CIRRIG Concepts

Container nurseries irrigate in order to resupply water loss through evapotranspiration (ET), the combined processes of plant transpiration and substrate evaporation. CIRRIG has two strategies (zone types) for outputting irrigation run times that meet daily changing container water requirements:

● **ET Zone Types** Container ET is estimated considering input plant parameters (percent plant cover, container size and spacing, plant height and width) and weather. The irrigation depth required to resupply water loss is calculated based on the irrigation rate and the plant's irrigation-capturing ability.

● **LF Zone Type** Routine leaching fraction (LF=container leachate/water applied to the container) test results (e.g. 1X every 2-4 weeks) are input into CIRRIG. For determining irrigation run times, CIRRIG compares the weather of the past 24-hours with the weather associated with the last LF test and adjusts it up or down accordingly to the weather's effect on the ET rate. Unlike, ET Zone Type, this zone type is based on direct field measurement.

We have a great opportunity to apply water efficiently in the nursery if we use one of the two methods of guiding irrigation. Both methods are weather-based and account for rain.

Some Factors Used to Determine Irrigation Requirement

Evapotranspiration (ET) is the amount of water lost due to plant transpiration and substrate evaporation and represents the amount of water that needs to be resupplied through irrigation (or rain). ET is affected by weather and thus changes daily. ET is calculated on a 24-hour period.

Capture Factor (CF) is a measure of the plant canopy's capacity to channel irrigation water into the container that would otherwise fall between containers. As a plant's CF increases, irrigation rates can be reduced proportionately. CF is affected by plant species, plant size, and container spacing. ET Zone type estimates this effect.

Leaching Fraction (LF) is the volume of leachate divided by the volume of water applied to the container. Irrigation can be adjusted to provide a desired LF (e.g. 15%). Measured LF plays and integral role in LF zone type; LF is an adjustment factor in ET zone type calculations.

Rain has the potential to reduce or eliminate irrigation. CIRRIG determines when the rain fell and calculates its contribution in reducing the water deficit in the container substrate.

Evapotranspiration (ET)

Evapotranspiration is water evaporated from leaf (transpiration) and substrate (evaporation) surfaces. The potential rate of ET is affected by weather (primarily solar radiation and temperature) when substrate water is not limiting. The actual rate of ET is affected by plant cover (leaf area), container size and container spacing. Actual ET is less than potential ET when plant cover does not intercept all incoming radiation. A plant's leaf area index (LAI) is a measure of the plant canopy's capacity to intercept incoming solar radiation. LAI is the ratio of leaf area to ground area. As LAI increases, a greater percentage of incoming solar radiation is absorbed resulting in higher plant transpiration but lower substrate evaporation. Once an LAI of 3 (think of 3 layers of leaves over the ground) is reached, essentially all of the incoming solar radiation is captured by typical plant canopies and actual ET approaches potential ET. Because the determination of LAI is a difficult and time-consuming process, CIRRIG uses percent canopy cover to estimate light interception for ET calculations when the ET zone type is selected.

Fig. 1. Spirea plants (left) only partially covering the production area exhibit lower ET values than azalea plants (right) with high percent canopy cover and high ET rates.

Evapotranspiration is typically calculated as depth of water (inch) lost over the production area. Unlike field-grown plants with wide root distribution, container-grown plants are limited to receiving irrigation through the container top area. The end result is that ET (inch) is multiplied by the ratio of total area allotted each container to the top area of the container in order to calculate an equivalent container ET rate (inch/container). Container ET is directly related to the depth of irrigation required

$$\textbf{Container ET (inch/container)} = \text{ET (inch)} \times \frac{\text{total area alloted container (inch}^2\text{)}}{\text{container top area (inch}^2\text{)}}$$

Example

ET = 0.2 inch

Total area allotted each container = 150 in^2

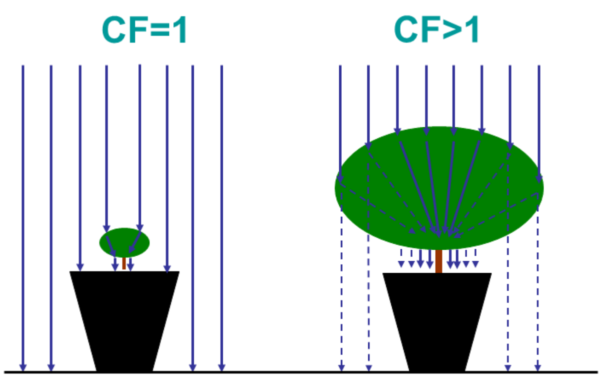
Container top area = 75 in^2

Container ET = 0.4 inch/container

Irrigation capture factor (CF)

The plant canopy affects the amount of irrigation water that enters the container. CF is the ratio of water entering the container with a plant compared to the amount of water that would enter the same container without a plant. CF values >1 indicate the plant is channeling water into the container that would otherwise have fallen un-captured between containers. Conversely, CF<1 indicates that the plant canopy is channeling water away from the container and irrigation rates would need to be increased according. As an example, a CF=2 indicates that twice as much water will enter the container than indicated by irrigation depth alone and thus one-half as much irrigation water needs to be applied. In general, plant species with tall, upright-spreading growth habit exhibit greater CF values then low, broad-spreading growth habits. As you might expect, CF is a dynamic parameter that increases as plant size increases particularly in relation to the container diameter. For ET zone type, CIRRIG estimates CF based upon the capturing ability of the plant species, plant size, container diameter and container spacing.

Capture factor (CF) describes a plant's capacity to channel water into the container that would otherwise fall between containers. CF is related to canopy size, plant species, and container size and spacing.



Leaching Fraction

LF testing measures the relative volume of leachate relative to the amount of irrigation water applied to the container. Procedures for LF testing are different for sprinkler versus micro-irrigated production but the principles are the same.

$$\mathrm{LF} = \frac{\text{volume leachate}}{\text{volume irrigation water applied to container}}$$

A low LF (e.g. <15%) indicates irrigation water is being efficiently applied. If LF is excessive, then irrigation can be adjusted:

$$\textbf{LF-adjusted run time (min)} = \text{test run time (min)} \times \frac{(100\% - \text{test LF}\%)}{(100\% - \text{target LF}\%)}$$

Example

Test LF = 40%

Test run time = 30 minutes

Target LF = 15%

Test ET = ET_{LF} = 0.24 inch

Adjusted run time (RT_{LF}) = 30 x (100-40) ÷ (100-15) = **21.2 minutes**

When a LF-sprinkler or LF-micro zone type is selected, the user routinely (every 2-4 weeks) measures LF. Results of the LF test along with real-time weather are then used to make daily adjustments to irrigation. To do this CIRRIG calculates two reference values associated with each LF test. One is an adjusted run time (RT_{LF}) and a second is the potential ET value based on the 24-hour of weather recorded prior to the LF test (ET_{LF}). Using the latest RT_{LF} and ET_{LF} as reference values, each day CIRRIG compares the present ET rate (ETo) to the reference ET rate (ET_{LF}) and adjusts irrigation run times accordingly:

$$\textbf{Irrigation run time (min)} = RT_{LF}\,\text{(min)} \times \frac{\text{ETo (inch)}}{ET_{LF}\text{(inch)}}$$

Following the example above:

If ETo for the past 24-hours = 0.20 inch

Irrigation run time = 21.2 minutes X 0.20/0.24 = **17.6 minutes**

Rain

We need to consider not only the amount of rain but also the time of day the rain fell in order to determine if the rain was effective in reducing the water deficit in the substrate. Rain falling soon after irrigation but before significant ET will not be effective, while rain falling at the end of the day after significant ET has occurred will. CIRRIG accounts for rain by doing an hourly balance between ET (loss) and rain (gain). Because ET is calculated on a 24-hr basis, we partition total daily ET into 24 hourly amounts based on the proportion of solar radiation observed for each hour of the 24-hour period. The final balance of water deficit is then output as the irrigation amount needed.

Other adjustments to consider

Irrigation uniformity (DU)* The uniformity of irrigation water distribution within the irrigation zone can be measured by placing irrigation collection cups (approx. 30 cups per 1000 sq ft) through the zone and measuring the volume of water collected after an irrigation event. The distribution uniformity (DU) is calculated as the average of the 25% lowest cup volumes divided by the overall average cup volume. It is desirable that DU is >80. If DU = 80%, for example, 25% of containers will be getting will be getting 20% less water than the amount suggested by the average irrigation application rate (inch/hour). CIRRIG allows the user to increase irrigation amounts so that low areas receive the recommended amount of irrigation. Of course, this means the certain areas will be receiving more than indicated.

LF* (* applies to ET Zone Type) For ET zone type, CIRRIG estimates the amount of irrigation water to apply to resupply water lost during the past day. If no leaching occurs, fertilizer salts can increase to undesirable levels in the substrate over time. For this reason, some leaching is usually recommended, particularly during dry periods of the year. The user can input a desired LF for each ET zone and CIRRIG will increase irrigation rates accordingly. This doesn't apply to LF zone types as LF testing is used directly for determining irrigation run times.

ET versus LF Zone Types

Zone type	Inputs that require monitoring	Labor involved
ET	Percent plant cover Container spacing Plant height and width*	Estimate percent plant cover Measure new spacing when respaced Measure every 2-4 weeks or after pruning
LF	LF test results	Perform LF test 1X every 2-4 weeks

* Plant height and width measurements needed to estimate CF only, can be disregarded if irrigation-capturing ability is "nil".

Routine LF testing is typically more labor-intensive than monitoring plant conditions in the irrigation zone. However, it should be emphasized that LF zone type is likely to be more accurate than ET zone types.

ET zone type estimates ET and CF based on plant production inputs (e.g. percent plant cover, plant height and width, spacing). Accurate irrigation output is dependent upon accurate estimation of these independent variables by CIRRIG functions as well as accurate input of the irrigation application rate (inch/hour). On the other hand, the LF zone type doesn't predict ET and CF. This is because the LF test measures the integrative effect all three factors on the net result (leachate). In other words, the LF test used in LF zone types is a direct measure of irrigation efficiency while estimation of ET and CF in ET zone types is an indirect approach. The user must decide on which zone type suits a particular situation, considering labor and ease of use.
* not entirely true as accurate irrigation application rate affects rain offset calculations

LF tests are more easily conducted with large containers on micro-irrigation. Permanent installation of a leachate collection apparatus is possible with large containers (see LF Testing). The volume of water applied can be easily determined by collecting water from adjacent emitters. LF testing for sprinkler-irrigated crops requires weighing containers before and after irrigation and thus requires more labor.