Department of Plant Sciences

IRRIGATION CALCULATIONS II: LEACHING FRACTION

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Refining irrigation can help growers decrease water and nutrient inputs, increase crop quality and uniformity, and decrease environmental impacts. This series covers calculations that nursery producers can use to assess and improve irrigation efficiency.

Leaching Fraction

Leaching Fraction (LF) is the ratio of the amount of water that leaches from a container compared to the total amount of water applied to that container.

Why measure LF?

LF can quickly give growers insight as to whether the duration of an irrigation event is appropriate. A high LF can lead to nutrient runoff and indicates the crops may be receiving too much water. A low LF can indicate that plants are not receiving enough water, which can cause salt build up, reduce growth or both.

For overhead sprinkler irrigation, the target LF is typically 10 to 15 percent, whereas for micro-irrigation it is higher, 25 to 30 percent.

What influences LF?

Factors that can influence LF largely break down into two categories: 1) those that influence how much water enters the container and 2) those that influence how much and how quickly water in the container drains. These include the species' inherent water use, canopy architecture, irrigation method and duration, container size and shape, and substrate composition. For instance, substrate components that are prone to becoming hydrophobic, such as pine bark, can form channels through which water quickly drains, increasing LF.

Calculating LF using the weight method.

Calculating LF

Leaching fraction can be measured by volume or by weight using this formula:

$$LF = \frac{Amount\ of\ leachate}{Amount\ of\ irrigation\ applied} \times 100\%$$

Each method has pros and cons. Measuring by weight requires an inexpensive kitchen scale, but saves time and accounts for the influence of capture factor. More information on capture factor can be found in the third publication in this series.

Measuring by volume requires only catch cans and a measuring cup or, better, a graduated cylinder. This method can be prone to error due to spillage and inability to account for the canopy's effect on irrigation that enters the container (capture factor). The weight-based method is considered superior because canopy effects can be significant and they are dynamic, for example, the effect changes after pruning.

Calculating LF by weight

1. Weigh the drainage cans.
2. Nest five or more planted containers inside drainage cans and place throughout the irrigation zone.
    a. Ensure that the planted container fits snugly into the drainage can so that irrigation cannot enter the drainage can.
3. Weigh nested containers.
4. Run a typical irrigation cycle.
5. Record the irrigation run time.
6. Allow planted containers to drain for one hour.
7. Weigh the nested containers again.
8. Determine total amount of irrigation applied.
    a. This is the post-irrigation nested container weight (step 7) minus the pre-irrigation nested container weight (step 3).
9. Remove the planted container from the drainage cans.
10. Weigh the drainage can with leachate.
11. Find the amount of leachate.
    a. This is the weight of the drainage can with leachate (step 10) minus the empty drainage can (step 1).
12. Divide the leachate weight (step 11) by the irrigation weight (step 8).
    a. Multiply by 100% to get leaching fraction.
13. Calculate average leaching fraction.
14. Assess changes to run time.
    a. If the leaching fraction is greater than desired, irrigation run time should be shortened.
    b. If leaching fraction is less than desired, irrigation run time should be lengthened.

Calculating LF by volume

1. Nest five or more planted containers inside drainage cans and place throughout the irrigation zone.
2. Place five or more catch cans at canopy height throughout the irrigation zone, paired with drainage cans.
    a. Use container sizes and catch cans with the same diameter.
    b. Ensure that the planted container fits snugly into the drainage can so that irrigation cannot enter the drainage can.
3. Run a typical irrigation cycle and record the run time.
4. Measure the volume of irrigation applied to each catch can.
    a. Do this immediately after irrigation ends to minimize errors due to evaporation.
5. Allow planted containers to drain for one hour.
6. Measure the volume of leachate collected in each drainage can.
7. Divide leachate volume (step 6) by the corresponding irrigation volume. (step 4).
    a. Multiply by 100% to get leaching fraction.
8. Calculate average leaching fraction.
9. Assess changes to run time.
    a. If the leaching fraction is greater than desired, irrigation run time should be shortened.
    b. If leaching fraction is less than desired, irrigation run time should be lengthened.

> **Tip 1**
>
> If you must use the volume method, use a graduated cylinder to improve your measurement accuracy, and thus your LF calculation, when measuring by volume. In a test comparing the accuracy of graduated cylinders and measuring cups, the percent deviation from the true volume was nearly twice as great for the measuring cup! The wide diameter of a measuring cup makes it difficult to accurately determine the water line. Buy a graduated cylinder that holds at least as much water as your heaviest irrigation event and add a heavy circular fitting to the base to prevent tipping.

Examples

By weight

To measure the LF of #3 containers, 5-gallon buckets were used as drainage cans. The empty 5-gallon buckets were weighed before beginning. One potted #3 container was nested in each 5-gallon bucket, ensuring there were no gaps through which irrigation could enter the drainage can. Nested containers were then weighed.

Irrigation was operated for one hour and then containers drained for one hour. Nested containers were then weighed again. Planted containers were removed and the drainage cans with leachate were weighed.

Can	Empty drainage can	Nested container pre-irrigation	Nested container post-irrigation	Drainage can + leachate
1	2 lbs.	25 lbs.	27 lbs.	2.75 lbs.
2	2 lbs.	27 lbs.	28.75 lbs.	2.7 lbs.
3	2.1 lbs.	23 lbs.	25.25 lbs.	3 lbs.
4	2.1 lbs.	24 lbs.	26 lbs.	2.95 lbs.
5	2.2 lbs.	21 lbs.	23 lbs.	3 lbs.

To calculate LF, first determine the total amount of irrigation applied:

$$Total\ irrigation = Post\ irrigation\ weight - Pre\ irrigation\ weight$$

Can	Post-irrigation	Pre-irrigation	Total irrigation
1	27 lbs.	25 lbs.	2 lbs.
2	28.75 lbs.	27 lbs.	1.75 lbs.
3	25.25 lbs.	23 lbs.	2.25 lbs.
4	26 lbs.	24 lbs.	2 lbs.
5	23 lbs.	21 lbs.	2 lbs.

Next find the amount of leachate:

$$Leachate = Drainage\ can\ with\ leachate - Empty\ can$$

Can	Drainage can + leachate	Empty drainage can	Leachate
1	2.75 lbs.	2 lbs.	0.75 lbs.
2	2.7 lbs.	2 lbs.	0.7 lbs.
3	3 lbs.	2.1 lbs.	0.9 lbs.
4	2.95 lbs.	2.1 lbs.	0.85 lbs.
5	3 lbs.	2.2 lbs.	0.8 lbs.

Divide the leachate amount by the irrigation amount then multiply by 100% to get LF:

$$LF = \frac{Leachate}{Total\ irrigation} \times 100\%$$

Can	Leachate	Total irrigation	LF
1	0.75 lbs.	2 lbs.	37.5%
2	0.7 lbs.	1.75 lbs.	40.0%
3	0.9 lbs.	2.25 lbs.	40.0%
4	0.85 lbs.	2 lbs.	42.5%
5	0.8 lbs.	2 lbs.	40.0%

To find the average LF, sum the LFs for each can and divide by the number of cans (omit outlier, if present):

$$Avg\ LF = \frac{Can\ 1\ LF + Can\ 2\ LF + \cdots + \ Can\ n\ LF}{n}$$

$$= \frac{37.5\% + 40.0\% + 40.0\% + 42.5\% + 40.0\%}{5}$$

$$= \frac{200\%}{5} = 40\%$$

In this example, the LF of 40% exceeds the target range so the irrigation run time should be decreased.

To adjust irrigation run time based on LF, use the following formula:

$$Desired\ run\ time = \frac{100\% - measured\ LF\%}{100\% - desired\ LF\%} \times measured\ run\ time$$

$$= \frac{100\% - 40\%}{100\% - 15\%} \times 60\ minutes$$

$$= \frac{60\%}{85\%} \times 60\ minutes = 42.4\ minutes$$

This new shortened run time of 42.4 minutes should yield a LF that is closer to the target of 15 percent; however, it is important to keep in mind that this applies to the specific plants used and at the specific growth stage and production conditions in which they were tested. Something as simple as pruning the crop could have a dramatic influence on LF. Because the factors that influence LF change throughout the season, it is important to assess LF at different points during the season.

By volume

Five catch cans were set up in an irrigation zone alongside five planted containers inside drainage cans. The irrigation ran for 45 minutes.

The volume of water collected in catch cans was measured immediately when irrigation concluded. Catch cans collected 2978mL, 3022mL, 2988mL, 3012mL and 3000mL. After an hour, the volume of leachate collected in drainage cans was measured.

Tip 2

Leachate can be combined and measured at one time (this can also be done with irrigation water) to save time, however, this will not allow you to identify atypical plants that should be excluded from the calculation.

Drainage cans collected 434mL, 303mL, 446mL, 455mL and 461mL.

To calculate LF, first divide leachate (drainage can) volume by irrigation (catch can) volume:

$$\frac{434mL}{2978mL}, \frac{303mL}{3022mL}, \frac{446mL}{2988mL}, \frac{455mL}{3012mL}, \frac{461mL}{3000mL}$$

$$= 0.146, \quad = 0.100, \quad = 0.149, \quad = 0.151, \quad = 0.154$$

Multiply by 100% to get LF for each plant:

$$0.146 \times 100\% = 14.6\%$$
$$0.100 \times 100\% = 10.0\%$$
$$0.149 \times 100\% = 14.9\%$$
$$0.151 \times 100\% = 15.1\%$$
$$0.154 \times 100\% = 15.4\%$$

Check for an outlier:

10.0% *is much less than* 14.6%*, the next lowest value.*
Therefore, the second plant is considered an outlier.

Calculate the average LF, excluding the outlier:

$$Avg\ LF = \frac{Plant\ 1\ LF + Plant\ 2\ LF + \cdots + Plant\ n\ LF}{n}$$

$$= \frac{14.6\% + 14.9\% + 15.1\% + 15.4\%}{4}$$

$$= \frac{60\%}{4} = 15\%$$

An LF of 15 percent falls into the target range so the current run time is sufficient.

Practice

1. Using the information listed in the table below, practice calculating leaching fraction based on weight.

Irrigation run time = 85 minutes

	Empty drainage can	Pre-irrigation	Post-irrigation	Drainage can + leachate
Can 1	2 lbs.	33 lbs.	38 lbs.	5 lbs.
Can 2	2.1 lbs.	36 lbs.	40.5 lbs.	4.35 lbs.
Can 3	2.1 lbs.	34 lbs.	39.5 lbs.	4.85 lbs.
Can 4	2.2 lbs.	37 lbs.	41 lbs.	3.8 lbs.
Can 5	2 lbs.	35 lbs.	39 lbs.	3 lbs.

A) Find total irrigation weight for each can (post-irrigation weight – pre-irrigation weight)

Can 1__________ Can 2__________ Can 3__________ Can 4__________ Can 5__________

B) Find leachate weight for each can (can + leachate weight – empty can weight)

Can 1__________ Can 2__________ Can 3__________ Can 4__________ Can 5__________

C) Find LF for each can [(answers to B ÷ answers to A) × 100%]

Can 1_________ Can 2_________ Can 3_________ Can 4_________ Can 5_________

D) Is there an obvious outlier that should be removed? _______________

E) Find the average LF for the zone, excluding the outlier (sum of answers to C ÷ 4)

F) Assuming a target LF of 15 percent, should the irrigation run time be increased or decreased?

G) Find the desired run time [(100% - answer to E) ÷ (100% - 15%) × 85 min]

A) 5lbs., 4.5lbs., 5.5lbs., 4lbs., 4lbs. B) 3lbs., 2.25lbs., 2.75lbs., 1.6lbs., 1lbs. C) 60%, 50%, 50%, 40%, 25% D) Yes, Can 5 E) 50% F) Decreased G) 50 minutes

2. Based on the values listed below, calculate leaching fraction based on volume.
   - Five catch cans and five drainage cans were used.
   - Irrigation was operated for 51 minutes during the collection period.
   - The following volumes were collected:

	Plant 1	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**
Catch cans	5018mL	4973mL	4987mL	4992mL	5030mL
Drainage cans	505mL	489mL	496mL	499mL	512mL

A) Find LF for each plant [(drainage can volume ÷ catch can volume) × 100%]

Plant 1________ Plant 2________ Plant 3________ Plant 4________ Plant 5________

B) Is there an obvious outlier that should be removed? _______________

C) Find the average LF (sum of answers to A ÷ 5 drainage cans)

D) Assuming a target LF of 15 percent, should the run time be increased or decreased?

E) Find the desired run time [(100% - answer to C) ÷ (100% - target LF) × 51 min]

A) 10.1%, 9.8%, 9.9%, 10.0%, 10.2%   B) No   C) 10%   D) Increased   E) 54 minutes

Worksheets for on-site calculations

Calculating LF by weight

1. Weigh drainage cans to be placed in the irrigation zone
    a. Number of drainage cans ______
    b. Empty drainage can weights ____
2. Nest plant containers inside drainage cans
    a. Ensure drainage cans fit snugly around the plant container so no irrigation can enter
        i. 5-gallon buckets are often used for #3 containers
3. Weigh nested containers
    a. Nested container weights (pre-irrigation) ____________________________________
4. Run a normal irrigation cycle and record duration
5. Irrigation run time __________ minutes
6. Allow plants to drain for 1 hour
7. Weigh nested containers again
    a. Nested container weights (post-irrigation) ____________________________________
8. Calculate the amount of irrigation water applied
    a. Irrigation weight = post-irrigation nested container weight – pre-irrigation nested container weight
    b. Irrigation weights____
9. Remove plant containers from drainage cans
10. Weigh drainage cans with leachate
    a. Drainage can with leachate weights ____
11. Calculate the amount of leachate drained
    a. Leachate weight = drainage can with leachate weight – empty drainage can weight
    b. Leachate weights____
12. Calculate individual LFs, note if there is an outlier
    a. LF = (leachate weight ÷ irrigation weight) × 100%
    b. LFs = ____
13. Find average LF, omit outlier if present
    a. Average LF = add all LFs ÷ number of drainage cans
    b. Average LF = __________%
14. If average LF falls outside the target range (typically 10% to 20%), proceed to step 15
15. Calculate the desired run time based on the LF
    a. Desired run time = [(100% - calculated LF) ÷ (100% - target LF)] × current run time
    b. Desired run time = __________min

Calculating LF by volume

1. Place at least five catch cans in the irrigation zone being evaluated
   a. Number of catch cans ______
2. Nest several plant containers inside drainage cans of the same diameter and place within the irrigation zone
   a. Ensure drainage cans fit snugly around the plant container so no irrigation can enter
      i. 5-gallon buckets are often used for #3 containers
   b. Number of drainage cans ______
3. Run a normal irrigation cycle and record duration
   a. Irrigation run time __________minutes
4. Record the volume of irrigation from each catch can
   a. Measure immediately to prevent errors due to evaporation
   b. Irrigation volume(s) ____
5. Allow plants to drain for 1 hour
6. Record the leachate volume from each drainage can
   a. Leachate volume(s) ____
7. Calculate individual LFs, note if there is an outlier
   a. LF = (leachate volume ÷ irrigation volume) × 100%
   b. LFs = ____
8. Find average LF, omit outlier if present
   a. Average LF = add LFs ÷ number of drainage cans
   b. Average LF = __________%
9. If the average LF falls outside the target range (typically 10% to 20%), proceed to step 10
10. Calculate the desired run time based on the LF
    a. Desired run time = [(100% - calculated LF) ÷ (100% - target LF)] × current run time
    b. Desired run time = __________min

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 further explanation on how leaching fraction can be used to determine run time, please see:

Million, J. and T. Yeager. 2020. Monitoring leaching fraction for irrigation scheduling in container nurseries. UF/IFAS Extension, ENH1268. https://edis.ifas.ufl.edu/publication/EP529.

Million, J. and T. Yeager. 2021. Use of routine leaching fraction testing to guide irrigation at a container nursery. J. Environ. Hortic., 39 (3): 108-114. https://doi.org/10.24266/0738-2898-39.3.108.

For an in-depth guide on how to utilize leaching fraction to determine nursery irrigation scheduling including accounting for salt levels, please see:

Owen Jr., J.S., A.V. LeBude, A. Fulcher, and L.R. Oki. 2019. Leaching fraction: A tool to schedule irrigation for container-grown nursery crops. Virginia State University and Polytechnic Institute, Publication SEPS-128P. https://vtechworks.lib.vt.edu/bitstream/handle/10919/93158/SPES-128.pdf?sequence=1.

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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