UNIVERSITY OF FLORIDA
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**Central Florida Research and Education Center**

**Cut Foliage Research Note**

**CFREC Cut Foliage Research Note RH-96-C**[1]

# Determining Irrigation Water Application Rates

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Knowledge of the water application rate of an irrigation system can be very useful. This information is necessary to determine the length of time needed to run the irrigation system in order to replenish soil moisture to a desired level, to apply a given quantity of water to activate a soil-applied chemical, or to inject a chemical so that it is applied at the recommended concentration. The following methods, tables and equations can be used to measure, look up, or calculate irrigation water application rates typical of both *over-the-crop* and *over-the-shadehouse* irrigation systems used in the cut foliage industry.

Irrigation water application rates can be determined physically by placing straight-sided, flat-bottomed containers called catch cans throughout the area to be irrigated, running the irrigation system for a known length of time when winds are calm, and measuring the depth of water in the containers at the end of the irrigation period. Steel cans, like those in which soups and coffee come, with their tops removed serve well as catch cans. Cans should be tall enough or placed high enough so that the crop does not interfere with irrigation water reaching the cans and they should not be placed near the perimeter of the irrigated area if irrigation application rates there are not typical of application rates throughout the rest of the irrigated area. Catch cans should also be placed throughout the irrigated area in sufficient numbers and with care so that variations in application rates due to pressure differences and other variables can be detected. These variations are minimized in properly designed irrigation systems. The catch can technique will give an indication of the uniformity of water distribution, or lack thereof, if enough cans are used and they are properly placed.

The average water application rate can be determined by summing the individual depths of water collected in each can and dividing that total by the number of catch cans used. If you calculate the average depth of water in the catch cans to be **c**" (0.125") and the irrigation system was run for 20 minutes then the application rate is **d**" per hour (0.375"/hr). This application rate is equivalent to about 170 gal/acre/minute and is typical of irrigation systems designed in the 1970s for cold protection of crops like leatherleaf fern [*Rumohra adiantiformis*] and plumosus fern [*Asparagus setaceus*] (Dean, 1966; Harrison and Conover, 1970). If an average of **c**″ (0.125″) is collected in 30 minutes, the application rate is ¼″ per hour (0.25″/hr). This lower application rate of about 113 gal/acre/minute is more typical of irrigation systems designed for cold protection in the 1990s using more rapidly rotating frost-protection sprinklers (Stamps, 1993). For conversions of other application rates from inches per hour to gallons per acre per minute see Table

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1 on page 5. Water application rates (in inches per hour) for other average catch can water depths and irrigation run times can be calculated as:

$$\left( \frac{average\ depth\ (in\ inches)}{minutes\ irrigated} \times \frac{60\ minutes}{hour} \right) = inches/hour$$

Shadecloth over the top of a shadehouse, like crop foliage mentioned above, disrupts the pattern of water reaching the ground when testing the *over-the-shadehouse* irrigation system. Therefore, water catch cans used to measure *over-the-shadehouse* irrigation system water application rates should be placed on the shadecloth on top of the shadehouse. As when testing *over-the-crop* systems, the cans should be placed so that variations in application rates can be detected. Although *over-the-shadehouse* irrigation systems are not typically used for fertigation and chemigation, uniformity of application may be important for obtaining a good ice seal during cold protection.

Another way to determine the water application rate of an irrigation system, if it is equipped with a *calibrated, correctly functioning* flow meter, is to record the initial meter value and run the system for a given amount of time and record the final meter reading. Then, knowing the number of gallons of water applied and the size of the irrigated area, the water application rate (in inches per hour) can be calculated as:

$$\frac{\left( \frac{gallons\ applied}{acres\ irrigated} \times \frac{60\ minutes\ per\ hour}{minutes\ irrigated} \right)}{27{,}154\ gallons\ per\ acre\text{-}inch} = inches/hour$$

An acre-inch (27,154 gallons) is the amount of water necessary to cover an acre with water an inch deep.

Alternatively, if the irrigation system is run at a constant pressure and the flow meter indicates the flow rate in gallons per minute (gpm), then the water application rate (in inches per hour) can be calculated as:

$$\frac{flow\ rate\ (gpm)\ \div\ 453}{acres\ irrigated} = inches/hour$$

The constant 453 was derived by dividing an acre-inch by 60 minutes per hour.

Irrigation water application rates can also be approximated using tables and / or equations if one knows the sprinkler spacing, spacing pattern, and the water application rate for individual sprinklers. The water application rate for individual sprinklers can be determined directly by running the system for a given time interval at a known water pressure and catching all the water coming out of individual sprinklers. One way to do this is to attach a piece of tubing over the sprinkler to divert the water into a container on the ground. The output from several sprinklers at varying distances from the pump should be measured. The volume of water collected is then measured and converted to gallons per minute. For example, if 4.5 gallons of water are collected after two minutes, the application rate is 2.25 gal / sprinkler / minute. Sprinklers applying water at that rate and spaced on 34′ × 34′ centers would apply about 0.19″ / hr. Overall irrigation system water application rates for sprinklers with different flow rates or spacings (in the square pattern and used for over-the-crop irrigation) can be approximated using Table 2 on page 6. Table 3, also on page 6, can be used to estimate water application rates for over-the-shadehouse irrigation systems based on sprinkler spacing on either square or diamond patterns.

In lieu of direct measurements, sprinkler nozzle orifice size and water pressure at the nozzle can be used to estimate sprinkler water application rates. The water pressure at the sprinklers can be measured using a Pitot tube attached to a pressure gauge. The open end of the Pitot tube is placed to intercept the spray of water as it leaves the nozzle orifice and the pressure is read off the gauge. Tables 4 and 5 can be used to estimate individual sprinkler water application rates if one knows the sprinkler nozzle orifice size (often imprinted or color coded on the nozzle) and nozzle water pressure. However, estimates using tables do not reflect variations in flow rates caused by inadequate design, insufficient maintenance, or aging of irrigation systems. For example, orifice diameters may become enlarged over time due to abrasion and/or water pressure in irrigation systems may decrease as deposits build up on the inside walls of pipes. These changes can affect the distribution pattern and water application rate from individual sprinklers and therefore the use of the tables would be inappropriate. Table 4 on page 7 lists approximate sprinkler water application rates based on nozzle orifice size, water pressure, and sprinkler type for rotary impact sprinklers commonly used in *over-the-crop* irrigation of cut foliage crops. The frost-protection sprinklers listed in Table 4 differ from ordinary rotary impact sprinklers by having more rapid rotation rates and non-circular orifices. Using Table 5 on page 8, one can determine the approximate water application rate of sprinklers typically used to apply water *over-the-shadehouses* to seal them with ice during periods when crops must be cold protected.

Irrigation water application rate (in inches/hr) can also be determined for sprinklers spaced in rectangular, square or triangular patterns using the following equation:

$$\frac{gal/\mathrm{min}/sprinkler \times 96.3}{S \times L} = inches/hr$$

$$where\ S = spacing\ of\ sprinklers\ along\ the\ lateral\ (in\ feet)$$
$$and\ L = spacing\ between\ the\ laterals\ (in\ feet)$$

For example, an irrigation system that had sprinklers spaced on 34′ centers with each sprinkler applying 1.5 gallons of water per minute would have an application rate of:

$$\frac{1.5\ gal/min/sprinkler \times 96.3}{34' \times 34'} = \frac{144.4}{1156\ ft^2} = 0.12''\ of\ water/hr$$

The constant 96.3 was derived as follows:

$$\frac{43{,}560\ ft^2/acre \times 60\ minutes/hour}{27{,}154\ gallons/acre\text{-}inch\ of\ water} = 96.3$$

To determine water application rates in terms of gallons/minute the following equation can be used:

$$\frac{inches/hour \times 27{,}154\ gallons/acre\text{-}inch}{60\ minutes/hour} = gallons/acre/minute$$

Continuing the example:

$$\frac{0.12\ inch/hour \times 27{,}154\ gallons/acre\text{-}inch}{60\ minutes/hour} =$$

$$\frac{3{,}258\ gallons/acre/hour}{60\ minutes/hour} =$$

$$54\ gallons/acre/minute$$

Additional information on irrigation management for cut foliage crops can be found in University of Florida / Institute of Food and Agricultural Sciences / Cooperative Extension Service Bulletin 300 – *Irrigation and Nutrient Management Practices for Commercial Leatherleaf Fern Production in Florida.*

## Literature Cited

Dean, R. H. 1966. Use of Water Sprinklers to Protect Fern Against Freeze Damage. Proc. Fla. State Hort. Soc. 79:420-424

Harrison, D. and C. A. Conover. 1970. Irrigation of Leatherleaf and Plumosus Ferns. Univ. of Fla., Inst. of Food and Agr. Sci., Agr. Engineering Mimeo Rpt. 70-7.

Stamps, R. H. 1993. Reducing water use during cut-foliage production. HortScience 28:287–289.

**Table 1**. Conversion of irrigation water application rates from inches per hour to gallons per acre per minute.

| **Inches/hour** | **Gallons/acre/minute** |
|---|---|
| 0.10 | 45 |
| 0.11 | 50 |
| 0.12 | 54 |
| 0.13 | 59 |
| 0.14 | 63 |
| 0.15 | 68 |
| 0.16 | 72 |
| 0.17 | 77 |
| 0.18 | 81 |
| 0.19 | 86 |
| 0.20 | 91 |
| 0.21 | 95 |
| 0.22 | 100 |
| 0.23 | 104 |
| 0.24 | 109 |
| 0.25 | 113 |
| 0.26 | 118 |
| 0.27 | 122 |
| 0.28 | 127 |
| 0.29 | 131 |
| 0.30 | 136 |
| 0.31 | 140 |
| 0.32 | 145 |
| 0.33 | 149 |
| 0.34 | 154 |
| 0.35 | 158 |
| 0.36 | 163 |
| 0.37 | 167 |
| 0.38 | 172 |
| 0.39 | 177 |
| 0.40 | 181 |

**Table 2**. Approximate ***over-the-crop*** irrigation rates (in inches per hour) based on sprinkler water application rate (in gallons per minute) and sprinkler spacing (in feet) for systems with sprinklers spaced in square patterns.

| **Sprinkler spacing (ft)** | **Sprinkler water application rate (gallons per minute)** | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1.00** | **1.25** | **1.5** | **1.75** | **2.0** | **2.25** | **2.5** | **2.75** | **3.0** | **3.25** | **3.5** | **3.75** | **4.0** | **4.25** | **4.5** | **4.75** | **5.0** |
| **30′ × 30′** | 0.11 | 0.13 | 0.16 | 0.19 | 0.21 | 0.24 | 0.26 | 0.29 | 0.32 | 0.35 | 0.37 | 0.40 | 0.43 | 0.45 | --- | --- | --- |
| **32′ × 32′** | 0.09 | 0.12 | 0.14 | 0.16 | 0.19 | 0.21 | 0.23 | 0.26 | 0.28 | 0.31 | 0.33 | 0.35 | 0.38 | 0.40 | 0.42 | 0.45 | --- |
| **34′ × 34′** | 0.08 | 0.10 | 0.12 | 0.15 | 0.17 | 0.19 | 0.21 | 0.23 | 0.25 | 0.27 | 0.29 | 0.31 | 0.33 | 0.35 | 0.37 | 0.40 | 0.42 |
| **36′ × 36′** | --- | 0.09 | 0.11 | 0.13 | 0.15 | 0.17 | 0.19 | 0.20 | 0.22 | 0.24 | 0.26 | 0.28 | 0.30 | 0.32 | 0.33 | 0.35 | 0.37 |
| **38′ × 38′** | --- | --- | 0.10 | 0.12 | 0.13 | 0.15 | 0.17 | 0.18 | 0.20 | 0.22 | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.32 | 0.33 |
| **40′ × 40′** | --- | --- | --- | 0.11 | 0.12 | 0.14 | 0.15 | 0.17 | 0.18 | 0.20 | 0.21 | 0.23 | 0.24 | 0.26 | 0.27 | 0.29 | 0.30 |

**Table 3**. Approximate ***over-the-shadehouse*** irrigation rates (in inches per hour) based on sprinkler water application rate (in gallons per minute) and sprinkler spacing (in feet) for systems with sprinklers spaced in square or diamond patterns.

| **Sprinkler spacing (ft)** | **Sprinkler water application rate (gallons per minute)** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **3.50** | **3.75** | **4.00** | **4.25** | **4.50** | **4.75** | **5.00** | **5.25** | **5.50** | **5.75** | **6.00** | **6.25** | **6.50** | **6.75** | **7.00** | **7.25** |
| **Square pattern** | | | | | | | | | | | | | | | | |
| **48′ × 48′** | 0.15 | 0.16 | 0.17 | 0.18 | 0.19 | 0.20 | 0.21 | 0.22 | 0.23 | 0.24 | 0.25 | 0.26 | 0.27 | 0.28 | 0.29 | 0.30 |
| **60′ × 60′** | 0.09 | 0.10 | 0.11 | 0.11 | 0.12 | 0.13 | 0.13 | 0.14 | 0.15 | 0.15 | 0.16 | 0.17 | 0.17 | 0.18 | 0.19 | 0.19 |
| **68′ × 68′** | 0.07 | 0.08 | 0.08 | 0.09 | 0.09 | 0.10 | 0.10 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.14 | 0.14 | 0.15 | 0.15 |
| **Diamond pattern** | | | | | | | | | | | | | | | | |
| **48′ × 60′** | 0.23 | 0.25 | 0.27 | 0.28 | 0.30 | 0.32 | 0.33 | 0.35 | 0.37 | 0.38 | 0.40 | 0.42 | 0.43 | 0.45 | 0.47 | 0.48 |
| **60′ × 72′** | 0.16 | 0.17 | 0.18 | 0.19 | 0.20 | 0.21 | 0.22 | 0.23 | 0.25 | 0.26 | 0.27 | 0.28 | 0.29 | 0.30 | 0.31 | 0.32 |

**Table 4**. Approximate water application rates based on nozzle orifice size, water pressure and type of rotary impact sprinklers used for ***over-the-crop*** irrigation.

| Sprinkler nozzle orifice size | Nozzle water pressure in pounds per square inch | Approximate gallons per minute | |
|---|---|---|---|
| | | Conventional sprinklers | Frost-protection sprinklers |
| 3/32" | 25 | --- | 1.32 |
| | 30 | --- | 1.45 |
| | 35 | 1.50 | 1.57 |
| | 40 | 1.61 | 1.67 |
| | 45 | 1.71 | 1.78 |
| | 50 | 1.80 | 1.87 |
| 7/64" | 25 | 1.73 | 1.81 |
| | 30 | 1.89 | 1.98 |
| | 35 | 2.05 | 2.14 |
| | 40 | 2.20 | 2.28 |
| | 45 | 2.32 | 2.42 |
| | 50 | 2.44 | 2.55 |
| 1/8" | 25 | 2.21 | 2.36 |
| | 30 | 2.44 | 2.58 |
| | 35 | 2.66 | 2.79 |
| | 40 | 2.86 | 2.98 |
| | 45 | 3.04 | --- |
| | 50 | 3.22 | --- |
| 9/64" | 25 | 2.83 | --- |
| | 30 | 3.10 | --- |
| | 35 | 3.36 | --- |
| | 40 | 3.61 | --- |
| | 45 | 3.82 | --- |
| | 50 | 4.03 | --- |
| 5/32" | 25 | 3.43 | --- |
| | 30 | 3.78 | --- |
| | 35 | 4.10 | --- |
| | 40 | 4.40 | --- |
| | 45 | 4.68 | --- |
| | 50 | 4.95 | --- |

**Table 5**. Approximate water application rates based on nozzle orifice size and water pressure of rotary impact sprinklers used for ***over-the-shade-house*** irrigation.

| Sprinkler nozzle orifice size | Nozzle water pressure in pounds per square inch | Approximate gallons per minute |
|---|---|---|
| **9/64″** | 25 | 2.9 |
| | 30 | 3.2 |
| | 35 | 3.4 |
| | 40 | 3.6 |
| | 45 | 3.8 |
| | 50 | 4.0 |
| **5/32"** | 25 | 3.5 |
| | 30 | 3.8 |
| | 35 | 4.2 |
| | 40 | 4.5 |
| | 45 | 4.7 |
| | 50 | 5.0 |
| **11/64"** | 25 | 4.3 |
| | 30 | 4.6 |
| | 35 | 5.0 |
| | 40 | 5.4 |
| | 45 | 5.7 |
| | 50 | 6.0 |
| **3/16"** | 25 | 5.0 |
| | 30 | 5.5 |
| | 35 | 6.0 |
| | 40 | 6.4 |
| | 45 | 6.8 |
| | 50 | 7.2 |