Department of Plant Sciences

IRRIGATION CALCULATIONS III: CAPTURE FACTOR

February 2023
Lauren Fessler, Department of Plant Sciences
Amy Fulcher, Department of Plant Sciences

Increasing irrigation efficiency continues to be a focus in the U.S. and worldwide as water quality and availability decrease. Nursery producers can use capture factor as a tool to refine irrigation scheduling and thereby improve irrigation efficiency and decrease leaching and runoff.

Little Lime® hydrangeas from unpruned to lightly pruned to pruned hard. CF values for these plants, from left to right, were 1.4, 1.7 and 1.1. A) Side view. B) Top view. Image credit: Carolyn Krauss.

Capture factor

Capture factor (CF) is a measure of the plant canopy's capacity to channel overhead irrigation into the container.

$$CF = \frac{irrigation\ water\ captured\ by\ planted\ container}{irrigation\ water\ captured\ by\ empty\ container}$$

What influences CF?

CF is affected by a number of factors, including canopy size and architecture, which are influenced by crop species, severity and frequency of pruning, and plant age; container size and spacing; and emitter type. A CF of 1 indicates that the plant has no effect on the amount of water captured, a CF greater than 1 indicates that the plant is funneling water into the container, and a CF less than 1 indicates that the plant is shedding water outside the container.

Case study:

Research conducted at the University of Tennessee found that Yoshino cherries shed water and have a capture factor of 0.8 while Kwanzan cherries funnel water toward their base and have a capture factor of 1.7. Placed in the same irrigation zone, containers of Kwanzan cherries received more than twice as much water as containers of Yoshino cherries. This example is based on 5-foot-tall trees in No. 5 (4.5-liter) containers using impact sprinklers. The plant species as well as plant size, plant spacing, container size and irrigation type will all affect capture factor. As this case study shows, capture factors vary widely, even between closely related plant species, and is worth accounting for when deciding what plants to place together in

Calculating CF

1. Identify and label at least five representative plants within the irrigation zone.
2. Measure the top diameter of the plant containers in centimeters (cm).
3. Calculate the surface area (A) of the top of the plant containers ($A = \pi r^2$).
    a. Find the radius of each container by dividing the diameter by 2.
    b. Square the radius, then multiply by pi (3.14159) to get the surface area (cm^2).
4. Nest plant containers into tight-fitting drainage cans to catch all leachate that drains from the plant containers.
    a. Ensure that irrigation cannot directly enter the drainage cans.
5. Weigh the nested containers (to nearest 0.01 kilogram).
6. Place the nested containers in the irrigation zone.
7. Measure the diameter of the catch cans in centimeters (cm).
8. Calculate the surface area of the catch cans ($A = \pi r^2$).
    a. Find the radius of each catch can by dividing the diameter by 2.
    b. Square the radius, then multiply by pi (3.14159) to get the surface area (cm^2).
9. Place the catch cans in the irrigation zone so that the opening is at the same height as the top of the canopy of plants in the nested containers.
10. Run a typical irrigation event.
11. Weigh the nested containers again.
12. Calculate the amount of irrigation water that entered the plant containers.
    a. Subtract the pre-irrigation weight (step 5) from the post-irrigation weight (step 11).
13. Multiply by 1,000 to convert kilograms to centimeters cubed.
    a. 1 kg = 1,000 g = 1,000 cm^3
14. Calculate the depth of the water collected by the plant containers.
    a. Divide irrigation volume (step 13) by the surface area of each plant container (step 3).
15. Using weight or volume, measure the amount of water in the catch cans.
    a. 1g = 1 mL = 1 cm^3
    b. If there is little water in the catch cans, using a small graduated cylinder to measure volume may be a more appropriate method than weighing, depending on your scale range and resolution.
16. Calculate the depth of the water collected by the catch cans.
    a. Divide the collected amount (step 15) by the surface area of each catch can (step 8).
17. Calculate CF.
    a. Divide the depth of the water captured by the plant container (step 14) by the depth of the water captured by the catch can (step 16).

Example

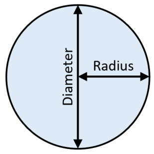
Six plants in containers with a diameter of 16 centimeters were placed into drainage cans. The nested containers were weighed and then placed in the irrigation zone. Six catch cans with a diameter of 10 centimeters were also placed in the irrigation zone. A typical irrigation cycle was run. Nested containers were then weighed again and the volume in each catch can was measured.

Rep	Nested container pre-irrigation	Nested container post-irrigation	Catch can volume
1	1.25 kg	1.85 kg	157 mL
2	1.28 kg	1.89 kg	158 mL
3	1.32 kg	1.91 kg	161 mL

4	1.35 kg	1.94 kg	153 mL
5	1.33 kg	1.95 kg	155 mL

First, find the plant container's surface area:

$A = \pi r^2$



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

$$A = 3.14159 \times (\frac{16\ cm}{2})^2$$

$$A = 3.14159 \times (8cm)^2$$

$$A = 3.14159 \times 64cm^2$$

$$A = 201.1cm^2$$

Next, find the surface area of the catch can:

$$A = \pi r^2$$

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

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

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

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

$$A = 78.5\ cm^2$$

Determine the amount of irrigation applied to the plant container:

$$Plant\ container\ irrigation\ weight = Post\ irrigation\ weight - Pre\ irrigation\ weight$$

Rep	**Post**-irrigation	**Pre**-irrigation	Irrigation weight
1	1.85 kg	1.25 kg	0.60 kg
2	1.89 kg	1.28 kg	0.61 kg
3	1.91 kg	1.32 kg	0.59 kg
4	1.94 kg	1.35 kg	0.59 kg
5	1.95 kg	1.33 kg	0.62 kg

Find the average irrigation weight:

$$Avg\ irrigation\ weight = \frac{Irrigation\ weight\ 1 + Irrigation\ weight\ 2 + \cdots + Irrigation\ weight\ n}{n}$$

$$= \frac{0.60kg + 0.61kg + 0.59kg + 0.59kg + 0.62kg}{5}$$

$$= \frac{3.01kg}{5} = 0.602kg$$

Convert the plant irrigation weight to volume (1 g = 1cm^3):

$$0.602kg \times \frac{1000cm^3}{1kg} = 602cm^3$$

Convert plant irrigation volume to depth by dividing by the surface area of the plant container:

$$\frac{602cm^3}{201.1cm^2} = 3.0cm$$

Find the average volume of irrigation collected by the catch cans (1 mL = 1 cm^3):

$$Avg\ volume = \frac{Volume\ 1 + Volume\ 2 + \cdots + Volume\ n}{n}$$

$$= \frac{157mL + 158mL + 161mL + 153mL + 155mL}{5}$$

$$= \frac{784mL}{5} = 156.8mL = 156.8cm^3$$

Convert catch-can irrigation volume to depth by dividing by the surface area of the catch can:

$$\frac{156.8cm^3}{78.5cm^2} = 2.0cm$$

Calculate CF by dividing the plant irrigation depth by the catch-can irrigation depth:

$$CF = \frac{3.0cm}{2.0cm} = 1.5$$

The CF value is greater than 1, which means that this plant is funneling water into the container.

Practice

1. Based on the given information and the values below, calculate CF. Small trees were planted in containers with a diameter of 28 centimeters. Five representative trees were selected and placed in drainage cans. These nested containers were then weighed and placed in the irrigation zone. Five catch cans with a diameter of 9 centimeters were also placed in the irrigation zone. A typical irrigation cycle was run, and the following data were collected:

Rep	Nested container pre-irrigation	Nested container post-irrigation	Catch-can volume
1	3.52 kg	4.55 kg	129 mL
2	3.48 kg	4.47 kg	128 mL
3	3.51 kg	4.48 kg	131 mL
4	3.46 kg	4.42 kg	124 mL
5	3.53 kg	4.51 kg	125 mL

A. Find the surface area of the plant container. [$3.14159 \times (\text{diameter} \div 2)^2$]

B. Find the surface area of the catch can. [$3.14159 \times (\text{diameter} \div 2)^2$]

C. Find the irrigation weight for each plant. (post-irrigation weight – pre-irrigation weight)

Rep 1_________ Rep 2_________ Rep 3_________ Rep 4_________ Rep 5_________

D. Find the average plant irrigation weight. (sum of answers to C ÷ 5)

E. Convert plant irrigation weight to volume in centimeters cubed. (answer to D × 1,000)

F. Convert plant irrigation volume to depth in centimeters (answer to E ÷ answer to A).

G. Find the average catch-can irrigation volume. (sum of catch-can volumes ÷ 5)

H. Convert catch-can irrigation volume to depth. (answer to G ÷ answer to B)

I. Calculate CF. (answer to F ÷ answer to H)

J. Does this tree funnel or shed water? ________________________

A) 615.8cm^2 B) 63.6cm^2 C) 1.03kg, 0.99kg, 0.97kg, 0.96kg, 0.98kg D) 0.986kg
E) 986cm^3 F) 1.6cm G) 127.4mL H) 2.0cm I) 0.8 J) shed

More Resources

For an 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. 111 pages.
extension.tennessee.edu/publications/Documents/PB1836.pdf

For a comprehensive, step-by-step guide to 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.

edis.ifas.ufl.edu/pdf/EP/EP458/EP458-Duu1n86nyz.pdf

For an in-depth discussion on the dynamic influences of capture factor, please review:

Million, J. and T. Yeager. 2015. Capture of sprinkler irrigation water by container-grown ornamental plants. HortScience, 50 (3): 442-446.

doi.org/10.21273/HORTSCI.50.3.442

Acknowledgements

The authors thank Kristopher Criscione and Grace Pietsch, PhD, for their careful review of this publication and Amber Gunter, Carolyn Krauss and Jakob Johnson for their assistance with its preparation. The authors would also like to acknowledge Tom Yeager, PhD, and Jeff Million, PhD, University of Florida, for their research and development of accessible information on capture factor.

UTIA INSTITUTE OF AGRICULTURE THE UNIVERSITY OF TENNESSEE
Real. Life. Solutions.™