

Uniformity of Sprinkler and Microirrigation Systems for Nurseries¹

D.Z. Haman, A.G. Smajstrla and D.J. Pitts²

Nursery production in Florida requires irrigation. The majority of the systems found in container and field nurseries are pressurized irrigation systems, which are sprinklers or some type of microirrigation. Most microirrigation systems are found in field nurseries or in the larger, 3 gallon and more, container production systems. The majority of Florida nurseries, especially those that produce plants in smaller containers, use overhead sprinkler systems.

Two terms which describe the performance of irrigation systems are **uniformity** and irrigation system **application efficiency**. A typical application efficiency of a well-designed and managed sprinkler irrigation system in a container nursery is only about 25% due to necessary container spacing. This efficiency will be further reduced by nonuniform water application. For that reason, it is critical that the irrigation system be designed for high uniformity and that this high uniformity be maintained throughout the life of the system.

Concept of Uniformity in Irrigation

The coefficient of uniformity is an indicator of how equal (or unequal) the application rates are throughout the nursery. A low coefficient of uniformity indicates that the application rates are very different, while a high coefficient indicates that they are very similar in value and the water is distributed evenly to all plants.

Low coefficients of uniformity in sprinkler or microirrigation systems can be due to numerous factors, such as:

- Inadequate selection of delivery pipe diameters (submains, manifolds, and laterals).
- Inadequate selection of sprinkler head and nozzle in sprinkler irrigation or emitters in microirrigation.
- Inadequate sprinkler overlap in sprinkler irrigation, or too large spacings that are between emitters in line source emitters in microirrigation.

1. This document is BUL321, one of a series of the Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date June 1997. Reviewed June 2003. Visit the EDIS Web Site at <http://edis.ifas.ufl.edu>.

2. D.Z. Haman, associate professor, A.G. Smajstrla, professor, Department of Agricultural and Biological Engineering, Gainesville, FL; D.J. Pitts, assistant professor, Southwest Florida Research and Education Center, Immokalee, FL, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

- Wind effects on sprinklers and microsprinklers.
- Changes in system components with time, such as changes in pump efficiency, pressure regulation, or nozzle size.
- Nozzle or emitter clogging.
- Too high or too low operating pressure.

Field Evaluation of Nursery Irrigation Systems

The performance of a sprinkler or microirrigation systems can be evaluated by measuring **operating pressures, application rates, and the uniformity of water application under nursery conditions**. Knowledge of these factors is important in order to determine the causes of poor uniformities. They also allow for identification of changes in design, installation, and maintenance which can improve water application uniformity. The above measurements are also necessary for efficient and effective irrigation system management. Field evaluation of the system should be conducted at least annually to monitor changes in system performance and to identify the needs for maintenance or repair.

Measuring Operating Pressures

It is important to monitor pressures at various critical points in a irrigation system. A well-designed and well-installed system will have permanent pressure gauges at the critical points such as the pump outlet, both sides of the filtration system, and at the inlet to each irrigated zone. They allow the system manager to monitor the performance of the system and help to pinpoint any problem in the system. For example, low pump discharge pressure may be the result of pump wear, insufficient impeller speed, excessive drawdown, or may be an indication of problems downstream of the pump such as broken pipe, too many zones running at the same time, or excessive discharge from the nozzles. These gauges should be checked periodically for proper functioning and replaced as needed.

Sprinkler Irrigation Systems

A sprinkler is designed to operate efficiently over a specific range of pressures, and its performance is reduced at other pressures. Excessive pressures produce very small droplets, resulting in fogging, irregular rotation, and higher water application near the sprinkler. Operating pressures that are too low produce a doughnut-shaped spray pattern with very little water near the sprinkler. The system uniformity will definitely be affected if sprinklers aren't operated within the range of pressures specified by the manufacturer.

Periodically, operating pressures within each zone should be tested to evaluate system performance. They can be measured at the sprinkler nozzles using pitot tube attached to a pressure gauge. The pitot tube should be placed about 1/8-inch from the nozzle and adjusted until the highest constant pressure can be read. This procedure is illustrated in Figure 1. Pressures should be recorded at various points of the irrigation zone with the close and distant sprinklers included in the test.

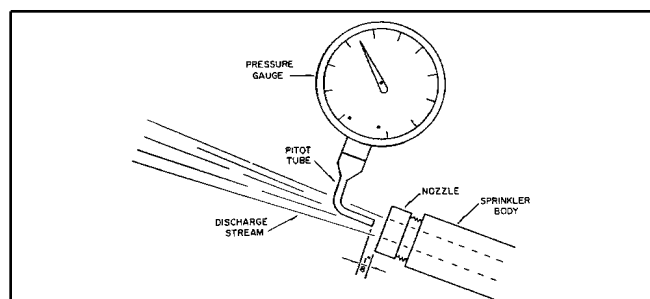


Figure 1 .

Microirrigation Systems

Some microirrigation systems use pressure-compensating emitters or have pressure or flow regulation at the inlet to each lateral to minimize pressure variation throughout the system. However, most systems have pressure control only at the inlet to the manifolds and use emitters with flow rate dependent on the pressure within the line. In this case, large variation in pressure can have a significant impact on the uniformity of water distribution throughout the system.

Pressures can be measured using a portable pressure gauge equipped with a flexible tube and a

fitting which allows replacement of an emitter with a gauge. The pressure distribution in the lateral line with a large number of emitters (more than 10) will not be significantly affected by blocking one emitter while the others continue to flow. Some portable pressure gauges are manufactured with a needle on a flexible tube for direct insertion into the lateral line. This method functions well for laterals constructed out of the heavier materials with the walls at least 0.04 inches thick, which are typically used in nursery systems. In these lines, the needle opening tends to close when the needle is removed. In addition, pressures should be measured at the inlet to the laterals and at the end of laterals to determine pressure drop along the lines.

Measuring Application Rates

To schedule the irrigation events it is necessary to know the sprinkler or emitter application rates. The measurement of application rates under field conditions will verify the design of the system. Periodic measurements of the application rates will also determine whether changes in application rates occurred with time. This type of test should be performed at least once each season.

Sprinkler Application Rates

The application rate for sprinkler irrigation systems is expressed in inches/time. It refers to the depth of water applied over an irrigated area during an irrigation event. Basically, there are three techniques to determine the water application rate of a sprinkler system:

- The water flow rate into the zone can be measured and the application rate can be calculated based on the area of this zone,
- The application rate can be calculated from measurement of the average flow rate and area covered by each sprinkler, and
- The application rate can be measured directly with catch cans or rain gauges in the nursery.

It is recommended that each irrigation zone includes a flow meter for monitoring the amount of water applied during the irrigation event. This flow meter can be used to determine the water flow rate

(gpm) to the zone. The flow rate per acre can be calculated from the size of the zone (gpm/acre). Based on the fact that each acre-inch is approximately equal to 27,000 gal of water, the application rate (inches/hr) can be determined (Example 1).

Example 1. The flow rate to a 2-acre zone is 200 gpm. What is the application rate in inches/hr to this zone? (1 acre-inch of water is approximately equal to 27,000 gal)

$$200 \text{ gal/min} / 2 \text{ acres} = 100 \text{ gpm/acre}$$

$$100 \text{ gal/min-acre} * 60 \text{ min} = 6000 \text{ gal/hr-acre}$$

$$27,000 \text{ gal/ac-in} = 0.22 \text{ inches/hr}$$

For regularly spaced sprinklers, the application rate can be calculated from the average sprinkler discharge and the spacing between the sprinklers using Equation 1 :

$$AR = 96.3 \cdot q / (S \cdot D) \tag{1}$$

where:
 AR - application rate, expressed in inches/hr.
 q - sprinkler discharge rate in gallons per minute (gpm).
 S - sprinkler spacing along the lateral in ft.
 D - sprinkler spacing between laterals in ft.

Equation 1 .

Example 2. Using Equation 1 , calculate the application rate for sprinklers with a discharge of 3 gpm spaced on a 30 ft x 30 ft rectangular pattern.

$$AR = 96.3 * 3 / (30 * 30) = 0.32 \text{ inches/hr}$$

Sprinkler discharge rates can be determined by directly measuring the volume discharged per unit time in the nursery. A flexible hose, which can be slipped over the sprinkler can be used to redirect the water into a graduated cylinder or other container of known volume. Also, specification tables can be used for predicting the sprinkler flow rates after measuring the pressure at the nozzle with a pitot tube; however, this applies only to new nozzles since the discharge may change with nozzle wear. The nozzles should be checked for wear or distortion with a drill bit having the diameter specified for the nozzle.

The application rate can be also measured directly with catch cans or rain gauges. The application rate is the average depth measured per unit time of system operation. It is recommended that 16 to 24 cans be used for this measurement. A typical layout of the cans is presented in Figure 2 . These

measurements should be repeated in a few representative locations of the nursery as demonstrated in Figure 3 . Catch cans should all be of the same size and shape, and they should be located in a regular grid pattern and clear from any vegetation. Preferably, they should be placed close to the soil surface but if it is necessary, they can be elevated above vegetation. A few drops of light weight oil can be placed in the cans before the test in order to reduce evaporation during the tests. In Figure 2 , the depth of measured water is presented below each can. The numbers in parentheses represent the absolute values of deviation from the average measurement. These values are used in the evaluation of system uniformity.

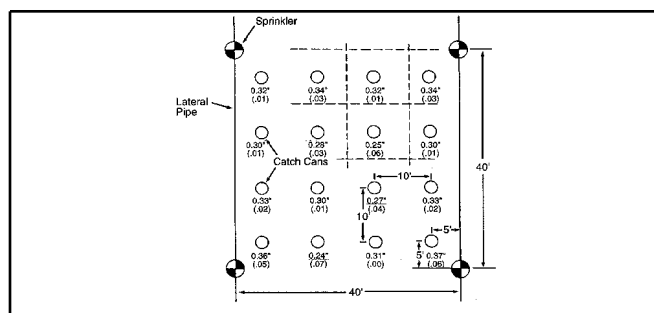


Figure 2 .

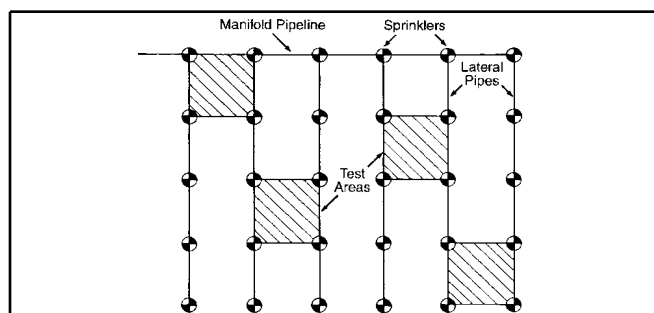


Figure 3 .

Emitter Discharge Rates

Microirrigation systems apply water in a discrete manner, without covering the entire area of the nursery. It is much easier to discuss the discharge rate for these system in terms of volume/time applied by each emitter rather than an application rate in inches/time as in overhead sprinkler systems. The flow rates from emitters must be known for irrigation scheduling and management. The tests should be performed to verify design and installation and changes in application rates that may occur with time. The techniques to perform these tests in the

nursery are similar to techniques for measurement of discharge rates from the sprinkler nozzles. The following measurements can be used to determine emitter flow rates:

- Measuring water application into the zone and calculating the rate of application from number of emitters within the zone.
- Collecting a known volume of water from randomly selected emitters throughout the system and calculating the flow rate by dividing the volume by time in which it was collected.

Nursery Evaluation of Sprinkler Irrigation Uniformity

Uniformity of water application with sprinkler irrigation systems is usually reported as either the Distribution Uniformity (DU) or Christiansen's Uniformity Coefficient (UC). Distribution Uniformity is based on the low quarter of irrigated area. This implies that the lowest 1/4 of the measurements is used for the calculations (Equation 2).

$$DU = \frac{\text{avg. low qt. depth}}{\text{overall avg. depth}} \cdot 100\% \quad (2)$$

Equation 2 .

Example 3. To demonstrate how Equation 2 is used, DU is calculated for the measurements presented in Figure 2 . The average of all measurements is 0.31 in.

$$DU = ((0.24 + 0.25 + 0.27 + 0.28)/4) / 0.31 * 100\% = 83.9\%$$

Another widely-used method is Christiansen's Uniformity Coefficient which is expressed in Equation 3 .

$$UC = 1 - \frac{\text{avg. deviation from avg. depth}}{\text{overall avg. depth}} \cdot 100\% \quad (3)$$

Equation 3 .

Example 4. Again, using measurements presented in Figure 2 , the average deviation can be calculated by averaging the absolute values of the differences between each measured depth and the average depth for 16 points (0.46/16 = 0.029 in). This is divided by the overall average depth (0.31 in). From Equation 3:

$$UC = (1 - (0.029 / 0.31)) * 100\% = 92.7\%$$

Normally, DU values are lower than the UC values for the same set of data. For high value crop and any system where chemicals are applied with irrigation water, the uniformities should be high (DU greater than 80%, or UC greater than 87%). When coefficients fall below the acceptable values for a given system the repairs and adjustments should be performed as soon as possible.

Field Evaluation of Uniformity of Nursery Microirrigation System

Standards for the uniformity of water application for microirrigation systems have been developed by the American Society of Agricultural Engineers (ASAE). Acceptable uniformity ranges for various microirrigation systems are presented in Table 1 . These ranges represent the economically efficient range of uniformities. Design for higher uniformities than those shown will increase the initial system cost without sufficient justification in plant performance due to improved uniformity. However, designs for lower uniformities will result in reduced production and/or wasted water and fertilizes.

The uniformity must be higher for widely spaced plants, where each individual emitter serves one plant only. In production systems where each plant has access to two or more emitters, the variation among emitter discharges is less critical. Also, because steeper slopes result in more costly designs, lower uniformities are permitted to balance system initial costs. The uniformity of water application can also be improved by the use of more expensive, pressure compensating emitters which are characterized by the same flow rate under significant pressure variation. Pressure compensating emitters are frequently used where there is significant variation in topography of the nursery or other conditions which make it difficult to design the lateral lines within permissible flow variation.

The method of uniformity evaluation for microirrigation systems presented below provides a quick nursery test which does not require any specialized equipment. This test can be used by irrigation system designers, installers, purchasers, or managers. The method is based on statistical

evaluation. Uniformity of the irrigation system (U) is defined in statistical terms (Equation 4).

$$U = 100\% (1.0 - V) \quad (4)$$

Equation 4 .

In this equation, V is the statistical coefficient of variation which is a measure of the variability of the individual emitter flow rates from the average emitter flow rate. It is the standard deviation of the individual flow rates divided by the average flow rate. Since this equation expresses uniformity in relative terms the method can be used regardless of the magnitude of emitter flow rates.

The procedure requires a minimum of 18 measurements to evaluate an irrigation system or a zone of an irrigation system. These 18 measurements should include the extreme conditions encountered in the system such as entrances to the laterals, distant end, midpoints, etc. It is not necessary to measure flow rates from the emitters tested. Rather, the time to fill a specific container (a constant volume), such as soft drink bottle, can be used. The time required to fill the container can be accurately measured using a watch with a second hand. Therefore, no special equipment is necessary to perform this test of uniformity at the nursery.

All 18 times required to fill the container should be recorded. First, the largest 1/6 of the measurements, T_{max} (in this case 3) should be added together. Then, the smallest 1/6 of measurements, T_{min} should be added. These two numbers (T_{max} and T_{min}) are used in Figure 4 to determine the uniformity of water application.

Example 5. For the data listed in Table 2 , we have 18 measurements of time. The three greatest times (1/6 of all measurements) recorded are 107 sec, 110 sec, and 108 sec. The sum of these three times, T_{max} , is 325 sec. The smallest times recorded were 89 sec, 91 sec, and 87 sec. The sum of these three measurements, T_{min} , is 267. From Figure 4 , the intersection of the vertical line drawn at T_{min} and the horizontal line drawn at T_{max} falls between 90% and 100% which can be interpreted as being an "Excellent" uniformity.

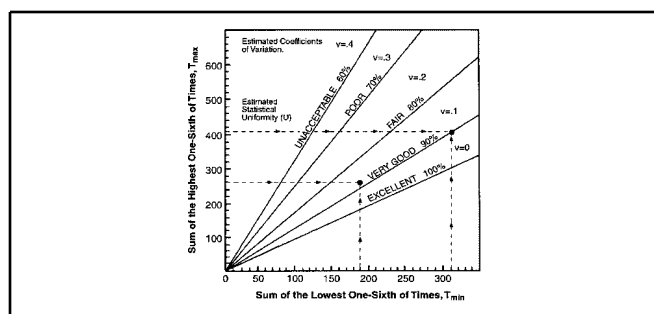


Figure 4 .

The method presented above is a statistical method. The degree of certainty that the values read from Figure 4 are accurate changes depending on the degree of variation among the measurements. If the uniformity calculated from 18 samples is 90%, the confidence limits for this uniformity are $\pm 3.5\%$ (Table 3). This means that we can be confident (with 95% certainty) that if we need 90% uniformity, the actual field uniformity would be in the range of 86.5 to 93.5%. However, as indicated in Table 3 , we are less confident of the results when the uniformity is low. If the first 18 measurements indicate low uniformity, the number of measurements should increase to 36 or 72 depending upon the calculated uniformity. Note that T_{max} and T_{min} are then calculated from 1/6 of the measurements which is 6 and 12, respectively.

Field procedure summary for evaluation of nursery microirrigation system uniformity:

1. Start the system and run it at its design operating pressure long enough to purge air from the lines.
2. Measure the amount of time required for each of 18 (or more) emitters to fill a container. Be sure that the emitters sampled represent all parts of the irrigation system.
3. Compute T_{max} by adding 3 longest times (or 1/6 of the number of emitters measured) required to fill the container.
4. Compute T_{min} by adding the 3 shortest times (or 1/6 of the number of emitters measured) required to fill the container.
5. From Figure 4 determine the field uniformity at the intersection of a vertical line drawn from T_{min} and horizontal line drawn from T_{max} .

6. If the uniformity is too low or if the confidence interval is too great, take more field data until the desired confidence interval is obtained.

References

Smajstrla, A.G., B.J. Boman, G.A. Clark, D.Z. Haman, D.J. Pitts and F.S. Zazueta. 1990. Field Evaluation of Microirrigation Water Application Uniformity. IFAS Ext. Bul. 265, University of Florida, Gainesville, FL.

Smajstrla, A.G., B.J. Boman, G.A. Clark, D.Z. Haman, D.J. Pitts and F.S. Zazueta. 1990. Field Evaluation of Irrigation Systems: Solid Set or Portable Sprinkler Systems. IFAS Ext. Bul. 266, University of Florida, Gainesville, FL.

ASAE. 1989a. Field evaluation of micro irrigation systems. EP405.1. ASAE Standards. Amer. Soc. Ag. Eng., St. Joseph, MI.

ASAE. 1989b. Design and installation of micro irrigation systems. EP409. ASAE Standards. Amer. Soc. Ag. Eng., St. Joseph, MI.

Smajstrla, A.G., D.S. Harrison and F.S. Zazueta. 1984. Field evaluation of trickler irrigation systems: Uniformity of water application. IFAS Ext. Bul. 195. University of Florida, Gainesville, FL.

Merriam, J.L. and J. Keller. 1978. Farm Irrigation System Evaluation: A Guide for Management. Utah State University. Logan, UT. 271 pages.

Table 1.

Table 1. Acceptable uniformities for microirrigation systems designed to provide all plant's water requirements in times of drought (ASAE).		
Emitter Type	Soil Slopes	Uniformity Range (%)
Point source on widely spaced (greater than 13 ft) plants	flat	90 - 95
	steep	85 - 90
Point source on closely spaced (less than 13 ft) plants	flat	85 - 90
	steep	80 - 90
Line source on row production	flat	80 - 90
	steep	75 - 85

Table 2.

Table 2. Sample data set for Figure 1 example.		
Data Point	Pressure (psi)	Measured Time (sec)
1	26	65
2	27 (high #2)	62 (low #1)
3	22 (low #3)	80
4	25	74
5	21 (low #1)	90 (high #1)
6	26	68
7	26	64 (low #2)
8	24	76
9	25	72
10	28 (high #1)	64 (low #3)

Table 2.

11	25	67
12	24	81
13	23	86 (high #3)
14	24	77
15	21 (low #2)	88 (high #2)
16	25	72
17	24	78
18	27 (high #3)	66

Table 3.

Table 3. Confidence limits (95% level) on statistical uniformity estimates.					
Uniformity US (%)	Number of Samples				Variability Vqs
	18	36	72	144	
90	3.5	2.4	1.7	1.2	0.1
80	7.3	5.0	3.4	2.4	0.2
70	11.2	7.8	5.4	3.8	0.3
60	16.2	10.9	7.6	5.4	0.4