ENH895

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Implementation Guide for Container-Grown Plant Interim Measure[1]

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Introduction

The purpose of this guide is to provide detailed information for use by greenhouse and nursery operators conducting specific fertilization and irrigation management practices to establish a waiver of liability for recovery costs resulting from nitrate contamination of ground water. This waiver is facilitated by the 1994 legislation (Chapter 576.045, F.S.) that provided for interim measures. Interim measures are the best available information at this time. The interim measure document may be viewed on the World Wide Web (http://www.fngla.org/ , http://www.tbwg.org, or http://www.floridaagwaterpolicy.com). Even though this publication was written specifically to help nursery operators implement fertilization and irrigation practices for the management of nitrate nitrogen, the concepts and principles are applicable to other nutrients, such as phosphorus, and potential groundwater contaminants.

Nutrient Management

Container Nutritional Testing

Obtaining representative samples for evaluation of the container nutritional status is an important part of the testing process. Nutrients are removed from the substrate by liquid extraction that may be performed by nursery operators or performed by laboratory personnel. If laboratory personnel perform the nutrient extraction, the nursery operator will remove substrate from several containers and send substrate to laboratory where the liquid extraction of nutrients from the substrate is performed. Several samples are extracted in order to obtain average results representative of the nutritional status of the crops under consideration. Not all laboratories use the same procedures, so test results can differ between laboratories. Consequently, interpretation of results is very important.

Nursery operators may perform nutrient extractions rather than sending substrate to laboratories. The methods commonly used by nursery

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2. Thomas H. Yeager, Associate Professor, Environmental Horticulture Department, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611. The use of trade names in this publication is solely for the purpose of providing specific information. It is not a guarantee or warranty of the products named, and does not signify that they are approved to the exclusion of others of suitable composition.

operators to obtain liquid extracts include Pour-Through (PT) or leachate collection, Suction Cup Lysimeter (SCL), and Saturated Substrate Extraction (SSE). Liquid extracts from container substrates are needed for determination of nitrate nitrogen NO_3-N, electrical conductivity (EC), pH, and other nutritional parameters. EC and pH are routinely evaluated on liquid extracts obtained by nursery personnel. However, the liquid extracts may be sent to a laboratory for detailed analyses. Substrate nutrient extraction methods other than those mentioned here may be used, but interpretation of results may vary with extraction method and nutrient requirement of crops.

General Sampling Considerations

Nutrients may accumulate in specific locations in substrate due to irrigation patterns and fertilization methods. Therefore, one isolated sample will not give an accurate representaof the nutristatus of the substrate. In addition, plants grown in different substrates, plants receiving different irrigation schedules, and plants fertilized differently should be sampled independently.

Construct a diagram of the nursery growing beds and divide the nursery into blocks (groups of plants), which contain plants that are treated and grown under similar conditions. For example, plants grown in the same substrate and irrigated similarly would comprise a block. Plants that receive less irrigation water, or that are grown in a different substrate, or that have a different fertilization schedule would comprise another block. The intent of such blocking is to group plants treated similarly that can be represented by a single SSE sample (composite of 5-20 sub samples), or three to five PT or SCL samples. Results from these samples should apply logically to all plants treated similarly.

For example in Figure 1, if blocks 1-4 were each composed of different crops (i.e. plants treated differently), samples would be obtained from each block each sampling time by sampling randomly from beds or groups 1-6 within each block. If blocks 1-4 were each composed of the same crops, (plants treated similarly) samples could be randomly selected from beds 1-6 in blocks 1-4.

Samples from container-grown plants in greenhouses may be obtained in a similar manner. In this case, each block might represent a different greenhouse, while beds would represent greenhouse benches.

After the decision has been made to perform the extractions on-site, one or more of the following three extraction procedures can be used.

Sampling for Pour-through (PT) and Suction Cup Lysimeter (SCL)

Leaching or extract should be collected randomly from three to five containers to obtain an average value for the three to five individual samples. This average value should be representaof the growth substrate nutristatus for the crops or plants under consideration.

Pour-through Extraction (PT)

This procedure is usually only practical for containers with volumes of five gallons or less because larger containers are too heavy to lift. The PT enables rapid sample collection without removing substrate from individual containers or groups of small containers that form cavities in trays. To conduct the procedure, irrigate plants and allow time for drainage (2 hours to overnight) and equilibrium of moisture and nutrients within the substrate. Uniform substrate moisture levels are critical to obtaining consistent results with time. After this equilibration period, the container must be elevated above a collection vessel so that leachate or extract is not contaminated with debris or salts on the perimeter of the container. The bottom or sides of the container or flat should not be wiped before collecting leachate. Using a circular motion, apply just enough distilled water or irrigation water to the substrate surface to yield 30 to 50 ml (1.0 to 2.0 oz) of leachate (liquid) from the container or flat (Figure 2). See Table 1 for approximate volumes to apply. Leachate samples should be filtered before sending them to a laboratory.

Table 1. Approximate volume of water to apply to obtain 50 ml (2.0 oz) of PT extract.

	Water to apply	
Container size	**milimiters**	**ounces**
4-6 inch pot	75	2.5
6 1/2 azalea pot	100	3.5
1 quart	75	2.5
1 gallon	150	5
3 gallon	350	12
5 gallon	550	18.5
Cavities or cells in flats	50	2

Containers should be at container capacity for about 30 minutes (for cavities or cells in flats and small containers) to 2 hours (for larger containers) before applying water.

The volumes of water are estimates so actual amount may vary depending on crop, substrate, or environmental conditions. Adapted from 1, 2, 3of PourThru, Whipker et al. 2001).

Suspension Cup Lysimeter Extraction (SCL)

*This procedure enables rapid sample collection without removing substrate from large containers (greater than 5 gallons) or physically moving containers. Lysimeters are about 24 inches long and 2 inches in diameter with a porous ceramic cup (one-half bar air entry) on the end (*Figure 3*). Lysimeters are positioned about 2 inches from the container side and remain in position during crop production. A hole should be made in the substrate slightly smaller than the lysimeter diameter so that the lysimeter fits snug within the substrate. One to 2 hours after irrigation, a vacuum pump is used to create a vacuum within the lysimeter tube. After about 15 minutes, the vacuum results in liquid extracted from the substrate collecting in the lysimeter tube. Extract is removed from the lysimeter using a syringe fitted with an extension tube. Once the extract is removed from the lysimeter, nutrient analyses can be conducted. Lysimeters (model 1900 L24) and accessories may be obtained from Soil Moisture Equipment Company, Santa Barbara, CA 03105 (*http://www.soilmoisture.com*).*

Sampling for Saturated Substrate Extract

Using a soil sample probe (Figure 4) or a pointed object such as a spatula, substrate is removed from each of 5 to 20 containers representative of the crop or plants under consideration. Blend the cores together into one uniform sample. The upper layer of substrate cores may be disturbed and should be discarded. Save about 200 mL (1/2 pint) of the total sample for saturation.

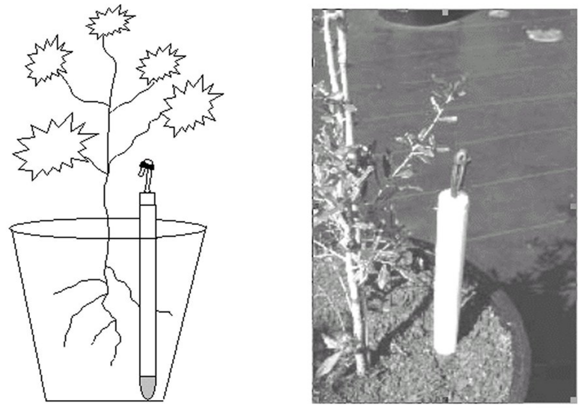

Figure 3. Suction Cup Lysimeter (SCL) placed vertically in container larger than 5-gallons.

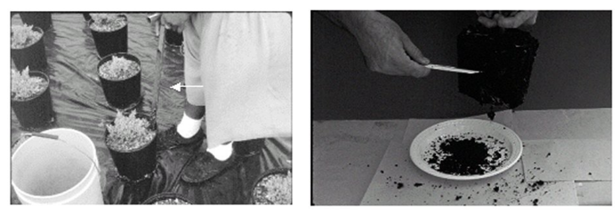

Figure 4. Suction Cup Lysimeter (SCL) placed vertically in container larger than 5-gallons.

Saturated Substrate Extract (SSE)

The saturated substrate extract procedure may be conducted with any size containers. The procedure involves removing substrate randomly from 5-20 containers and saturating about a 200-mL (0.8-cup) volume of substrate with distilled water. Slowly add distilled water while stirring until the substrate surface is shiny, but no free water moves across the surface when the beaker is tilted. For best equilibration, allow the saturated sample to sit for 2 to 6 hours. Extract the substrate solution by vacuum filtering the saturated substrate (Figure 5).

Interpretation of Extract Results

Laboratories conducting nutrient extractions can provide an interpretation for their extract results. Interpretations are used to manage fertilizer applications so that desirable nutrient levels are

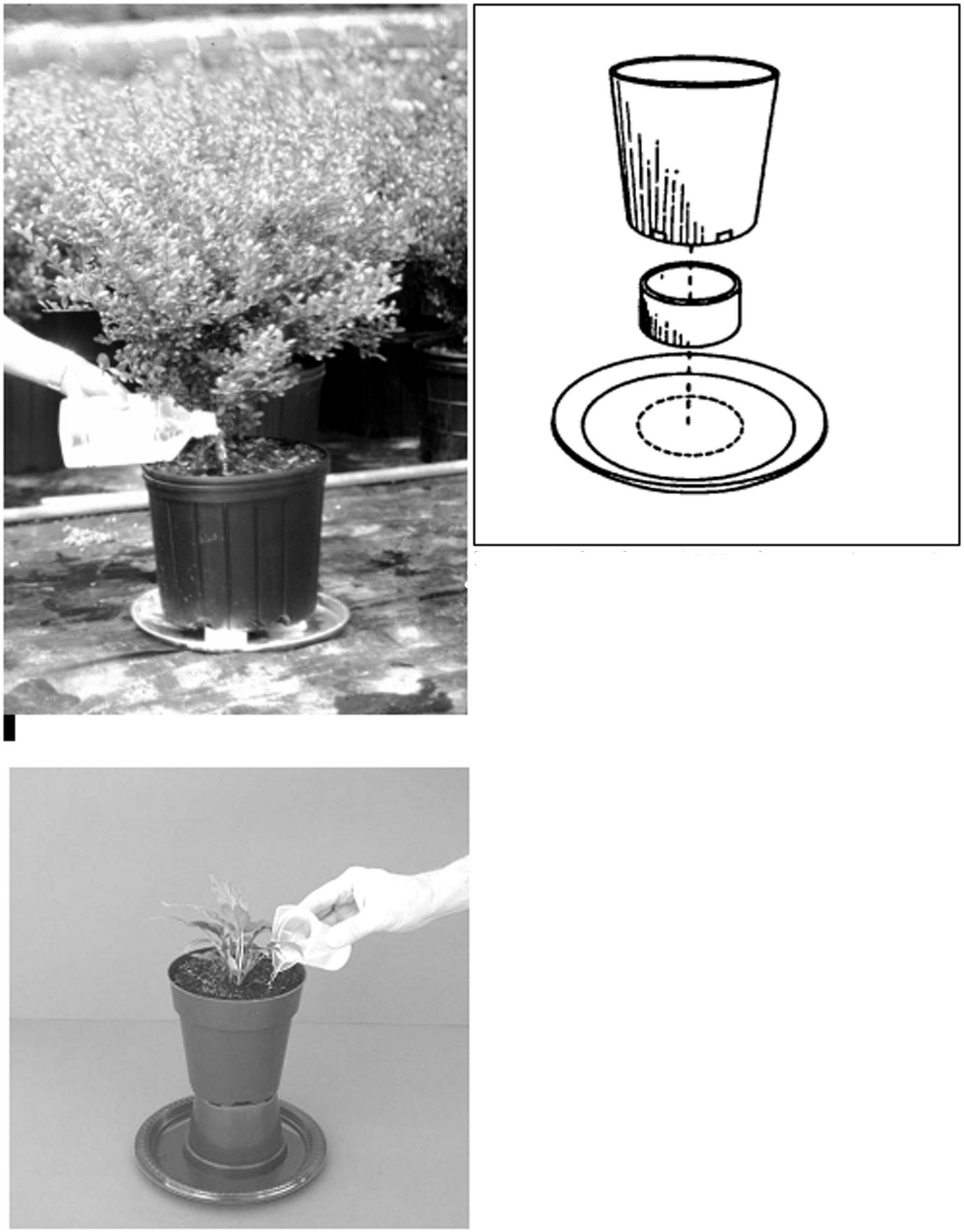

Figure 2. In the PT extraction procedure, the container must be elevated in order not to contaminate the leachate or extract.

maintained in the substrate. Nursery personnel conducting their own extraction may use the values in Table 2 as a guide. Nutrient levels given in Table 2 are for the PT, SCL, and SSE for most container-grown plants. However, adjustmust be made for plants known to be sensitive to fertilizer additions. The guidelines given in Table 2 are based on using distilled water for the nutrient extraction procedure. If irrigation water is used for the PT or SCL extraction, background levels of nutrients in the irrigation water should be subtracted from the results of extraction before making interpretations based on

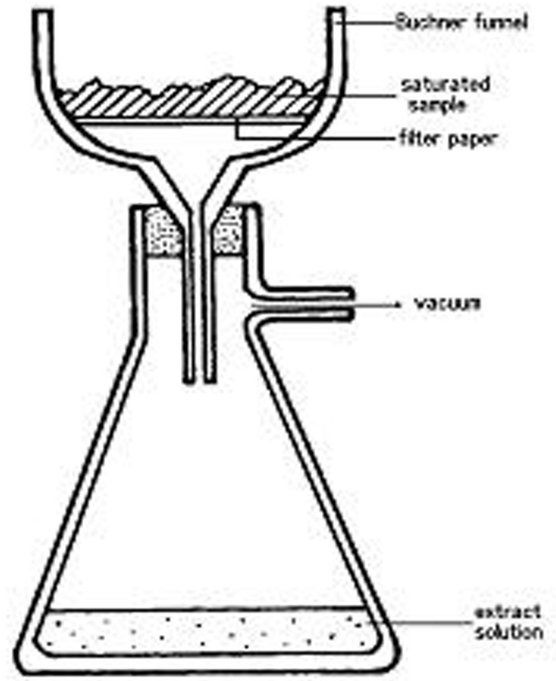

Figure 5. Vacuum filtering the saturated substrate to obtain the extract.

Table 2 values. In addition, removing substrate from the containers as required for the SSE, may damage some controlled-release fertilizer prills. This can result in excessive salts in the extract and erroneous EC interpretations. Meters needed to make EC determinations are available from several companies (Table 3). Meters should be calibrated prior to use. Calibration solutions are available from companies that supply meters. Calibration details are given in *Diagnostic and Monitoring Procedures for Nursery Crops* (Ingram, et al., 1990).

Table 2. Desirable electrical conductivity (EC) and nitrate nitrogen (NO_3-N) levels for container substrates fertilized with controlled-release and/or solution fertilizer.

Analysis	Woody plants[z]	Bedding and interior plants
Electrical condS/m (mmhos/cm)	0.8 to 1.5	1.5 to 2.8
Nitrate-N, mg/L (ppm)	50 to 100	100 to 200

Table 2. Desirable electrical conductivity (EC) and nitrate nitrogen (NO_3-N) levels for container substrates fertilized with controlled-release and/or solution fertilizer.

Values are for the PT, SCL, and SSE methods of extraction. Plants with low nutritional requirements may grow adequately with lower levels. [z]Adapted from *Best Management Practices, Guide for Producing Container-Grown Plants* (Yeager, et al. 1997). [y]Adapted from *Michigan State Univ. Ag. Facts*, Warncke, D. and D. Krauskopf. 1983. Extension Bul. E1736.

Irrigation Management

Irrigation Application Considerations

The container substrate and a uniform irrigation application are integral components of irrigation management.

Container Substrate

The amount of irrigation water applied to the container should replenish water used by the plant and replenish the amount of water a container substrate can retain. The water used by the plant is available water and is a portion of the total water in the substrate. The total amount of water a substrate can retain (available + unavailable water) is the container water capacity. A substrate's water holding capacity at irrigation is related to the pre-irrigation substrate water content. The wetter a substrate is, the less water it will hold, so adjust the daily irrigation volume according to the substrate water content in order to minimize leaching. Increasing the water holding capacity of the substrate can result in decreased frequency of irrigation. Substrates with a high proportion of fine particles retain more water than substrates with a low proportion of fine particles. Conversely, a substrate with a high proportion of coarse particles has a lot of air space and a relatively low water holding capacity. Consequently, leaching of pesticides and nutrients is likely to occur. Choose components of container substrates or container substrates that are best adapted to plants and management. Use stable substrate components that do not decompose rapidly. Substrate waste and plant waste should be recycled.

Table 3. Partial lists of contacts for EC meters

Apple Sci. Inc. www.applesci.com PO Box 778 Chesterland, OH 44026 800 932-3056	**Corning Inc.** Corning.com 45 Nagog Park Acton, MA 01720 800 492-1110
Advanced Measurements and Controls www.advmnc.com 15806 NE 160th St Woodinville, WA 98072 800 897-6266	**Denver Instrument Co.** www.denverinstrument.com 6542 Fig St. Arvada, CO 80004 800 321-1135
Barnstead International www.barnstead.com 2555 Kerper Blvd. Dubuque, IA 52001 800 446-6060	**Fisher** www.fishersci.com 2000 Park Lane Pittsburg, PA 15275 800 766-7000
Beckman www.beckman.com 4300 N Harbor Boulevard Fullerton, CA 92834 714 871-4848	**Green Air** www.greenair.com PO Box 1318 Gresham, OR 97030 800 669-2113
Caprock Development Inc. www.caprockdev.com/tools.htm PO Box 95 Morris Plains, NJ 07950 800 222-0325	**Hanna Instruments Inc.** www.hannainst.com 584 Park East Drive Woonsocket, RI 02895 401 765-7500
Cole Parmer Instruments www.coleparmer.com 625 East Bunker Court Vernon Hills, IL 60061 800 323-4340	**Horiba Instruments, Inc.** global.horiba.com/analy_e/ 5900 Hines Dr. Ann Arbor, MI 48108 800 346-7422
IRC www.qasupplies.com 1185 Pineridge Rd. Norfolk, VA 23502 800 472-7205	**Yellow Springs Instrument Co.** www.ysi.com 1725 Brannum Lane Yellow Spring, OH 45387 800 765-4974
Control Co. www.control3.com 308 W. Edgewood Friendswood, TX 77546 281 482-1714	**Yokogawa** www.yokogawa.com 5010 Wright Rd, Suite 200 Stafford, TX 77477 281 340-3900
Mettler-Toledo www.mt.com 1900 Polaris Parkway Columbus, OH 43240 800 mettler	**Milwaukee Instruments, Inc.** www.miltestersusa.com 2471 Hurt Dr. Rocky Mount, NC 27804 252 443-3630
Myron L Co. www.myronl.com 6115 Corte del Cedro Carlsbad, CA 92009 760 438-2021	**Omega** www.omega.com One Omega Dr. Stamford, CT 06907 800 848-4286

Table 3. Partial lists of contacts for EC meters

Thermo Orion www.orionres.com 500 Cumming Center Beverly, MA 01915 978 232-6000	**WTW Measurement System Inc.** www.wtw-inc.com/ 3170 Metro Parkway Ft Myers, FL 33916 941 337-7112

Suggested physical characteristic values for container substrates after irrigation and drainage for plants grown outdoors are (% volume): total porosity 50 to 85%; air space 10 to 30%; container water capacity 45 to 65%; available water content 25 to 35% and unavailable water content 25 to 35%; and bulk density 0.19-0.70 g/cc (Yeager, et al. 1997). Joiner (1981) suggests the following for foliage plant substrates (% volume): air space 5 to 30%; container capacity 20 to 60%; and bulk density 0.30 to 0.75 g/cc. These guidelines may be adjusted based on crop response and container size.

Uniform Irrigation Application

Irrigation systems should be designed to achieve appropriate uniformity. Check uniformity close to the pump and far away from the pump in zones representing different irrigation infrastructures or delivery systems. Uniformity should be checked at least once a year. Non-uniform systems may contribute to leaching and runoff, hence potential contamination of ground water.

Evaluation of Overhead Sprinkler Irrigation Application Uniformity

Uniformity of water application with overhead sprinkler irrigation systems is often reported as **Distribution Uniformity (DU)**. It is an indicator of how equal (or unequal) the application rates are in the nursery. A low **DU** (below 60%) indicates that application rates are very different, while a high **DU** (80% or higher) indicates that application rates over the area are similar in value and that the water is distributed evenly to all the plants. **Distribution Uniformity** is based on the low quarter of the irrigated area. The calculation of **DU** requires that the catch can test be performed in the irrigation zone. The following is an example of the catch can test.

Example

In Figure 6, 16 straight-sided catch cans have been placed in the irrigation zone. The depth of water collected in these cans after running the system for one hour is presented below each can. The average application rate in this zone is the average depth collected in the cans and is equal to 0.8 in/hr.

(0.7 + 0.8 + 0.9 + 0.6 + 0.8 + 0.7 + 0.9 + 0.7 + 1.0 + 0.8 + 0.8 + 0.9 + 1.0 + 0.8 + 0.9 + 1.0) / 16 = 0.8 in/hr

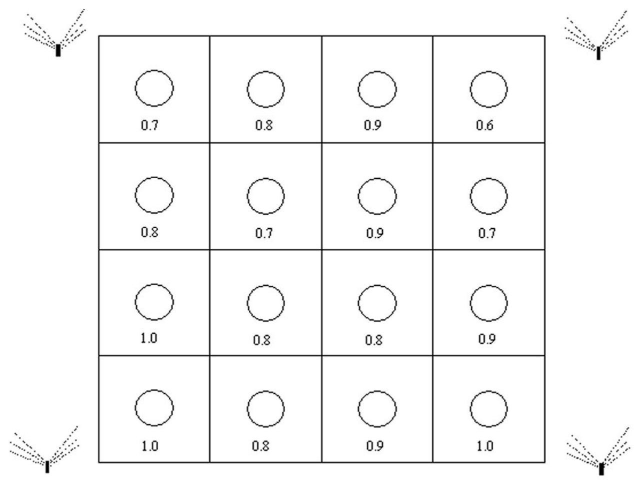

Figure 6. The distribution of catch cans between four sprinklers spaced in a square grid pattern. The number below each circle represents the depth of water caught in one hour at that location.

Now, in order to calculate Distribution Uniformity, the lowest one-fourth or quarter of the measurements from our example are selected. The other value we must know is the average depth of application during the test, which was calculated above.

DU = (average low quarter depth / overall average depth) x 100%

For the application rates presented in Figure 6, average low quarter depth = (0.6 + 0.7 + 0.7 + 0.7) / 4 = 0.7 in/hr.

DU = 0.7 / 0.8 x 100% = 87.5%

For high value crops, such as container-grown nursery plants, it is recommended that the **DU** be greater than 80%.

Low uniformity in overhead sprinkler systems can be due to numerous factors, such as:

- Improper pipe diameters (submain, manifolds, and lateral).
- Too high or too low operation pressure.
- Improper sprinkler heads and nozzles in sprinkler irrigation.
- Inadequate sprinkler overlap.
- Wind effects on water distribution.
- Changes in system components with time, such as changes in pump efficiency, pressure regulation, or nozzle size.
- Nozzle clogging.

The uniformity may change with time. When this coefficient falls below the acceptable value, system repairs and adjustments should be performed as soon as possible.

Evaluation of Microirrigation Uniformity

Measurements of the time required to fill the same bottle must be performed at a minimum of 18 locations throughout the irrigation zone. The statistical uniformity nomograph (Bralts and Kesner, 1983) is based on statistical coefficient of variation and can be used to determine the overall application uniformity (Figure 7). If the uniformity is low, more than 18 measurements of time (seconds) may be necessary to increase the confidence level of the uniformity measurement.

To perform the test you need a small container, such as empty bottle, and a watch with a second hand

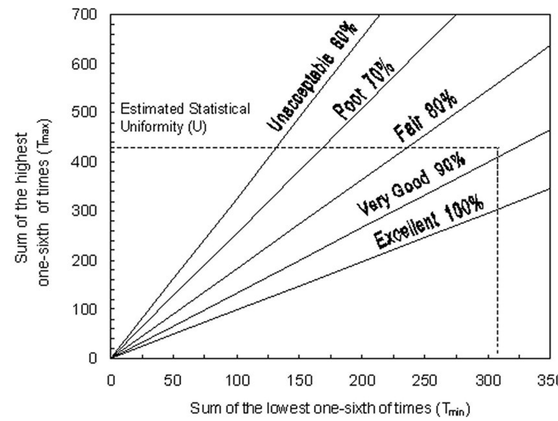

Figure 7. Microirrigation uniformity nomograph. (Bralts, V. F. and C. D. Kesner. 1983. Drip Irrigation Field Uniformity Estimation. Transactions of the Amer. Soc. Ag. Eng. 26(5): 1369-1374.

so you can record the time to fill each bottle at each location. The following steps are required.

Determine how many measurements represent one-sixth of the total locations in the zone. For example, if a total of 18 measurements are performed, this number is 3.

1. Add the lowest three measurements of time (seconds) and mark the sum on the x-axis of the nomograph.
2. Add the highest three measurements of time (seconds) and mark the sum on the y-axis of the nomograph.
3. If the sums do not fit on the scale or if the value is very small so that it is difficult to read, the sums can be multiplied or divided by a common factor.
4. Read the water application uniformity at the intersection of the two lines passing through these points.

Example

Assume that water was collected randomly from 18 emitters throughout an irrigation zone. The time to fill the same bottle was recorded in Table 4.

1. One-sixth of 18 data points = 3
2. 102+105+110 = 317 seconds (lowest 3 values). Mark this value on horizontal (x) axis of the

nomograph and draw a vertical line through this point.

3. 130+145+150 = 425 seconds (highest 3 values). Mark this value on the vertical (y) axis of the nomograph and draw a horizontal line through this point.

4. Read the uniformity of application. The point of intersection of these lines falls in the section of 80% to 90% that indicates "very good" uniformity of the system. The uniformity of water application by microirrigation emitters should be at least in the category "very good" (see Figure 7), especially if fertilizers are injected into the system.

Table 4. Data set for micorirrigation

Location	Measured time (seconds) to fill bottle
1	110 (low #3)
2	125
3	130 (high #1)
4	105 (low #2)
5	115
6	145 (high #2)
7	102 (low #1)
8	118
9	150 (high #3)
10	120
11	128
12	125
13	114
14	119
15	112
16	110
17	120
18	111

Low uniformities in microirrigation systems can be due to factors, such as:

- Improper pipe diameters (submains, manifolds, and laterals)
- Too high or too low operation pressure
- Emitters not appropriate for system design
- Clogged emitters
- Changes or wear on system components
- Changes in pump output and pressure

Efficient Irrigation

Minimize Water and Nutrient Loss

Nursery operators shall manage irrigation applications to facilitate minimal leaching of nutrients from containers and minimize water and nutrient loss from production areas. Maintain minimal distances between overhead-irrigated containers to maximize coverage of irrigated area. Cyclic irrigation may be used to decrease the amount of water and nutrients exiting the container. Cyclic irrigation entails dividing the amount of irrigation per day into several applications of short duration rather than making one irrigation application.

Plant Water Requirement

Consider plant water requirements and schedule irrigation based on plant demand. Plant demand will vary by species and size of plants but container weight, color or feel of substrate, indicator plants or plants used to indicate moisture stress can be used to determine irrigation schedules. *Best Management Practices - Guide for Producing Container-Grown Plants* (Yeager, et al., 1997) and *Opinions on Plant Irrigation Requirements* (Henley, et al. 2000) contain partial lists of species with low, medium, or high water requirements. Plants should be grouped based on daily water requirement. The amount of water applied should be based on the amount of available water used or lost from the substrate.

Record Keeping

Records are vital for making management decisions, particularly when situations arise that are different than the norm. For example, records of irrigation water applied may be helpful when determining the cause of aberrant plant growth. The example forms below (Tables 5-7) facilitate recording information that will be useful for making fertilization and irrigation management decisions. Additionally, nursery operators that have agreed to follow interim measures for producing container-grown plants shall maintain records of the information presented in the forms; however, an alternative format is acceptable.

Table 5. Example form for fertilization records.

Sampling Date	Crop* or Combination of Crops Representative of at Least 50% of Production	Container Size (inch or gal)	Location (field, block or house, bench)	Elec. Cond. (dS/m or mmhos/cm)	Nitrate-N (ppm**)	Lab*** or Name of Person That Performed Test

* A crop is defined as plants treated similarly, i.e. various species with similar nutrition requirement and similar irrigation requirement.

** Values are nitrogen from nitrate. Nitrogen is 22.5% of nitrate.

*** Provide name of laboratory conducting tests if samples were sent to a laboratory.

Literature

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Table 6. Example form for overhead irrigation application uniformity records.

Sampling Date	Zone or Location (field, block or house, bench designation)	Average Amount Water/Catch Can* (ml or inches)	Irrigation Duration for Test (min or hr)	Average Application Rate (inches/duration)	DU (>80%)	Person That Performed Test

*Attach diagram of catch cans with amount of water in each can.

Zone or Location	System Improvements/Adjustments	Date

Table 7. Example form for microirrigation application uniformity records.

Sampling Date	Zone or Location (field, block or house, bench designation)	Sum Lowest of Times to Fill Bottles* (seconds)	Sum Highest of Times to Fill Bottles* (seconds)	Uniformity from Nomograph	Average Application Rate (ml/duration)	Person That Performe d Test

*Attach diagram of bottle locations with amount of time (seconds) to fill each bottle.

Zone or Location	System Improvements/Adjustments	Date