Department of Plant Sciences

IRRIGATION CALCULATIONS I: DISTRIBUTION UNIFORMITY, APPLICATION RATE AND RUN TIME OF CONTAINER GROWN CROPS

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Lauren Fessler, Extension Assistant, Department of Plant Sciences
Amy Fulcher, Professor, Department of Plant Sciences

Water scarcity is a growing concern worldwide. Therefore, it is important for nursery producers to continue their efforts to increase irrigation efficiency. To do this, growers need to assess their current irrigation applications, which will allow them to identify areas for improvement. This series covers calculations that nursery producers can use to quantify irrigation applications.

Overhead irrigation using wobbler emitters.

Distribution Uniformity

Distribution uniformity (DU) measures an irrigation system's ability to deliver water uniformly throughout the irrigation zone.

Why is DU Important?

Poor DU wastes water, decreases application efficiency and decreases crop uniformity. Plants in areas that receive too little water may grow slower than the rest of the crop and may not finish by the end of the intended production schedule. To avoid this issue, growers often increase their irrigation run time to ensure that even the driest parts of the zone receive adequate irrigation. This leads to over-irrigation in the wetter parts of the zone, which can increase disease pressure (e.g., root rot) and can leach nutrients and pesticides. A uniform application is an important first step to improving water use efficiency.

A DU of less than 60 percent indicates a serious problem with either system infrastructure or design. A DU between 60 percent and 80 percent shows an opportunity for improvement and may mean that run time is longer than necessary. A DU greater than 80 percent is desirable.

Application Rate

Application rate is a measure of the amount of water applied by an irrigation system over a given time period.

Why is Application Rate Important?

Calculating irrigation application rate is important for determining if plants are receiving the intended amount of water during each application event. Knowing the water requirements of the crop and the application rate allows producers to determine the optimal irrigation run time.

Calculating DU and Application Rate

To assess the inherent characteristics of your irrigation system, measure when there is little to no wind, less than 5 mph (about 8 kph), and preferably less than 3 mph (about 5 kph). Capturing the influence of wind can be valuable, but the greater the wind, the more it will influence DU and the more difficult it will be to determine your system's inherent uniformity. It is safe to assume that with greater wind, your DU will decrease. Additionally, in order to replicate the water pressure during a regular irrigation event, conduct the test with the same zones running as normally would be and record the pressure.

Tip 1:

A pressure gauge with pitot tube is a simple and inexpensive method to check water pressure.

To calculate DU and application rate, a grid of identical catch cans is required. The University of Florida recommends at least 20 catch cans per 1000 square feet. Using a multiple of 4 is necessary for calculations. Ideally DU is measured when the plot is empty. If plants are present, place catch cans just above the plant canopy. For micro-irrigation systems, emitters should be placed directly into catch cans without raising or lowering the spaghetti tubing from its normal position when watering the crop plant, although pressure compensating emitters will help prevent changes in flow rate due to height changes.

After placing catch cans, run a typical irrigation cycle and record the amount of water in each catch can. Map and record where each volume occurred to help when later correcting areas with abnormally high and low volumes. If using straight-sided catch cans, depth of irrigation can be directly measured. If using catch cans that are not straight-sided, then extra steps are needed to determine application rate.

Calculations with Straight-Sided Catch Cans

1. Place catch cans in a grid pattern throughout the zone.
2. Run a typical irrigation cycle.
3. Record the duration of the irrigation event, water pressure, wind speed and direction.
4. Measure and record the level of water in each catch can using a ruler.
5. Calculate the average depth of water from all catch cans.
6. Calculate the average depth of the lowest 25 percent of catch cans.
7. To calculate DU, divide the average of the lowest 25 percent (step 6) by the overall average (step 5) then multiply by 100.
8. Divide the average depth of irrigation (step 5) by the run time (step 3) to get the depth of irrigation per minute.
9. Multiply the depth of irrigation per minute by 60 to get the application rate per hour.

Tip 2:

A tape measure can be an easy, readily available tool for measuring depth.

Calculations with Catch Cans that are Not Straight-Sided[a]

1. Place catch cans in a grid pattern throughout the zone.
2. Record the inner diameter of the top of the catch can.
3. Run a typical irrigation cycle.

4. Record the duration of the irrigation event, water pressure, wind speed and direction.
5. Measure and record the volume of water in each catch can using a graduated cylinder or a scale – see Tip 3.
6. Calculate the average volume of water from all catch cans.
7. Calculate the average volume of the lowest 25 percent of catch cans.
8. To calculate DU, divide the average of the lowest 25 percent (step 7) by the overall average (step 6) then multiply by 100.
9. Find the area of the catch can.
    a. First divide the diameter (step 2) by 2 to find the radius.
    b. Then square the radius and multiply by pi (3.14159).
10. Divide the average volume (step 6) by the area of the top of the catch can (step 9) to get the depth of irrigation.
11. Divide the average depth of irrigation (step 10) by the run time (step 4) to get the depth of irrigation per minute.
12. Multiply the depth of irrigation per minute by 60 to get the application rate per hour.

[a]Top diameter ≠ bottom diameter. Many buckets are not straight-sided.

Tip 3:

Because 1 mL = 1g = $1cm^3$, weight is a faster option to obtain irrigation application volume. If catch cans of the exact same weight are used, tare the scale for one empty bucket. Then each bucket can be weighed, eliminating the need to pour each catch can's sample. Pouring into a graduated cylinder is slower than weighing and introduces a greater possibility of spilling. If you must pour, use a funnel.

Example

A grid of 20 non-straight-sided catch cans (each with a top diameter of 10 cm) is laid out throughout the irrigation zone. The irrigation runs for 20 minutes. The max wind speed recorded during irrigation was 1 mph (1.6 kph). Cans collected 73mL, 71mL, 68mL, 67mL, 66mL, 65mL, 64mL, 63mL, 62mL, 61mL, 60mL, 59mL, 58mL, 57mL, 56mL, **52mL**, **51mL**, **50mL**, **49mL**, and **48mL**. Lowest volumes are **bold**.

To calculate the DU, first find the average volume collected:

$$\frac{\left(\begin{matrix}73mL+71mL+68mL+67mL+66mL+65mL+64mL+63mL+62mL+61mL+\\60mL+59mL+58mL+57mL+56mL+52mL+51mL+50mL+49mL+48mL\end{matrix}\right)}{20}$$

$$=\frac{1200mL}{20}=60mL$$

Next find the average volume collected for the lowest 25 percent:

$$\frac{(52mL+51mL+50mL+49mL+48mL)}{5}=$$

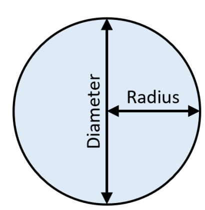
$$\frac{250mL}{5}=50mL$$

Divide the average of the lowest 25 percent by the overall average and multiply by 100 to find DU:

$$\frac{50mL}{60mL}\times 100\% = 0.83\times 100\% = 83\%$$

To find the application rate, first find the area of the top of the catch can:

$$A = \pi r^2$$



$$A = 3.14159 \times (\frac{diameter}{2})^2$$

$$A = 3.14159 \times (\frac{10\ cm}{2})^2$$

$$A = 3.14159 \times (5cm)^2$$

$$A = 3.14159 \times 25cm^2$$

$$A = 78.5cm^2$$

Next divide the average volume by the area to get the average depth (note: 1mL = 1cm^3):

$$\frac{60cm^3}{78.5cm^2} = 0.76cm$$

Next divide the average depth by the irrigation run time:

$$\frac{0.76cm}{20\ minutes} = 0.038cm/minute$$

Next multiply the depth per minute by 60 to get the depth per hour:

$$\frac{0.038cm}{1\ minute} \times \frac{60\ minutes}{1\ hour} = 2.3cm/hour$$

To convert from cm to inches, divide by 2.54:

$$\frac{2.3cm}{1\ hour} \times \frac{1\ inch}{2.54cm} = 0.9\ inches/hour$$

In this example, a desirable DU (greater than 80 percent) was found which means that irrigation is being applied reasonably evenly throughout the zone; however, there may still be an opportunity to improve uniformity and ultimately reduce water use.

Application Run Time

The application rate in this example was 0.9 inches per hour. To find the optimal run time for this area, you'll need to also know the water requirements for the plants in this area.

If they need 0.45 inch of water per day, then they'll need a total of 0.5 hours (or 30 minutes) of irrigation run time per day.

$$\frac{0.45\ inch}{1\ day} \div \frac{0.9\ inch}{1\ hour} = \frac{0.45\ inch}{1\ day} \times \frac{1\ hour}{0.9\ inch} =$$

$$0.5\ hours/day$$

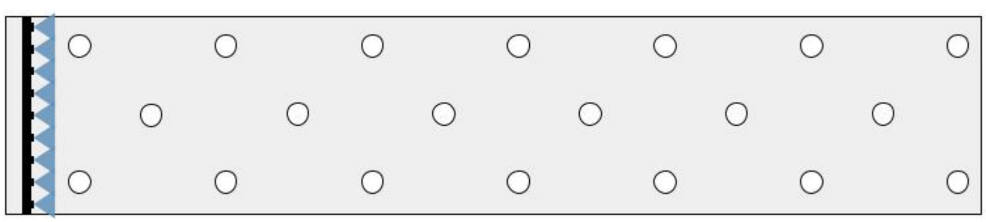
$$\frac{0.5\ hours}{1\ day} \times \frac{60\ minutes}{1\ hour} = 30\ minutes/day$$

This could be split into 10 minutes three times per day as a cyclic irrigation schedule, which may improve water application efficiency.

It is important to take into account if running the irrigation in other zones simultaneously will impact the pressure and therefore application rate of the selected zone.

Using A Boom?

These same techniques can be used to assess DU and application rate when using a boom to irrigate seedlings. Place catch cans along the length of the area covered by the boom as shown below.



Practice

1. Based on the values listed below, calculate DU and application rate. Assume catch cans used were straight sided and wind speed did not exceed 3 mph (4.8 kph). Note: For brevity, multiple catch cans are listed with the same volume. This is unlikely in a nursery.

    - 24 total catch cans were used
        - 3 catch cans collected 1/8 inch (0.125 inch)
        - 6 cans collected 3/16 inch (0.1875 inch)
        - 6 cans collected 1/4 inch (0.25 inch)
        - 6 cans collected 5/16 inch (0.3125 inch)
        - 3 cans collected 3/8 inch (0.375 inch)
    - Irrigation ran for 30 minutes during the collection period

2. Find the average depth collected (sum of irrigation depth ÷ 24 catch cans)

B) Find the average depth collected by lowest 25 percent (sum of irrigation depth of lowest 25 percent ÷ 6 catch cans)

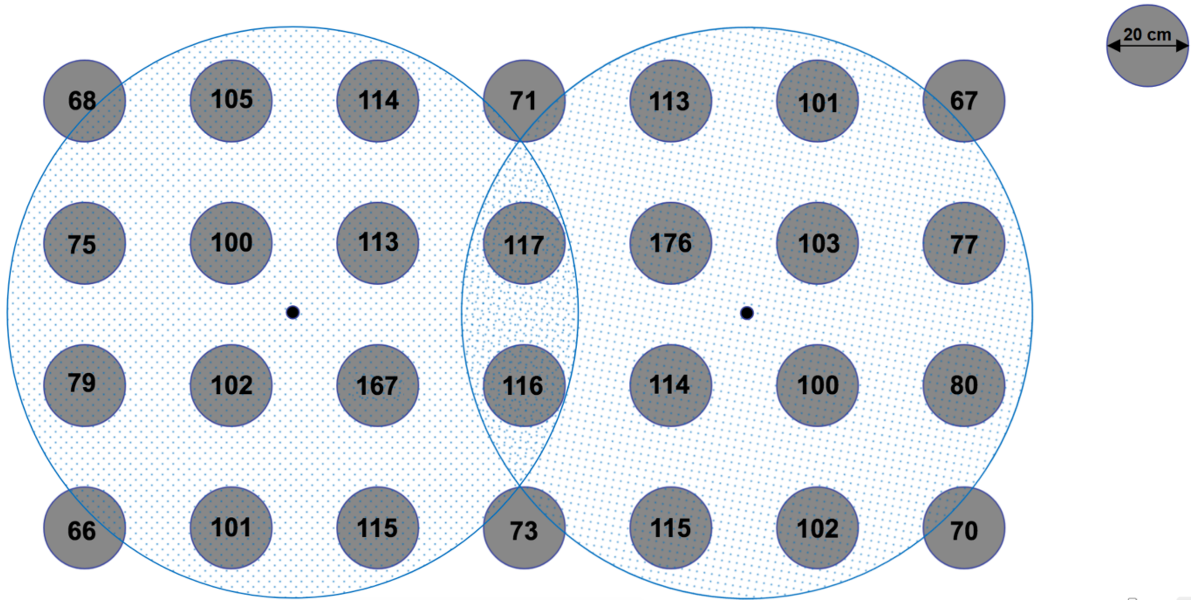
C) Find DU (answer to B ÷ answer to A) × 100 percent

D) Find the application rate per minute (answer to A ÷ irrigation run time)

E) Find the application rate per hour (answer to D × 60 min/hr)

A) ¼" = 0.25" B) 5/32" = 0.15625" C) 62.5% D) 1/120" per min = 0.0083" per min E) ½" per hr = 0.5" per hr

2. Using the information listed in the diagram below, practice calculating distribution uniformity and application rate. Assume wind speed did not exceed 3 mph (4.8 kph). Catch cans volumes listed in mL. Run time = 30 minutes. Catch can diameter = 20 cm.



DU	Application rate
A) Find average volume (sum of volumes ÷ total number of catch cans)	D) Find the area of the catch can opening [3.14159 × (diameter ÷ 2)^2]
	E) Find the average depth collected (answer to A ÷ answer to D) in cm
B) Find average volume of lowest 25 percent (sum of volumes of lowest 25 percent ÷ number of catch cans in the lower quarter)	F) Find application rate per minute (answer to E ÷ irrigation run time) in cm
	G) Find application rate per hour (answer to F × 60 minutes/hr) in cm
C) Find DU (answer to B ÷ answer to A) × 100 percent	
	H) Convert application rate from cm/hr to in/hr (answer to G ÷ 2.54 in/cm)

A) 100mL B) 70mL C) 70% D) 314.16cm^2 E) 0.318cm F) 0.011cm/min G) 0.64cm/hr H) 0.251"/hr

Worksheet for on-site calculations

1. Place a multiple of four catch cans in irrigation zone (more cans increase the ability to identify areas that receive abnormally high or low irrigation volumes)
    a. Total number of catch cans ______
    b. 25 percent of total catch cans______ (total number of catch cans ÷ 4)
    c. Inner diameter of catch can opening __________cm
2. Run a normal irrigation cycle and record duration, water pressure, wind speed and direction
    a. Irrigation run time __________min
    b. Water pressure _____________psi
    c. Wind speed _______________mph
    d. Wind direction ____________
3. Record each catch can's water volume (in cm^3) using a graduated cylinder or scale
    a. 1 mL = 1 cm^3 = 1 g
    b. Catch can volumes ____
4. Calculate the average volume of water in all catch cans.
    a. Average volume = add all catch can volumes ÷ total number of catch cans
    b. Average volume = __________cm^3
5. Calculate the average volume of water in the lower 25 percent of catch cans
    a. Average volume in the lower 25 percent = add lower 25 percent catch can volumes ÷ 25 percent of catch cans
    b. Average volume of water in the lower 25 percent = __________cm^3
6. Calculate DU
    a. DU = (Average volume in the lower 25 percent ÷ average volume of all catch cans) × 100 percent
    b. DU = (__________cm^3 ÷ __________cm^3) × 100 percent = __________%
7. Calculate the area of the catch can opening
    a. Area = $\pi \times r^2 = 3.14159 \times (\text{diameter} \div 2)^2$
    b. Area = __________cm^2
8. Calculate the average depth of water in all catch cans
    a. Average depth = average volume ÷ area of catch can opening
    b. Average depth = __________cm
9. Calculate the irrigation depth per minute
    a. Application rate per minute = average depth ÷ irrigation run time
    b. Application rate = __________cm/min
10. Calculate the irrigation depth per hour
    a. Application rate per hour = application rate per minute × 60 minutes/hour
    b. Application rate = __________cm/hr
11. Convert application rate to inches
    a. Application rate in inches = application rate in cm ÷ 2.54 inches/cm
    b. Application rate = __________in/hr

More Resources

For in-depth explanation of these and other nursery irrigation concepts, calculations, and success stories from field and container nurseries experimenting with new methods of improving their irrigation scheduling, please consult:

Yeary, W., A. Fulcher, and B. Leib. 2016. Nursery irrigation: A guide for reducing risk and improving production. UT Extension Publication PB 1836. 111pp. https://extension.tennessee.edu/publications/Documents/PB1836.pdf.

For a comprehensive, step-by-step guide of nursery irrigation calculations, please see:

Million, J. and T. Yeager. 2021. Measuring the sprinkler irrigation requirement of container-grown nursery plants. UF/IFAS Extension, ENH1197. https://edis.ifas.ufl.edu/pdf/EP/EP458/EP458-Duu1n86nyz.pdf.

For an in-depth discussion of advanced irrigation concepts including design, calculations, and irrigation scheduling, and an outstanding glossary, please review:

Owen Jr., J.S., A.V. LeBude, and M.R. Chappell. 2016. Advanced irrigation management for container-grown ornamental crop production. Virginia State University and Polytechnic Institute, Publication HORT-218P. http://www.nurserycropscience.info/water/system-design-and-management/efficiency/hort-218-pdf.pdf.

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