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Optimal Spacings for Two Common Landscape Irrigation Sprinklers

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ABSTRACT

A simple irrigation system providing sufficient watering needed to make a plant grow is not very difficult. However, to set up a system which provides uniform distribution of water is more difficult. Uniformity coefficients such as Distribution Uniformity and Christiansen coefficient of Uniformity can be used to compare systems and layouts. After measuring the distribution of water from a single sprinkler, a densogram is created with software. The densogram is a numerical and graphical representation of the overlap pattern that the sprinklers create on a given area of surface that is being irrigated. By varying the distance between the sprinklers and also changing the pattern in which they are laid out, the program is able to show which layout is the most efficient. Optimum sprinkler spacings (resulting in the greatest uniformity) for a commonly-used rotary sprinkler were 38 feet for a triangular layout and 31 feet for a square layout. For the square layout, there was little loss of uniformity for spacings up to about 48 feet. For a commonly-used spray sprinkler, optimum spacings were 12 feet for a triangular layout and 15 feet for a square layout.

INTRODUCTION

Many people have the misconception that water sprinkler systems are to be set up so that the radius of ground covered by each sprinkler is to just barely reach the coverage of another sprinkler. However, sprinklers should be designed to be set up so that the overlap of adjacent sprinklers creates the most uniform water application pattern.

As early as about 5000 BC the Egyptians along the Nile River used irrigation systems (Hoffman et al., 1990). Modern systems are becoming more advanced by each passing day. But the goal of all irrigation systems remains the same: apply water uniformly, thereby minimizing both over-watered and under-watered areas. The one-dimensional uniformities of multiple sprinklers using various spacings and layout geometries are able to show how water may be distributed along a single path. This information is not enough to get a thorough understanding of what types of patterns and how the grid of a system and layout of sprinklers will appear. A better understanding can be gained by calculating two-dimensional uniformities based on multiple sprinklers, varying their layout and spacing. By testing all practical combinations of layout and spacing, optimal system designs can be identified. The objective of this study was to
determine the optimum sprinkler spacings for two commonly used landscape irrigation sprinklers.

**MATERIALS AND METHODS**

The two sprinklers used for this experiment were the TORO 800 Rotor and the TORO 570 Spray. These sprinklers are common in landscape irrigation systems. A sprinkler test stand was used for the previous experiment to collect the data. Our sprinkler test stand was a barrel with a small opening that restricted water application to about 15° of the entire horizontal arc of coverage. A water pressure gauge was attached to the hose running from the faucet to the sprinkler inside of the barrel. The water pressure at the sprinkler was maintained at 30 psi by adjusting a gate valve. Water was collected using plastic cones placed in one foot increments. Volume caught in each cone was divided by the test time then converted to calculate the precipitation rate in inches per hour. Two tests of precipitation rate were performed. The results of the two tests were similar and the averages of the two tests are used in this study.

Uniformity of application was calculated using the precipitation rate measurements and the SPACE PRO program (Center for Irrigation Technology, 2000). Using the previously recorded precipitation rate data, Distribution Uniformity (DU) and Christiansen coefficient of Uniformity (CU) percentages are calculated. In order to fully understand the way that the DU and CU are changed according to the distances that the sprinklers are from one another, one must first realize how they are calculated. The DU is calculated as (Rochester, 1995):

\[
DU = 100 \left( \frac{X_{LO}}{X} \right)
\]  

where: \(X_{LO}\) is the average of the lowest 25% of the precipitation rates and \(X\) is the mean of all precipitation rates

The CU is a little more difficult. An advantage to using CU instead of DU is that it will give a more overall average instead of using the lower quarter of findings. The CU is calculated as:

\[
CU = \frac{\sum (X_i - X) \cdot (X - X_i)}{n \cdot (X - X)^2}
\]

where: \(X_i\) is the \(i^{th}\) individual measurement of precipitation rate \(X\) is the mean of all precipitation rates, and \(n\) is the number of measurements
The initial step was to add a new profile record according to the type of sprinkler that is being used, and a graph of the data is then given. After the new profile is saved, a densogram was created and uniformities calculated. The program gives the choice of what type of layout the sprinklers are to be placed in, the water flow, and distance between the sprinklers. For this experiment, both the equilateral triangular and square sprinkler layouts were studied. The only factor that was varied is the distance between the sprinklers. Spacings were varied in 1-foot increments from 11 to 22 feet for the spray sprinkler and from 11 to 55 feet for the rotary sprinkler.

RESULTS: WATER DISTRIBUTION OF A SINGLE SPRINKLER

During the initial experiments of collecting the data along a straight line out from a single sprinkler, water application varied linearly with distance from the 570, a spray sprinkler (Figure 1). A linear equation can be fit to the water distribution from the spray sprinkler: \( PR = 32.5 - 2.5 \times \text{feet from sprinkler} \). This equation can be used in a spreadsheet or other analytical tool to calculate water application at any point within an irrigation system. Calculating overlapping patterns is straightforward for linear water distributions such as the 570 but is more difficult for non-linear distribution. Water distribution from the rotor (800) was not linear (Figure 2). Other software tools such as Space Pro make such analysis more convenient.

![Figure 1. Precipitation rate with distance for the Toro 570.](image-url)
RESULTS: WATER DISTRIBUTION OF SPRINKLER SYSTEMS

The optimal spacing (resulting in the greatest uniformity) for the Toro 800 rotary sprinkler in a triangular layout was 38 (Figure 3). This distance corresponds to the distance of throw of a single sprinkler (Figure 2). The DU and CU were 92% and 95%, respectively, with the sprinklers at this spacing. Experiment results show that when the distance between sprinklers is increased the DU and CU decrease. Likewise, when the distance is decreased between sprinklers, the CU and DU decrease because the center of the area receives excess water and others remain at the small accumulations of precipitation.

Figure 2. Precipitation rate with distance for the Toro 800.
When the Toro 800 Rotor sprinkler is in a square layout (Figure 4), the results vary slightly compared to the triangle layout. In this layout, when the distance between the sprinklers is extended slightly beyond 38 feet, the DU and CU increase slightly. These results are due to that when the distance is 32 feet, the precipitation at the center of the region is rather high even though it brings about the highest DU and CU. Separating the sprinklers helps and it was found that moving the sprinklers 45 feet apart brings the best DU and CU. At a spacing of 45 feet, the DU is 78% and the CU is 86%. Anything beyond that reduces the uniformity. Also different with the square layout compared to the triangle is that when the distance between the sprinklers is decreased, the DU and CU continue to increase because the overlapping of the sprinkler radii results in equal amount of water being fed to each part of the region.

Figure 3. DU and CU of Toro 800 in a triangular layout.
When the Toro 570 Spray is in a triangular layout, the optimal spacing is 13 feet (Figure 5). When the distance between each sprinkler is 13 feet, the DU and CU are 95 and 97%, respectively. Using this layout offers a large amount of room for error in the distances between each sprinkler because from spacings 10 to 20 feet, the uniformity decreases only slightly. However, when the distance is increased or decreased beyond either of these points, the DU and CU decrease in percentages because of gaps and increases in water precipitation created all over the region being watered.

Figure 4. DU and CU of Toro 800 in a square layout.

Figure 5. DU and CU of Toro 570 in a triangular layout.
When using the Toro 570 Spray in the program as a square layout, the most uniform spacing was 15 feet, giving a DU of 92% and a CU of 95% (Figure 6). When the spacing is increased, the DU and CU decrease dramatically (Figure 6). Likewise, when the distance is decreased between each sprinkler, the DU and CU is decreased because there are excess amounts of water near the bases of each sprinkler and gaps in the region surrounding the large amounts in the center.

![Figure 6. DU and CU of Toro 570 in a square layout.](image)

Either of these sprinklers can be used to design an irrigation system that applies water uniformly. The maximum DU and CU values greater than 90% indicate that water is being applied uniformly. When local and installation conditions allow these sprinkler spacings, uniform water application can be achieved.
CONCLUSIONS

When using the Toro 800 Rotor in a square layout, setting the sprinklers 31 feet apart will create the most efficient distribution with a DU of 93%. When in a triangular layout, the optimal distance between the sprinklers is 38 feet apart giving a DU of 92%. The optimal spacing for the Toro 570 Spray in a square layout is 15 feet with a DU of 89%. For the 570 in a triangular layout, the optimal spacing is 12 feet, giving a DU of 95%. The variation of uniformity due to spacing change was small for the triangular layout, resulting in uniform water application at a variety of spacings.

REFERENCES

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