Uniform Water Distribution From Low Pressure Rotating Sprinklers

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ABSTRACT

Population of India has probably crossed 1150 million marks by the end of 2007 (Survey of Indian Agriculture 2007). The estimated requirement of food grains by 2020 will be 307.75 million tonnes to meet the balanced diet norms prescribed by Indian Council of Medical Research. In 2007, the production of food grains was only 212.62 million tonnes. The gap of 95.13 million tonnes has to be narrowed down by adopting modern scientific approaches for efficient management of scarce land and water resources at a sustainable manner.

Sprinkler irrigation is one of the modern scientific approaches which is becoming more and more popular in India in regions of water scarcity where available water is insufficient to irrigate the command area by surface irrigation. Uniformity of water distribution at four different nozzle pressures and three different spacing was studied for both plastic and brass type of sprinklers. The deviation of uniformity coefficient of plastic sprinklers from that of brass sprinklers was found to be from 0 to 2 %. It was also observed that optimum uniformity of water distribution was obtained at a nozzle pressure of 2.0 kgf/cm^2 in normal windy condition. The uniformity of water distribution decreased with the increase of nozzle pressure beyond 2.0 kgf/cm^2 for small and medium size nozzles.

Comparison was made among different sprinklers and lateral spacing of 6.1 m x 6.1 m, 6.1 m x 12.2 m and 12.2 m x 12.2 m. It was observed that the spacing of 6.1 m x 6.1 m gives better distribution for low pressure sprinklers for all combinations of nozzle pressures and sizes. It was recommended to operate the low pressure sprinklers at a sprinkler and lateral spacing of 30 % of the spray diameter. It was also observed that the effect of wind velocity on uniformity of water distribution was less for wind velocities below 4 km/h and moderate for wind velocity below 7 km/h and the distribution pattern gets distorted at high wind velocity of 15 km/h.

Keywords: Sprinkler, lateral spacing, uniformity coefficient, nozzle pressure, wind velocity, India

1. INTRODUCTION

Population of India has probably crossed 1150 million marks by the end of 2007. The estimated requirement of food grains by 2020 will be 307.75 million tonnes to meet the balanced diet norms prescribed by Indian Council of Medical Research. In 2007, the production of food grains was only 212.62 million tones. The gap of 95.13 million tones has to be narrowed down by adopting modern scientific approaches for efficient management of scarce land and water resources at a sustainable manner.

The average intensity of cultivation can be increased to 200-300 % by introducing micro-irrigation (Sivanappan, 1992). The sprinkler irrigation system is one such micro- irrigation system which consists of conveying water to the field by aluminium or high density polyethylene pipes and distributing it over the field under pressure through a system of nozzles. To create pressure, a booster pump or high speed low discharge pump is necessary.

Since the water is conveyed through pipes, the seepage and evaporation losses which are about 20 % in well irrigated areas and 50 % in canal irrigated areas are eliminated (Sivanappan, 1992). Further the system can be designed to distribute the required depth of water uniformly which is not possible in surface irrigation.

Sprinkler irrigation can be used for almost all crops (except rice) and on most of the soils. The method is particularly suited to sandy soil which has a high infiltration rate. The basic objective of sprinkler irrigation is to simulate rainfall and to apply uniformly a calculated depth of water at a predetermined application rate. The irrigation efficiency of sprinklers will depend upon the degree of uniformity of water application. The uniformity of water distribution can be measured by a statistical parameter known as uniformity coefficient. Over the past six decades, many uniformity coefficients have been proposed to express the degree of uniformity of water distribution of sprinklers. Such uniformity coefficients have been applied in making recommendation for the selection of sprinkler systems. The present research work is primarily concerned with the uniformity of water distribution from the low pressure sprinklers made up of corrosion resistant brass alloy and strong plastic and the factors affecting the distribution.

Taking the above factors into consideration a research work was conducted in the College of Agricultural Engineering and Technology, OUAT, Bhubaneswar, India with the objectives as mentioned below.

i. To compare the performance of plastic sprinklers with that of brass sprinklers
ii. To find out suitable combination of nozzle sizes, nozzle pressures and spacing for the efficient use of the low pressure rotating sprinklers
iii. To find out the effect of wind velocity and direction on the uniformity of water distribution from the low pressure rotating sprinklers

Seginer (1992) developed an automatic apparatus for measuring single radius sprinkler water distribution patterns. Any number of consecutive trials with different operating pressures and riser tilts could be conducted automatically. Water heights in the precipitation gauges were measured sequentially utilizing a single pressure transducer, computer controlled solenoid valves were used to connect gauges to the transducer and to drain the system. Comparisons among results were made on the basis of normalized unit patterns. The normalization considered the effect of riser tilt, since this affects the amount of water collected along the radius. He performed 200 individual trials. These provided an estimate of the measurement of errors. The transducer error was less than 1 per cent of the readings, but variation among replications was an order of larger magnitude.

Li, J. et al (2001) conducted field experiment to observe the spatial variations of water in the soil and to study the response of crop growth and yield to non-uniform water application during the irrigation season of winter wheat in north China. Christiansen uniformity coefficients (CUC) were used in his article to quantify the uniformity of sprinkler water distribution above and below canopy, in soil water content, plant height, leaf area index (LAI), and crop yield. The results demonstrated that CUCs for water storage in the soil were always greater than 90% even though sprinkler uniformities varied from 57% to 89% during the irrigation season. Also, the uniformities of plant height, leaf area index (LAI,) and crop yield were higher than those for water application by conventional system and seem to be insensitive to spatial variation of applied water. The influence of sprinkler uniformity on crop yield was not as important as it was in their previous modeling. A reduced uniformity might not have necessarily resulted in lower yield.

Montero, J. et al (2001) conducted more than 300 tests with different sprinkler nozzle pressures in order to determine the main factors that affect the water application at field level using solid set systems (experimental plots and actual irrigation installations). Radial leg tests have been previously performed to find the water distribution pattern. Afterwards both outdoor single-sprinkler and block irrigation tests have also been performed to know the water distribution pattern distorted by wind action. Results show that the main factors to be controlled are: the radial application rate distribution pattern, the sprinkler spacing, the time of irrigation and the riser height. For a certain sprinkler the radial pattern is determined by working pressure, nozzle and use or not use of the jet-straightening vane (VP) within the main nozzle. The main non-controlled factor is wind speed (W). Results showed that higher Coefficients of Uniformity (CU) were attained with two nozzles than with a single nozzle under low wind speeds. VP must be incorporated for wind speed higher than 2 m/s with the aim of reducing the depletion of uniformity. A single nozzle must be used when the secondary nozzle has an incorrect design and then producing a big proportion of small-size drops.

James Koch (2003) studied on low pressure sprinkler distribution. He conducted research from July to November 2002 on sprinkler distribution of eight separate sprinklers to provide quantitative data with which irrigators can make informed decisions in sprinkler selection. During the research process several trends became apparent. Each sprinkler responds to increased pressure and nozzle size in the same manner. As the pressure and nozzle size increase a greater concentration of water occurs near the sprinkler head and average diameter of the droplets decreases. The pattern also widens because the throw distance increases. In some instances, the increased pressure causes better uniformity, while in others the effectiveness of the sprinkler is minimized.

2. MATERIALS AND METHODS

The experimental set up, data collected and methodology adopted to analyze the data and to carry out the research work were presented.

2.1 Study Area

The Central Farm of Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, Orissa, India was chosen for the test area. The test area is a leveled concrete floor which was free from obstacles that could block the free distribution of water. There were no trees or obstructions in the vicinity. A farm pond is located nearby the test area. Clean and pure water was available in the pond. The test was conducted in early morning hours during 6 am to 7 am so as to avoid evaporation losses. The weather was cool and calm with a wind speed range of 4.2 km/h to 5.7 km/h. The mean relative humidity and mean temperature were 69 per cent and 27.2^0C respectively.

2.2 Types of Sprinkler Heads

The sizes of nozzles tested are 5.56 mm x 3.175 mm, 5.16 mm x 3.175 mm, 4.76 mm x 3.175 mm, 4.37 mm x 2.38 mm and 3.97 mm x 2.38 mm. The bore of the nozzle is circular in shape. These rotating sprinkler heads were randomly selected from a single manufacturer.

2.3 Lateral and Sprinkler Spacing

The test was conducted for different lateral and sprinkler spacing. High density polyethylene (HDPE) pipes of 75 mm diameter. were used for lateral purpose. The length of pipe was 6.1 m. The spacing of the laterals was chosen 30 % and 50 % of spray diameter. The spacing of the sprinklers was also chosen as 30 % and 50 % of spray diameter to obtain uniform distribution of water in the crop field.

2.4 Range of Nozzle Pressures

The sprinklers operating at nozzle pressures ranging from 1.0 kgf/cm^2 to 2.5 kgf/cm^2 were categorized as low pressure sprinklers. The sprinklers heads were tested for low pressures. The four different pressures considered for the test were 1.0 kgf/cm^2, 1.5 kgf/cm^2, 2.0 kgf/cm^2 and 2.5 kgf/cm^2.

2.5 Arrangement of Catch-cans

The catch-cans were located within a sampling area enclosed by four sprinklers. The full field method was adopted for the testing purpose. The catch-cans were placed on a 1 m square grid in the sampling area for 6.1 m x 6.1 m spacing. The catch-cans were placed on a 2 m square grid in the sampling area for 6.1 m x 12.2 m and 12.2 m x 12.2 m spacing. The catch-cans were placed at the intersection point of the two diagonals of the square grid. Each catch-can was assumed to give the representative depth of catch over the square grids having the same dimensions as that of the spacing of catch-can, in which, it was centered.

2.6 Uniformity Coefficients

A measurable index of the degree of uniformity obtainable for any size of sprinkler operating under given conditions has been adopted and is known as the uniformity coefficient. The uniformity coefficient is a statistical measure of degree of uniformity of water distribution. Several researchers have presented a number of uniformity coefficients. Out of them, two of the most widely used Uniformity Coefficients were described here.

Christiansen's uniformity coefficient, UCC is given by J.I. Christiansen (1941)

$$UCC = 100\left[\frac{1 - \Sigma\left(X - \overline{X}\right)}{NX}\right] \qquad (1)$$

Where,

UCC = Christiansen's uniformity coefficient

X = depth of water collected from each catch-can, mm

$\overline{X}$ = arithmetic mean of the depths of water collected, mm

N = number of observations i.e. number of catch cans used in the test

$\Sigma\left(X - \overline{X}\right)$ = sum of absolute deviations from mean, mm

Christiansen's uniformity coefficient of brass sprinkler (UCCB) and Christiansen's uniformity coefficients of plastic sprinkler (UCCP) were computed.

Wilcox and Swailes' uniformity coefficient, UCW is given by J.C. Wilcox and J.E. Swailes (1947)

$$UCW = 100\left[1 - \frac{S}{\overline{X}}\right] \qquad (2)$$

Or UCW = 100[1 - C_v]

Where,

UCW = Wilcox and Swailes' uniformity coefficient, %

S = standard deviation of the depths of water collected from catch cans, mm

$\overline{X}$ = arithmetic mean of the depths of water collected, mm

C_v = coefficient of variation of depths of water collected

3. RESULTS AND DISCUSSION

In this study comparison was made between plastic and brass sprinklers, different nozzle sizes and different spacing. The effect of nozzle pressure and wind velocity on uniformity of water distribution and relationships between sprinkler irrigation pattern parameters were presented here.

3.1 Comparison between Plastic and Brass Sprinklers

The uniformity of water distribution was studied for both plastic and brass type of sprinklers. Various nozzle sizes of both types were tested at different nozzle pressures and spacing. Christiansen's uniformity coefficient (UCC) was computed from the depth of water collected in catch cans during the uniformity test. The average wind velocity, mean ambient temperature and mean relative humidity were recorded during the test as 5 km/h, 30.7^{0}C and 67 %, respectively.

The uniformity coefficients at different spacing and nozzle pressures for different nozzle sizes were found out and presented in Table 1. The deviation of uniformity coefficient of plastic sprinklers from that of brass sprinklers ranges from 0 to 2 %. Though the deviations are very small, but in most of the cases, the uniformity coefficients of brass sprinklers are slightly less than that of plastic sprinklers. The small deviation may be due to some uncontrollable factors like human errors, instrumental errors and abrupt change in wind speed. It is clear from the table that the plastic sprinklers are working as efficiently as the brass sprinklers from the uniformity distribution point of view.

It was also observed that the rotational speed of plastic sprinkler (2.5 revolutions per minute) was nearly double that of brass sprinklers (1.3 revolutions per minute). The relatively high rotational speed of plastic sprinklers was reducing the spray diameter. As the rotational speed of the plastic sprinklers was increased, the surface in contact between the air and the water was also increased. At very rapid rates of rotation the water as leaves the sprinklers does so as individual droplets rather than the solid stream. Hence the air resistance was much greater and the total distance of travel was shortened. The decrease in spray diameter had some adverse effects on the overlap of adjacent sprinkler settings. At the same time, one benefit of an early break up of the stream as it leaves the nozzles, rotating at higher speeds; was more effective distribution at lower nozzle pressures (Table 1). The former was compensated by the later. Thus, it was possible to obtain good distribution patterns later with relatively low nozzle pressures at a sacrifice of small decrease in spray diameter in case of a plastic sprinkler.

3.2 Effect of Nozzle Pressure on Uniformity of Water Distribution

All the sprinklers were tested at four different nozzle pressures. The various nozzle pressures operated were 1.0 kgf/cm^2, 1.5 kgf/cm^2, 2.0 kgf/cm^2 and 2.5 kgf/cm^2. It was observed that the uniformity coefficient is increasing with the increase of nozzle pressure for the combinations (Table 1, Fig. 1 and 2). It was also observed that the uniformity coefficient is increasing rapidly with the increase of pressure upto 2.0 kgf/cm^2. The uniformity coefficient is increasing at a slow rate beyond 2.0 kgf/cm^2 for bigger size nozzles. The uniformity coefficient decreased with the increase in pressure beyond 2.0 kgf/cm^2 for medium and smaller size nozzles. The uniformity of water distribution had dropped rapidly below nozzle pressure of 2.0 kgf/cm^2, because very low nozzle pressure caused more application of water near the sprinkler than at a distance from it for all spacing of laterals and sprinklers. Moreover, at low nozzle pressures only a small area is covered. At a very low nozzle pressure, the jet did not break up easily and most of the water fell at a smaller distance from the sprinkler. Due to this low nozzle pressure, larger water droplets are ejected and these can destroy the soil structure and damage the delicate crops.

Better uniformity of water distribution was obtained at a nozzle pressure of 2.0 kgf/cm^2. A further increase in nozzle pressure beyond 2.0 kgf/cm^2 caused an excessive break up of the jet and in many cases the uniformity coefficient decreased for smaller size nozzles. A nozzle pressure of 2.0 kgf/cm^2 performed as better as the nozzle pressure of 2.5 kgf/sq.cm for bigger size nozzles (Table 1). Operating the sprinkler at a lower nozzle pressure will result in a considerable power saving. It was observed that at higher wind speed and higher nozzle pressure the UCC deviation was more. It is, therefore, recommended to operate the low pressure sprinklers at a nozzle pressure of 2.0 kgf/cm^2 in normal windy condition (Table 2).

The model equations were developed between nozzle pressure and uniformity coefficient with high values of coefficient of determination (R^2) for different sprinkler and lateral spacing with different sprinkler types (Table 3). From this table it was revealed that the uniformity of water distribution in both the cases (brass and plastic sprinklers) were same in respective sprinkler and lateral spacing.

Table 1. Uniformity Coefficients of brass and plastic sprinklers for different nozzle sizes

Nozzle pressure kgf/cm^2	Sprinkler Spacing (S_S x S_L), m: 6.1 x 6.1			6.1 x 12.2			12.2 x 12.2		
	UCCB* %	UCCP** %	Deviation, %	UCCB %	UCCP %	Deviation, %	UCCB %	UCCP %	Deviation, %
Nozzle size 5.56 mm x 3.175 mm									
1.0	73.3	74.6	1.8	65.0	65.1	0.2	45.6	45.7	0.2
1.5	79.7	81.3	2.0	67.2	67.2	0.0	58.0	58.0	0.0
2.0	80.4	80.2	0.2	72.3	72.2	0.1	62.0	62.9	1.5
2.5	84.9	85.1	0.2	75.8	75.9	0.1	68.5	68.7	0.3
Nozzle size 5.16 mm x 3.175 mm									
1.0	71.5	71.7	0.3	69.1	69.5	0.6	54.2	55.0	1.5
1.5	85.0	85.8	0.9	75.5	76.2	0.9	62.0	62.4	0.6
2.0	85.8	86.0	0.2	78.8	78.8	0.0	68.5	69.2	1.0
2.5	85.4	86.0	0.7	79.3	79.4	0.1	70.1	70.4	0.4
Nozzle size 4.76 mm x 3.175 mm									
1.0	80.4	80.5	0.1	70.4	70.3	0.1	67.8	68.1	0.4
1.5	87.0	87.1	0.1	82.0	82.0	0.0	72.3	72.6	0.4
2.0	94.3	93.9	0.4	89.7	89.7	0.0	76.1	75.8	0.4
2.5	93.7	93.3	0.4	91.2	91.4	0.2	79.5	79.5	0.0
Nozzle size 4.37 mm x 2.38 mm									
1.0	76.3	75.8	0.7	72.0	72.1	0.1	62.1	62.2	0.2
1.5	87.2	86.7	0.6	78.2	78.3	0.1	65.3	65.5	0.3
2.0	92.0	92.1	0.1	81.1	80.9	0.2	72.1	72.0	0.1
2.5	90.2	90.1	0.1	80.9	81.0	0.1	72.3	72.2	0.1
Nozzle size 3.97 mm x 2.38 mm									
1.0	68.4	68.1	0.4	67.3	67.3	0.0	50.8	50.7	0.2
1.5	79.3	79.7	0.5	74.2	74.2	0.0	62.1	62.4	0.5
2.0	82.3	82.6	0.4	76.2	76.3	0.1	63.8	63.5	0.5
2.5	81.9	81.9	0.0	82.1	82.2	0.1	65.9	66.2	0.5

*UCCB – Christiansen's uniformity coefficient of brass sprinklers
**UCCP – Christiansen's uniformity coefficient of plastic sprinklers
S_S = Spacing between sprinkler S_L = Spacing between lateral

Table 2. Effect of wind velocity and its direction on uniformity coefficient

Nozzle pressure kgf/cm^2	Sprinkler Spacing (S_S x S_L), m 6.1 x 6.1			6.1 x 12.2			12.2 x 12.2		
	UCC at 4 km/hr %	UCC at 15 km/hr %	Deviation, %	UCC at 4 km/hr %	UCC at 15 km/hr %	Deviation, %	UCC at 4 km/hr %	UCC at 15 km/hr %	Deviation, %
Nozzle size 5.56 mm x 3.175 mm									
1.0	73.3	67.4	8.0	65.0	58.5	10.0	45.6	39.7	12.9
2.5	84.9	76.4	10.0	75.8	67.5	10.9	68.5	58.2	15.0
Nozzle size 4.76 mm x 3.175 mm									
1.0	80.4	72.3	10.1	70.4	62.0	11.9	67.8	57.0	15.9
2.5	93.7	81.5	13.0	91.2	77.5	15.0	79.5	65.2	18.0

Table 3. Model equations depicting relationship between nozzle pressure and uniformity coefficient

Sprinkler Type	Spacing (S_S x S_L)	Coefficient of determination (R^2)	Model equations
Brass	6.1 m x 6.1 m	0.94	y=10.541lnx + 80.475
	6.1 m x 12.2 m	0.98	y=15.682lnx + 70.866
	12.2 m x 12.2 m	0.98	y=8.293lnx + 67.336
Plastic	6.1 m x 6.1 m	0.94	y=10.128lnx + 80.653
	6.1 m x 12.2 m	0.98	y=15.864lnx + 70.746
	12.2 m x 12.2 m	0.995	y=3.74x + 64.65

3.3 Comparison Among Different Spacing

In general, it was observed that the spacing of 6.1 m x 6.1 m gives better distribution for all combinations of nozzle sizes and pressures. The spacing of 12.2 m x 12.2 m gives satisfactory distribution for the nozzle pressure beyond 2.5 kgf/cm^2. Considering the above facts, the following recommendations were made.

For low nozzle pressures, the spacing of sprinklers laterals should be 30 % of the spray diameter in normal windy conditions. The spacing can be increased to 50 % of the spray diameter for nozzle pressures beyond 2.5 kgf/cm^2 in normal windy condition. The spacing between the sprinklers is to be reduced to obtain the higher uniformity coefficient as detailed below.

For low wind speed (upto 6.4 km/hr) the spacing between sprinklers should be ≤ 60% of diameter of normal spray, for medium wind speed (6.4 to 12.8 km/hr) spacing should be ≤ 50% of diameter of normal spray and for high wind speed (above 12.8 km/hr) the spacing should be ≤ 30% of the diameter of normal spray (Shanmugam, 1990)

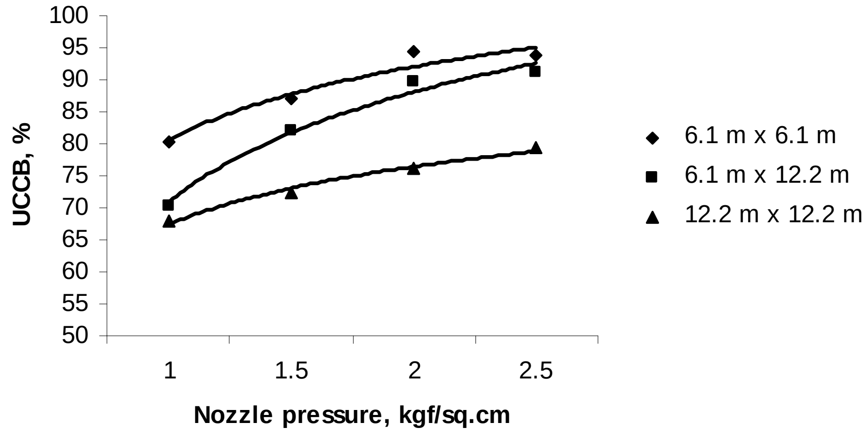

Fig 1. Variation of UCCB with nozzle pressure for different spacing

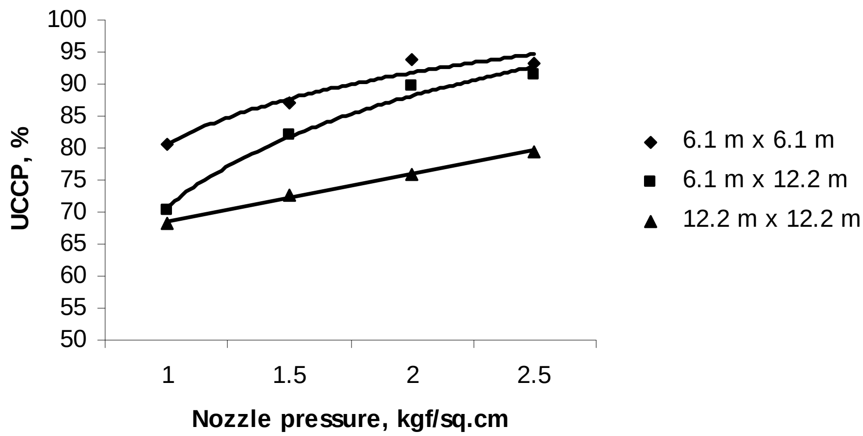

Fig 2. Variation of UCCP with nozzle pressure for different spacing

3.4 Effect of Wind Velocity and Direction on Uniformity of Water Distribution

The brass sprinklers with nozzle sizes 5.56 mm x 3.175 mm and 4.76 mm x 3.175 mm were tested at 6.1 m x 6.1 m, 6.1 m x 12.2 m and 12.2 m x 12.2 m spacing and nozzle pressures of 1.0 kgf/cm^2 and 2.5 kgf/cm^2 in windy condition. The average wind velocity during the test was recorded as 15 km/hr. Christiansen's Uniformity Coefficient was computed. The results were compared with that of observations taken at wind velocity of 4 km/hr. The results were presented in Table 2. It was observed that the distribution of water was uniform for wind velocities below 4 km/hr. But the Uniformity Coefficient decreased with the increase in wind velocity beyond 4 km/hr. However, even at wind velocities below 7 km/h, the uniformity coefficients were more or less satisfactory as it is close to the average wind speed (5 km/h) during the test period. The distribution pattern was distorted at high wind velocity of 15 km/hr. It was observed from the Table 2 that the deviations were increasing with the increase in nozzle pressures for all combinations. The effect of wind velocity was more at higher nozzle pressures than at lower nozzle pressures. At higher nozzle pressures, the droplet sizes were smaller and were easily dragged out in windy condition. Thus, the effect of wind velocity is more at higher nozzle pressures. The lower nozzle pressures are preferable to higher nozzle pressures in windy condition. It is recommended to operate the sprinklers at nozzle pressures below 2.0 kgf/cm^2 in windy condition.

Precipitation contour map at 6.1 m x 6.1 m spacing and wind velocity of 4 km/hour has been presented in Fig. 3. The contour map showed that more water is sprayed towards the windward direction and relatively less water is sprinkled towards the leeward direction. The difference of intensity of application is increased at high wind velocity, result in some under and over watering. It showed that water is more unevenly distributed at high wind velocity than at low wind velocity.

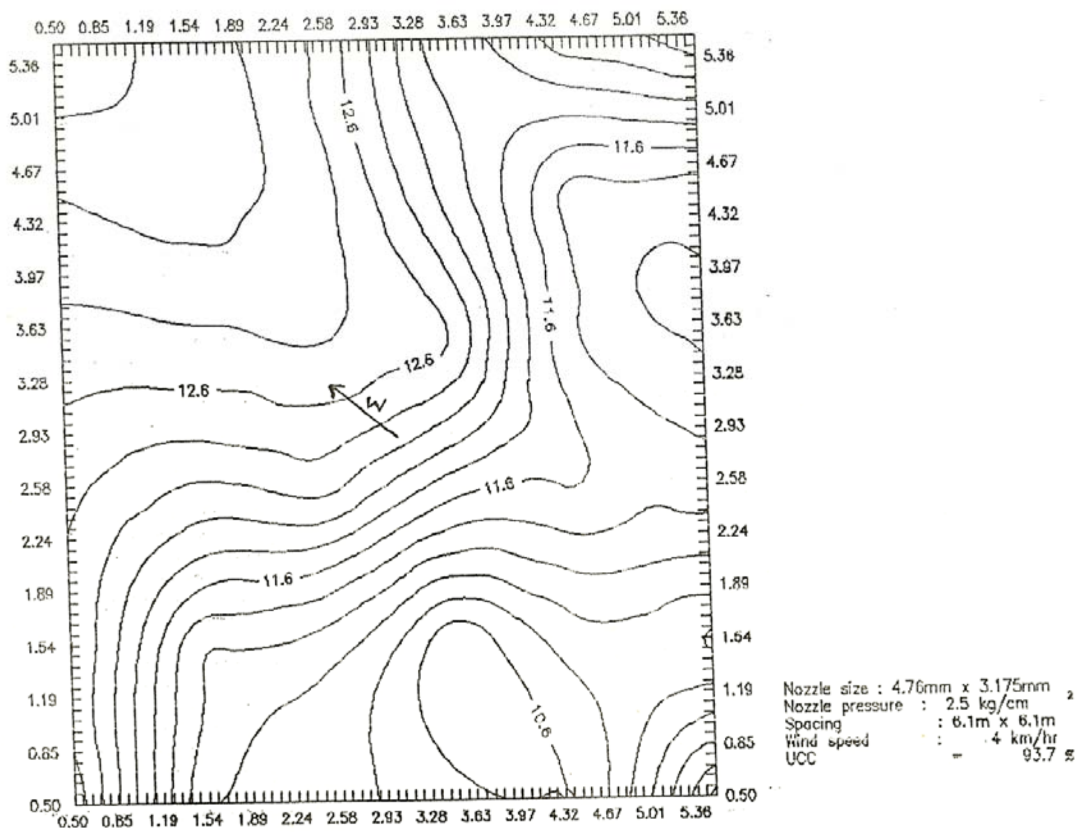

Fig. 3. Precipitation contours at 6.1 m x 6.1 m spacing and wind speed of 4 km/hour

4. CONCLUSION

Based on the results of this study, the following conclusions were drawn:

The uniformity of water distribution at different nozzle pressures and spacing were studied for both plastic and brass type of sprinklers. The deviation of uniformity coefficient of plastic sprinkler from that of brass sprinklers ranges from 0 to 2 %. The deviations may be due to human errors, instrumental errors and abrupt changes in wind speed. It was observed that the plastic sprinklers are working as efficiently as brass sprinkler from the uniformity distribution point of view.

All the sprinklers were tested at four different nozzle pressures of 1.0 kgf/cm^2, 1.5 kgf/cm^2, 2.0 kgf/cm^2 and 2.5 kgf/cm^2. It was observed that optimum uniformity of water distribution was obtained at a nozzle pressure 2.0 kgf/cm^2 in normal windy condition. The uniformity of water distribution was decreasing with the increase in nozzle pressures beyond 2 kgf/cm^2 for small and medium size nozzles. The nozzle pressure of 2.0 kgf/cm^2 performed as good as the nozzle pressure of 2.5 kgf/cm^2 for bigger size nozzles. It is, therefore, recommended to operate the low pressure sprinklers at a pressure of 2.0 kgf/cm^2 in normal windy condition.

Comparisons were made among different sprinkler and lateral spacing of 6.1 m x 6.1 m, 6.1 m x 12.2 m and 12.2 m x 12.2 m. It was observed that the spacing of 6.1 m x 6.1 m gave better distribution of water for low pressure sprinklers for all combinations of nozzle pressures and sizes. It is recommended to operate the low pressure sprinkler at a sprinkler and lateral spacing of 30 % of the spray diameter.

It was observed that the effect of wind velocity on uniformity of water distribution was less for wind velocities below 4 km/hr. The distribution pattern was distorted at high wind velocities of 15 km/hr. The effect of wind was more on medium and smaller size nozzles than that of bigger size nozzles. The effect of wind velocity on uniformity of water distribution was increased with the increase in nozzle pressures and spacing. It is recommended to select relatively bigger size nozzles for operating low pressure sprinklers in windy conditions.

5. ACKNOWLEDGEMENT

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