observed with increase in spacing of microsprinklers. At the rated pressure (2kg/cm^2), the maximum value of UCC (93.85%) was recorded for MS-V at 3m x 3m microsprinkler spacing with Wilcox-Swailes uniformity coefficient. The value of Hart uniformity confident was also highest (94.29%) at these pressure and spacing. The distribution uniformity recorded at these pressure and spacing for MS-V was 96.75%. More than desired value (70%) of Wilcox-Swailes uniformity coefficient was recorded only for MS-I, MS-III and MS-V for the spacings of 3m x 3m to 6m x 6m. For wider spacing (7m x 7m to 10m x 10m), the uniformity coefficients were less than 70% i.e. less than desired values. Considering the uniformity by Wilcox-Swailes and Merrium and Keller Criteria, MS-V shown superiority over all other microsprinklers.

Keywords: Distribution uniformity; Merrium and Keller; Microsprinkler spacing; Operating pressure; Wilcox-Swailes.

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INTRODUCTION

Optimum use of water is necessary in the field as per crop water requirement. Watering a single plant and its subsequent growth could be enhanced due to availability of soil moisture I the vicinity of root zone. However watering/irrigating thousands/millions of plants in the field through different irrigation systems may cause uneven distribution of irrigation water if system is not design properly. As such uniform distribution of water/moisture for whole crops in the field is of importance in view of better crop growth and higher crop production per hectare. The water distribution efficiency is directly proportional to uniformity of water application and therefore in many designs of pressurized irrigation systems, the uniformity is considered as design criteria. Sprinkler or microsprinkler irrigation uniformity is characterized by uniformity coefficients based on some measure of dispersion or scatter of the precipitation distribution. These coefficients are useful parameters of the irrigation practice and serve as a basis for the selection of sprinkler or microsprinkler systems.

The degree of uniformity obtainable with a sprinkler system depends largely on the water distribution pattern and spacing of the sprinklers (***Keller and Bliesner***, 1990). If the microsprinkler system is operated in low wind condition, during morning or evening hours, the effect of wind velocity and direction on uniformity of water application can be minimized however microsprinkler spacing and operating pressure becomes the devastating factors in affecting the uniformity. Several companies manufacture the emitting devices and diffent components of the micro-irrigation systems. Farmers, due to lack of technical knowledge of the micro-irrigation systems, install the systems in their farms through concerned engineers or staff from related companies. The after sell service or expected guidance may not be given to the farmers by the company staff or engineers. As such farmers might be of opinion that' "micro-irrigation (drip or microsprinkler) is bad !" and may deviate from using the new technology. It may be a hurdle in adopting the, good, water saving technology by the farmers. In this regard it become necessary to test the important components of the irrigation systems before installation. An emitting devices.

The information, on effect of these factors on uniformity coefficient, need to be generated for commercially available makes of microsprinklers. This information will be helpful for engineers for choosing the type of sprinkler and working conditions (operating pressure, sprinkler spacing, etc) in order to achieve high water distribution efficiency (***Tarjuelo*** et al, 1999).

Ravi Kishore et al. (2016) found Coefficient of uniformity of single emitter (CU) varied from 34.87 to 54.75 for the stake height of 0.30m, 38.81 to 58.25 at the stake height of 0.40 m, from 42.26 to 55.44 at the stake $\pi 2 /^5$ height of 0.50 m, from 53.07 to 67.01 at the stake height of 0.60 m and from 46.65 to 68.14 at the stake height of 0.70 m at different pressures. Similar testing of micro sprinklers was conducted at 0.5, 1.0, 1.5 and 2.5 kg/cm^2 pressure and for four heights (20, 35, 50 and 65 cm).

MATERIALS AND METHODS

The experiment was conducted for uniformity evaluation of five different makes of microsprinklers, designated as M-I, M-II, M-III, M-IV and M-V, at different pressures and spacing combinations.

As the concepts, principle of operation and pattern of flow through the microsprinkler are same as that of sprinkler, the testing procedure adapted for sprinkler was used for microsprinkler testing. The guidelines given in American Society of Agricultural Engineers Standard, ***ASAE-S 330.1*** "Procedure for sprinkler distribution testing for research purpose (ASAE, 2003) and Indian Standards: ***BIS (1984)***[2] were used for the study. Experiment was conducted on the concrete floor having slope less than 2 percent. The tests were conducted during early in the morning and late evening hours, as drifting and evaporation losses were the minimum due to lower sunshine and wind velocity. The catch cans were placed in rectangular array at the spacing of 0.5m × 0.5m and the observations on water collected in catch cans during one hour was recorded. The quantity of water collected in catch cans was measured and converted into precipitation rate, mm/h. Keeping in view the recommended operating pressure range for all types of microsprinklers, three operating pressures 1.0, 1.5 and 2.0 kg/cm^2 were selected for studying their effect on various uniformity coefficients. The riser height of 35 cm was kept constant for each observation.

Overlapping patterns and uniformity of water application

The emitting device, either sprinkler or microsprinkler, apply water in circular manner to obtain radial wetted area. Under normal condition each quarter of the circle receive same depth of water. Considering this, the distribution characteristics and uniformity coefficients for one-quarter area were developed utilizing the depth distribution data of a single nozzle and the overlapping patterns of various microsprinklers spacing were obtained. The uniformity coefficients given by Wilcox and ***Swailes*** (1947)[8], andMerriam and ***Keller*** (1978)[4], as detailed below, were computed and compared for each of the overlapping patterns of 3 m × 3 m, 4 m × 4 m, 5 m × 5 m, 6 m × 6 m, 7m × 7m, 8m × 8m, 9m × 9m and 10m × 10m.

Wilcox and Swailes uniformity coefficient

Wilcox and Swailes evaluated the distribution of sprinklers by using sum of squares of the deviations from the mean. Wilcox and Swailes uniformity coefficient (UCW) is defined as:

$$UCW = 100\,(1 - s / \bar{x})$$

Where, s=standard deviation of the observations

$\bar{x}$ = mean of observations

Merriam and Keller distribution uniformity

Merriam and Keller suggested a new parameter as distribution uniformity (DU) similar to USDA pattern efficiency indicates the uniformity of infiltration throughout the field. The following relation gives the distribution uniformity,

RESULTS AND DISCUSSION

$$DU = \frac{Average\ depth\ of\ water\ caught\ in\ lower\ quarter}{Average\ depth\ of\ water} \times 100$$

Wilcox-Swailes uniformity coefficient

The values of Wilcox-Swailes uniformity coefficients

Table 1: Wilcox-Swailes uniformity coefficients for microsprinklers

Pressure (kg/cm^2)	Microsprinkler spacing (m)	Wilcox-Swailes Uniformity Coefficient (Percent)				
		Make of Microsprinkler				
		MS-I	MS-II	MS-III	MS-IV	MS-V
1	3 x 3	89.50	86.10	85.90	82.73	89.75
	4 x 4	83.92	80.87	84.20	55.43	81.24
	5 x 5	74.99	69.09	81.34	15.36	79.58
	6 x 6	70.53	47.06	71.08	0.00	72.43
	7 x 7	60.00	0.00	47.62	0.00	51.22
	8 x 8	42.34	0.00	28.30	0.00	24.89
	9 x 9	23.71	0.00	5.26	0.00	0.34
	10 x 10	0.00	0.00	0.00	0.00	0.00
1.5	3 x 3	90.30	87.99	87.90	89.70	90.64
	4 x 4	84.35	82.18	86.50	77.32	84.07
	5 x 5	79.45	69.62	82.99	41.13	82.64
	6 x 6	74.80	61.20	70.90	4.18	76.70
	7 x 7	63.12	44.51	47.99	0.00	53.41
	8 x 8	48.35	31.26	30.64	0.00	35.50
	9 x 9	25.20	7.42	8.22	0.00	11.29
	10 x 10	0.00	0.00	0.00	0.00	0.00
2	3 x 3	91.60	89.84	93.18	91.04	93.85
	4 x 4	88.65	83.70	89.18	80.00	89.79
	5 x 5	80.24	77.29	83.77	49.05	83.44
	6 x 6	76.20	73.10	75.67	15.36	79.39
	7 x 7	69.50	52.46	54.09	0.00	77.69
	8 x 8	51.78	39.04	35.49	0.00	67.00
	9 x 9	30.35	15.54	13.71	0.00	47.76
	10 x 10	15.80	0.00	0.00	0.00	25.25

are presented in Table 1.

The highest values of Wilcox-Swailes uniformity coefficient were observed for lowest microsprinkler spacing (3m x 3m) at all pressures. The highest value of 93.18% was observed for MS-III at 2.0 kg/ cm^2 pressure and 3m x 3m microsprinkler spacing. Overall performance in respect of Wilcox-Swailes uniformity coefficient was found to be better for MS-I at 1.0 and 1.5 kg/cm^2 pressure and for MS-V at 2.0 kg/cm^2 for all microsprinkler spacing. For MS-IV more than 50% values were recorded only for 3m x 3m and 4m x 4m microsprinkler spacing at all these pressures.

The results revealed that fairly good Wilcox-Swailes uniformity coefficients (88 to 95%) were obtained for all types of microsprinklers at the rated pressure and 3m x 3m microsprinkler spacing. Further, uniformity coefficients were found increased at higher pressures. This happened as more area of coverage of individual microsprinkler resulted in a lesser deviation of water depth, at individual points, from the mean depth.

Distribution uniformity (DU)

Higher values of DU were recorded for all microsprinklers at 2.00kg/cm^2 pressure (Table 4). At this, rated, pressure the DU values were in the range of 0.40 to 91.47, 0 to 96.90, 0.12 to 92.61, 0 to 90.35 and 0.18 to 96.75% for MS-I, MS-II, MS-III, MS-IV and MS-V. The overall DU values were better for MS-I followed by MS-V at all pressures and spacing. It indicates that the water depth received in lower one-quarter wetted area in case of MS-I and MS-II was less deviated from mean as compared to other types of microsprinklers. The sharp reduction in DU value was observed in MS-IV (followed by MS-II) at all wider spacing. In case of MS-III the DU values were sharply reduced from 6 m x 6 m to 10 m x 10 m spacing. The sharp reduction in DU values (due to wider spacing) was recorded in MS-V from 3m x 3m to 7m x 7m microsprinkler spacing.

Table 2: Distribution uniformity for microsprinklers

Pressure (kg/cm^2)	Microsprinkler spacing (m)	Distribution uniformity (percent)				
		Make of microsprinkler				
		MS-I	MS-II	MS-III	MS-IV	MS-V
1	3 x 3	90.13	91.90	88.55	81.10	83.98
	4 x 4	86.24	85.41	87.10	46.90	77.84
	5 x 5	74.23	70.66	86.50	15.80	76.77
	6 x 6	73.80	37.60	55.36	0.00	70.70
	7 x 7	63.97	9.62	41.00	0.00	47.53
	8 x 8	55.07	0.00	27.00	0.00	23.10
	9 x 9	29.16	0.00	13.45	0.00	0.00
	10 x 10	0.13	0.00	0.04	0.00	0.00
1.5	3 x 3	90.56	92.84	90.90	88.98	86.00
	4 x 4	87.84	89.00	88.59	70.10	83.00
	5 x 5	73.20	75.65	87.78	37.09	82.03
	6 x 6	71.00	45.15	56.70	10.65	77.60
	7 x 7	66.81	23.08	42.01	0.00	52.09
	8 x 8	57.50	16.45	34.89	0.00	25.00
	9 x 9	27.60	0.00	17.03	0.00	6.99
	10 x 10	0.23	0.00	0.05	0.00	0.04
2	3 x 3	91.47	96.90	92.61	90.35	96.75
	4 x 4	87.65	90.24	89.84	75.12	88.31
	5 x 5	79.65	78.90	87.11	44.67	78.70
	6 x 6	74.35	69.20	66.31	15.69	73.34
	7 x 7	64.72	61.46	45.54	8.24	71.97
	8 x 8	58.12	44.16	36.87	0.00	66.70
	9 x 9	33.64	17.12	19.33	0.00	42.70
	10 x 10	0.40	0.00	0.12	0.00	0.18

Increased distribution uniformity was recorded for closer microsprinkler spacing. The higer distribution uniformity, similar to uniformity coefficients, was recorded for higher operating pressure. Similar trend of results were obtained by ***Seginer*** (1963)[7], ***Sakore*** (1992) and ***Shinde*** and ***Darde*** (1993).

CONCLUSIONS

- The variation in overall distribution of water in the overlapped area was less affected by pressures however more affected by microsprinkler spacing.
- The uniformity of water application (uniformity coefficient) decreases with increase in microsprinkler spacing and decrease in operating pressure. More deviation of water depth from mean depth was recorded in increased wetted areas and therefore reduced uniformity coefficient was observed in wider spacing.
- A fairly good value of DU (78%) was recorded at all three pressures and at 3m x 3m and 4m x 4m spacing for all the microsprinklers except MS-IV. It indicates that the water depth received in lower one-quarter wetted area of 3m x 3m and 4m x 4m spacing was less deviated from the average depth for all types of microsprinklers except MS-IV.
- Considering the overall uniformity of water application at all pressures and microsprinkler spacing, the performance of MS-V was best compared to other microsprinklers.

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