Evaluating the Application Uniformity of a Sprinkler System for Containerized Plants©

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INTRODUCTION

One way to significantly reduce the water volume applied by a fixed-grid of sprinklers to container-grown plants is to make certain the sprinkler system spreads water uniformly across the growing area. When non-uniform water application occurs, the irrigation duration must be increased, sometimes excessively, to ensure that all plants receive the required minimum water volume. However, increasing the duration applies additional water to plants that are already sufficiently wet and increases water and/or pumping costs. If the irrigation duration is not increased, then crop growth patterns in the form of taller and shorter plants usually occur with time.

Plants in containers are particularly affected by non-uniform water application since lateral water movement among containers does not occur. The factors most responsible for non-uniform water application include wind speed, wind direction, water pressure, sprinkler spacing, sprinkler height, nozzle selection, and slope.

Two questions must be asked when evaluating the application uniformity of your sprinkler system:

1) What water distributions occur under your normal operating and environmental conditions?
2) How would you rate the uniformity of each distribution?

By conducting simple water distribution tests under the predominant operating and environmental conditions, the data required to measure and rate the application uniformity of a sprinkler system is obtained. With each test, a grid of cups is placed within a defined test area. After sprinklers operate for a period of time, water volumes are collected and measured. Coefficients calculated using these volumes define the application uniformity. Comparison of these coefficients against a set of standards allows the application uniformity to be rated as very poor, poor, acceptable, or excellent.

SELECTING THE TEST AREA

Within a grid or along a line of evenly-spaced sprinklers having the same nozzles; located at the same height above ground; operating at the same water pressure; located on the same slope; and exposed to the same wind speed and wind direction, a repeating water-distribution pattern will result. It is this distribution pattern that is recorded and analyzed when measuring the application uniformity of a sprinkler system.

Areas containing the repeating water-distribution pattern are test area candidates. Figure 1 shows examples of these areas, which are usually rectangular. The X and Y test area dimensions are defined below for four sprinkler configurations.

1) A grid of full-circle sprinklers with rectangular spacing:
   X = Dimension between sprinklers along lateral lines
   Y = Dimension between laterals

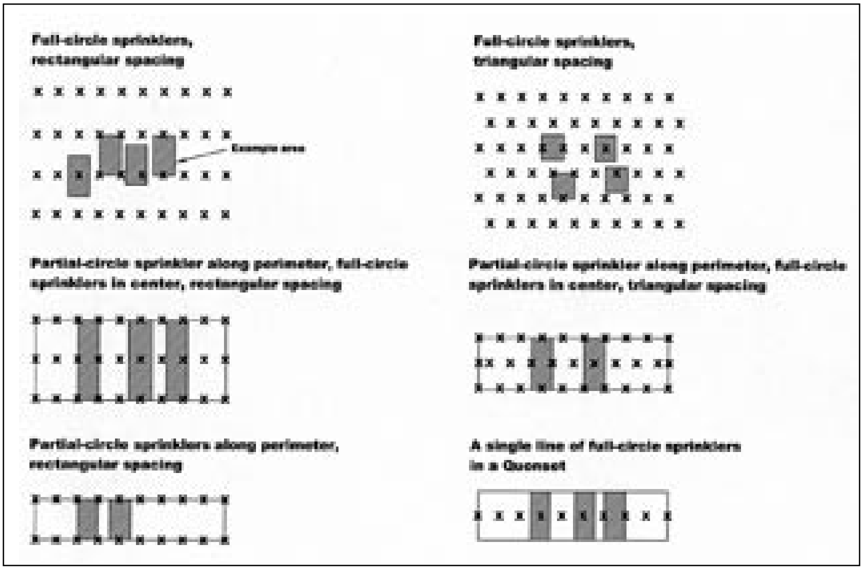

Figure 1. Areas containing a repeating water-distribution pattern.

2) A grid of full-circle sprinklers with triangular spacing:
   X = Dimension between sprinklers along lateral lines
   Y = Dimension between laterals
3) A single line of full-circle sprinklers:
   X = Dimension between sprinklers along the lateral line
   Y = Dimension of the growing-area width
4) Perimeter lines of partial-circle sprinklers:
   X = Dimension between sprinklers along the lateral line
   Y = Dimension of the growing-area width

When testing a sprinkler grid, locate test areas away from grid edges since the water distribution found in these areas rarely represents the distribution found within the grid.

STEPS TO PERFORM A WATER DISTRIBUTION TEST

1) Gather your test equipment:
   - 100 cups—plastic cups work well (3-1/2 in. D × 2-3/4 in. H)
   - Cup weights—metal washers or even gravel
   - Tape measure
   - Some way to mark cup locations when performing multiple tests
   - 100-ml graduated cylinder
   - Pressure gauge and possibly a Pitot tube
   - Watch or clock to record start and stop times
   - Anemometer to measure wind speed
   - Plastic tape or string to indicate wind direction
   - Pencil and paper
   - Any tools and parts to repair, adjust, and clean sprinklers

2) Identify the test area that contains the repeating water-distribution pattern.

3) Define the cup-test grid using a tape measure and a marking system.
   - Strive to use 60 cups, particularly for large areas. Never use less than 30 cups. It is better to have more cups than fewer. Note that 80 cups is the standard for research studies.
   - Place cups in a square test grid as much as possible. See cup spacing examples in Table 1. If plants in growing beds prevent you from using as many cup rows as you would like, then use fewer cup rows and but increase the number of cups in each row.

Table 1. Cup spacing examples.

Sprinkler spacing	Cup spacing	Cups per row	Rows	Total cups
40' × 60'	5' × 5'	12	8	96
40' × 40'	5' × 5'	8	8	64
30' × 30'	3'-9" × 3'-9"	8	8	64
20' × 30'	3'-4" × 3'-4"	9	6	54
20' × 20'	2'-10" × 2'-10"	7	7	49
10' × 20'	2' × 2'	10	5	50
10' × 10'	1'-5" × 1'-5"	7	7	49
4' × 15'	1' × 1'	15	4	60
2' × 3'	4" × 6"	6	6	36

4) Ensure that the system is ready for testing.
   - Each sprinkler must have the correct nozzles.
   - Sprinkler risers must be vertical and of the same height.
   - Barbed mini-sprinklers must be inserted in poly drop-tubes so they are vertical.

5) Install a pressure gauge on one of the sprinkler laterals near the test area. Use of a Pitot tube allows direct pressure readings at the nozzle.

6) Turn on all values for sprinklers that will drop water into the test area under your wind conditions.
   - Observe each sprinkler to ensure that it operates properly. Sprinklers must rotate freely. Nozzles can't be clogged.
   - Determine how many additional sprinklers or laterals must be turned on to achieve the desired test pressure if pressure is not regulated.

7) Turn off all valves and place the collection cups.
   - If wind or sprinkler water streams might knock cups over, weight cups using heavy metal washers or gravel.
   - If testing in growing area aisles, make certain that foliage does not interfere with sprinkler drops reaching the cups. Obstructing plants need to be moved or trimmed.

8) Start your test by turning on all necessary lateral valves.
   - If testing outdoors, the test time-of-day should be the same as that when you normally irrigate so prevailing wind conditions are represented.
   - Record the test start time.

9) Measure the water pressure and wind conditions every 10-15 minutes.
   - Record pressure and compare to your desired test pressure. Adjust as needed.
   - Record the wind speed and direction.

10) Constantly, check that all sprinklers operate properly during the test.

11) Stop the test by turning off lateral valves.
   - Record the test finish time.
   - Quickly move to sprinklers that are immediately adjacent the cup collection area and prevent any low-pressure water from draining into test cups.
   - The test duration is generally the duration you would use for your irrigation set. It is best if the duration is such that the lowest volume cups contain a minimum 30 ml of water.

12) Measure each cup volume using a graduated cylinder.
   - Secure the cup weight with your finger as you pour.
   - Read each cylinder volume at the bottom of the meniscus.

13) Critical information to record
   - Water volumes in rows and columns representing your test grid
   - Type of sprinkler, nozzles, and any unique parts or orientations
   - Sprinkler spacing—note sprinkler locations with respect to data
   - Cup spacing
   - Height from sprinkler nozzle to top of cup
   - Water pressure
   - Wind speed
   - Wind direction
   - Date and time of test
   - Test duration
   - Nursery test location

APPLICATION UNIFORMITY COEFFICIENTS

The irrigation industry has established several coefficients to measure water distribution uniformity. For a set of system, operational, and environmental parameters, the better of two or more irrigation system treatments is often identified when a relative coefficient comparison is made. The system having the higher coefficient (or lower for scheduling coefficient) usually has the higher application uniformity. Four frequently used coefficients are presented here:

Distribution uniformity (DU)

$$DU = \frac{\text{Average of the lowest volume quartile}}{\text{Average volume}} \times 100$$

The lowest volume quartile equals the 25% of cups having the lowest catch volumes.

Application uniformity generally increases as the DU increases to 100%.
With this coefficient, the wettest areas in a distribution are not considered.

Christiansen's coefficient of uniformity (CCU)

$$CCU = \left[1 - \frac{\text{Sum of absolute values of individual deviations from avg vol}}{\text{(\# of cups)(average volume)}}\right] \times 100$$

Application uniformity generally increases as the CCU increases to 100%.
With this coefficient, both the wettest and driest areas in a distribution are considered.

Scheduling coefficient (SC)

$$SC = \frac{\text{Average volume}}{\text{Average of all volumes in the driest area}}$$

The driest area is typically 5% of the total test area. It can also be 2% or 10%.
Application uniformity generally increases as the SC decreases to 1.

Coefficient of uniformity (CU)

$$CU = \left[1 - \frac{\text{Standard deviation of all volumes}}{\text{Average volume}}\right] \times 100$$

This coefficient is not used as frequently as those listed above.
Application uniformity generally increases as the CU increases to 100%.
With this coefficient, both the wettest and driest areas in a distribution are considered.

SEVERAL TESTS ARE REQUIRED

Validation of test results with those from a second or third test builds confidence in the data gathered under field conditions. In addition, several tests are often required because multiple factors work separately or in combination at different times of the day to affect how sprinklers spread water. For example, a prevailing lower wind speed in the morning results in one distribution pattern while a prevailing higher wind speed and wind direction change in the afternoon results in a different distribution pattern. Since irrigation must occur at both times, two water distributions characterize the system. Therefore, sprinkler system coverage is more completely characterized by several water distributions, each representative of a particular set of operational and environmental conditions under which the sprinklers are run. To define this character, tests must be conducted for the predominant sets of conditions.

APPLICATION UNIFORMITY RATINGS

The following application uniformity ratings (Table 2) were derived in 1999 in an attempt to answer the question "What do these coefficients mean?" Base rating data were provided by six irrigation system designers or researchers who have used uniformity coefficients to rate irrigation systems in the field. Values defining each coefficient range were averaged after removing the highest and lowest values.

If your application uniformity has a poor rating, then you are highly likely to see different plant growth patterns when you work diligently to minimize irrigation durations and save water. If your poor uniformity rating is confirmed by subsequent tests and you are serious about reducing water use, then you should consider making changes to your sprinkler system and/or the way you operate it.

Table 2. Application uniformity ratings.

	Very poor	Poor	Acceptable	Excellent
Distribution uniformity	< 74%	74-78%	79-86%	> 86%
Christiansen's coefficient of uniformity	< 78%	78-82%	83-91%	> 91%
Scheduling coefficient--5% window	> 1.57	1.57-1.33	1.32-1.20	< 1.20

Rating Sources: Richard Besan, University of Florida, April 14, 1998; Mark Burgess, Rain Bird, April 13, 1998; Mike Davidson, Amiad, January 29, 1998; Roger Lah, Rain Bird, January 30, 1998; Johan Oostenbrink, Netafim, April 29, 1999; Mike Saliwanchik, Senninger, April 21, 1998

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