DIAGNOSING TROUBLE SPOTS CAUSED BY AN IRRIGATION SYSTEM

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ABSTRACT—I discuss a testing procedure to determine the water distribution pattern of a sprinkler irrigation system and steps that may be taken to improve uniformity of application. All irrigation systems require testing and maintenance to assure that water application is as uniform as possible. Even new systems installed to a manufacturer's specifications should be "field tested" before use on a crop (Landis 1989).

CONSIDER THE EFFECTS OF UNEVEN DISTRIBUTION UPON YOUR CROP

Uneven distribution is a factor that is universal in irrigation systems. A Coefficient of Uniformity (CU) of 85 percent is considered the minimum acceptable value for both agricultural crops (Zimmerman 1966) and for tree nursery crops (Shearer 1981). Uneven distribution leads to several consequences that should be considered. For instance, you must irrigate sufficiently to get the minimum required water onto the driest areas. Doing this will over water all other areas. This not only wastes water and causes the over watered areas to be too wet but it also over applies any materials being added though your irrigation system. It also leaches out soluble materials previously incorporated into your potting mix. In heavier mixes, the over watered portion of the crop may be suffering from too little oxygen available for the roots. If you are trying to apply materials such as fertilizers and pesticides through the irrigation system, you can use simple math to calculate the variation in application rates. These variations in available moisture, oxygen, nutrients pesticides, etc. may explain a lot about the performance of your crop. Some of these effects are clearly visible in the nursery; showing definite patterns tied to the locations of the irrigation nozzles. Other effects are not clearly visible. Especially when there may be other compounding factors such as poor mixing of the potting media or uneven compaction of the media into the containers. Testing by collecting representative samples at known points is the best way to check irrigation distribution.

BEFORE TESTING YOUR SYSTEM

Consider having your data analyzed by others. There are university programs and irrigation system vendors who utilize sophisticated analysis programs to calculate factors such as Uniformity Coefficient, Distribution Uniformity, Scheduling Coefficient, etc. They may also provide "3D" graphics or "density" diagrams allowing visual analysis of irrigation distribution. However, these programs are likely to have certain data collection protocol to be followed for the programs to work properly. Be aware that data you collect on your own may not fit into their program. If there is a chance that you will be working with a university specialist or a vendor, it is highly advisable that you contact these sources before you begin testing.

Some newer programs only require a single sprinkler and one or two lines of collection containers. The computer program will do the rest, filling in overlapping sprinklers, etc. These are "neat" programs and are intended to save you time and effort. However, these programs rely mostly upon theory. Uneven pressure at individual nozzles and even the collision of water droplets can cause actual distribution to vary from the theoretical. You may want to make your collections exactly as required by the program but also run a couple "check" tests of the system using a full grid layout. Even a few collection containers placed in a larger grid will allow comparing actual distribution with the theoretical.

TESTING YOUR SYSTEM (ADAPTED FROM MERRIAM (1978))

1. Equipment needed:

   - Pressure gauge(s)—In addition to the gauge mounted on your irrigation system to monitor water pressure at the controls, you will want a hand held gauge that you can use to monitor pressure along the lines of your irrigation sets. Depending upon the design of your sprinkler nozzles, you may need to add a small device called a "pitot tube" which can be inserted into the water stream in the nozzle to measure water pressure.
   - Hose and container—A hose that will fit over the nozzle and gather all discharged water into a container. Measuring this discharged volume within a certain time will allow calculation of nozzle output over time (i.e., gallons per minute). This is useful to check nozzle performance against manufacturer specifications to determine nozzle wear.
   - Water collection containers—Two to 50 or more will be needed depending upon size and density of grid. These must have identical top openings. Paper or plastic cups work well. For traveling booms, consider using a row of pill cups, test tubes, etc. that fit inside a row of empty containers placed perpendicular to the boom.

     Note: To calculate actual application rates (i.e., inches per hour) you will need to measure the tops of the collection containers and calculate the collection area. This is usually expressed in square millimeters or square inches.

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Citation for proceedings: Barnett, J.P.; Dumroese, R.K.; Moorhead, D.J., eds. 2002. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Gen. Tech. Rep. SRS–56. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 63 p.

- Tape measure—Used to set out collection containers on the established grid. Also needed to measure the top opening of the collection containers.
- Paper—A preprinted form containing notes, section with grid marks to draw the grid, etc. Also to record trial results. (See attached example)
- Watch—A watch is needed to time application(s) of water during each test. A stopwatch is nice but a standard watch can be used.
- Graduated cylinder—Use to measure collected water. Should be accurate to 2 ml.
- Pencil—Record volumes of water collected.
- Calculator or computer (your choice)—Using raw collection data, one can calculate unending statistics. The mean volume collected and the percent of variation from this mean is a useful beginning point to determine just how uneven the distribution may be. A computer spreadsheet allows easy storage of records and graphing the results.

2. Lay out a grid of collection containers. Design a grid pattern between two or more sprinkler heads. The actual spacing of the grid needs to fit the seedling bed or container table. It can be varied depending upon the degree of detail needed. For instance, in a typical container bed situation, something like a 60 cm or even a 90 cm grid can be used to get a quick picture. A 15 to 25 cm grid may be chosen for fine-tuning the system. (Note: Once the grid spacing is determined, it is critical to place the collection containers at exact intervals with their tops level).
3. Record notes and sketch the grid onto a form. Develop a form onto which all data about the system and the test can be recorded for later reference. Include the "Test Identification Number". A number containing the year, month, day, and sequential test on that day (2001-01-15-01) is recommended. This type of system will provide for easy reference and, if used as a computer file name, will store your tests in the correct order in the file. Include a sketch of the grid being used. Sketch a north-facing arrow to show the orientation of the seedling bed and the collection containers. Draw in the location of the sprinklers (fig. 1).
4. Test the system. Water for a normal length of time. Record this time so the test can be repeated using other pressure settings, nozzles, etc. Measure and record the amount of water collected in each container. Use a graduated (laboratory style) cylinder or other suitable device to obtain an accurate measurement of volume in each collection container. If possible, record the collected quantities straight onto the paper grid. This will prevent confusion over where the collections were made and having the volumes listed on the grid will provide a quick visual analysis of the irrigation distribution pattern.

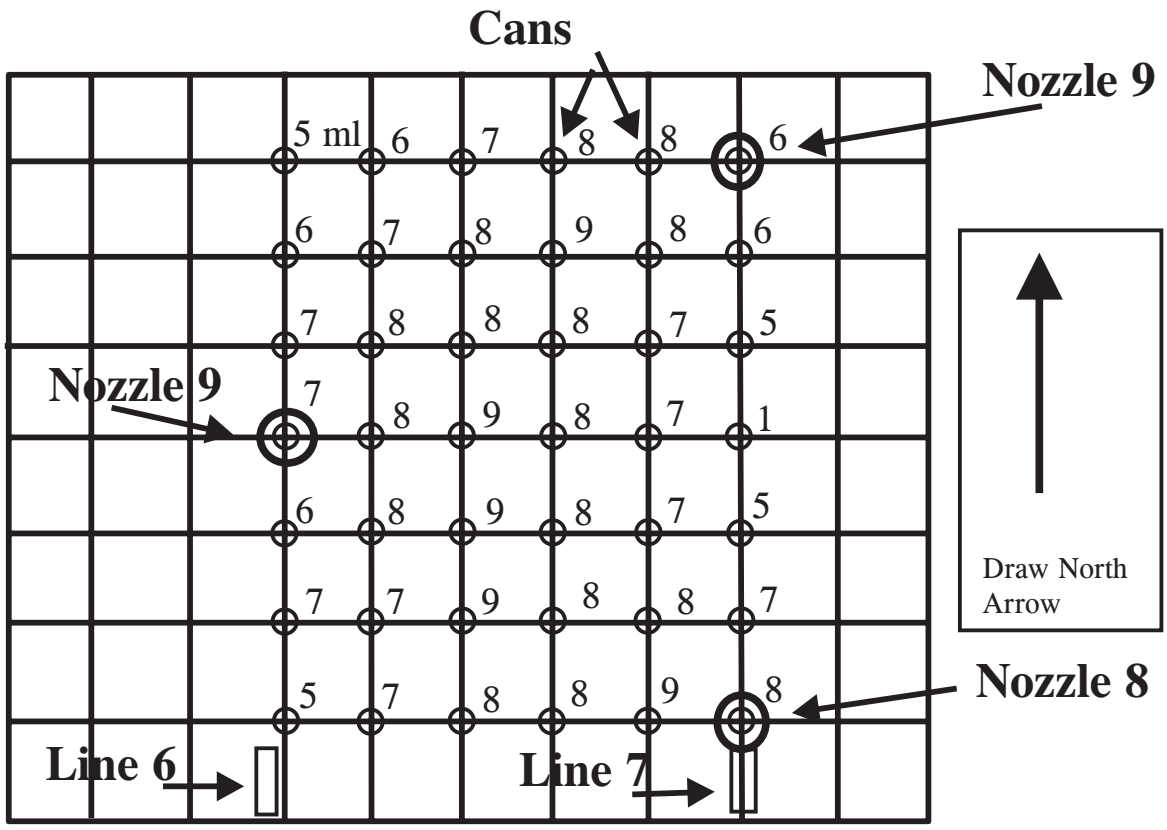

Figure 1—An example of a sampling grid.

For shelter house, shade house, or other open type facilities, you also need to consider wind conditions under which the system is operated. Be sure to record the wind direction and speed during each test. Add a compass and anemometer to your equipment list for such testing.

5. Follow up testing. Periodic checks of your irrigation system are required (at least once at the beginning of each crop). All nozzles wear over time. Especially nozzles lined with a soft material such as plastic or brass. Wettable powders such as fungicides are noted for increasing nozzle wear.

WATER DISTRIBUTION TEST RECORDS

There are any number of records that can be maintained. The following example of a test record combines system data, test data, and a sketch of the test layout with the collection data recorded directly onto the sketch. Doing so prevents field-to-office misunderstandings of where the data fits onto the grid. It also provides an on-the-spot visual of the test results.

IRRIGATION SYSTEM TEST RECORD EXAMPLE

Test number	2001-01-15-01
Nursery	Happy hollow
House or bed	House D1, table 6B
Irrigation system	Solid set
Nozzles	PDQ400
Spacing	9' / 9'
Type	Triangular
Location of grid	Line 6 nozzle 9 and line 7, nozzles 8 and 9.
Collection container	6 oz plastic wine glass
Inside diameter of top	72mm
Duration of test	30 min
Wind	NA
System pressure	65#
Technician	I. R. space cadet
Date	01/13/2001
Time	15:00

EXAMINING THE DATA

Modern spreadsheet programs allow data to be examined and displayed relatively easily. As long as the data grid remains the same from one test to the next, once a base spreadsheet is developed, new tests can be examined by just entering the sample collection data into the spreadsheet. All calculations and graphs will automatically adjust to the new data. The following spreadsheet can be used or improved upon. (Following example utilizes Microsoft® Office 2000 Professional, Excel. Other spreadsheet/graphing programs would be similar. The instructions are specifically for a grid of seven rows with six containers per row. You will have to change the cell addresses given below for other grids.)

1. Folder and test number—Enter your spreadsheet program. Set up a folder "Irrigation Testing", Name your spreadsheet "0000 Master Copy". Use Save-As to save into your Irrigation Testing folder. Once this master copy is completed, use "Save As" to save this test and future tests using the test number as the file name. The test number should contain "Year, Month, Day, Sequential Test Number" such as "2001-01-15-01" for the first test taken on January 15, 2001. This sequence of numbers will keep all the tests in your folder in order for easy reference
2. Enter test number—Type "Test Number" in cell D1 of the spreadsheet. Format font to 14 Bold. Enter with right arrow. Move right one more cell to F1 and type in the test number from the first test. Format this also to 14 Bold. Add a Highlight or light shadow (from the tipping bucket) to this entry (cells F1 and G1) to indicate that this entry will need to be changed for each test. Down arrow to skip down a couple of lines and left arrow left to cell D4.
3. Enter collection data—Type in "Volumes From Collection Cups" enter using down arrow and then left arrow to cell C5. Type in volumes from the test record. Enter each volume using the right arrow until the first row is entered. Then down arrow to the next line and use left arrow back to cell C6 where you will enter the second row of data. Continue until all data is entered. Now select all cells containing the name and all data and enter a heavy line around it. Now select just the cells with data and either highlight or enter a light shadow over the selected block to indicate that these entries will need to be changed for each test. Now down arrow a couple lines below your raw data table and arrow to cell C13.
4. Calculate the sum of all collections—Type in "Sum of All Collection Volumes". Enter with a right arrow and in cell G13 type in "=SUM(" then select all cells in the data table above and type ")". Arrow down and left to cell C14. This should enter the sum of all the collection volumes.
5. Calculate the average volume—Type in "Average Volume" and right arrow to cell G14. Type in "=SUM(" then select cell G13, type in the division sign "/" and then type in the number of data points in the test. (count the data points in the table). Enter an ")" to finish the formula. Arrow down and left to D17.
6. Calculate the deviation from the average—Type in "Deviation (+ or -) From Average". Enter with a down arrow and left to cell C18. Type in "=SUM(C5-G14)". Hit "Enter". Now copy this cell to the clipboard. Next, select this cell and a range of cells the same number down and across as the number of original volume data cells in the first box. Key "Enter" and you should have figures showing the difference between the original collection volumes and the average collection volume. Now select all cells containing the name and all data and enter a heavy line around it to form a box. Arrow down to Cell D27.
7. Calculate percent of deviation from the average—Type in "Percent (+ or -) From Average". Enter and arrow to cell C28. Type in "=C18/G14*100" Hit "Enter". Now copy this cell to the clipboard. Next, select this cell and a range of cells the same number down and across as the number of original volume data cells in the first box. Key "Enter" and you should have figures showing the percentages that the original collection volumes vary from the average collection volume . Now select all cells containing the name and all data and enter a heavy line around it to form a box.

The data boxes are of value in showing just where and how much the individual collection volumes vary, how much they vary from the average, and the actual percentage by which

they vary. You can pick out the areas being over watered and under watered just by viewing these tables. The table of percentages tells you how much over and under the volumes are running and also allows you to spot calculate actual application rates of fertilizers, pesticides, etc. that are being added through the irrigation system.

Graphs

For a more visual look at the data, try using the graphing program for your spreadsheet. The original collection cup data can be shown in graphs by just highlighting the row or rows you want in the graph and then using the graphing wizard to develop the graph of your choice. These can be placed right onto the spreadsheet for easy viewing and printing. Using this technique, one can develop the graphs that may be useful for analysis of the tests. You should be able to print the entire spreadsheet with the calculations and the graphs on one page.

Surface Chart—One type of graph that is very visual is the surface graph. Select the entire range of Volumes From Collection Cups. Under chart type, select “Surface”. Make other selections to format the exact graph that suits your needs. For use on a single spreadsheet, consider that less data on the graph is better as titles etc. take up a lot of space and do not add much to the visual impact of the overall graph.

Column Chart—A second type that may be useful is a “Column Graph” of the subtype “Clustered Column”. To use this type, select data in one row. This clearly shows how volumes vary across the row. To visualize the complete grid, create a very simple graph for each row and line the graphs up on the spreadsheet.

Future Data

Using a spreadsheet format has the added value of only having to change the number of the test and the collection data (the cells that you highlighted or darkened) for each test. All the data and graphs are based upon this information and recalculate as you change the data. Be sure to save the spreadsheet for each test if you want a permanent copy. Use “Save As” and the test number.

FINE-TUNING YOUR SYSTEM

1. Check Location of Nozzles. They should be located at equal distances along the supply line.
2. Check the Alignment of Nozzles. For most nozzles to operate properly, they must be installed exactly on the top (or bottom) of the supply line. Any that are tilted may be causing distribution problems. Check them using the cup test. If they are causing uneven water distribution, they must be reinstalled.
3. Adjust the System. Water distribution of both solid set and traveling boom type irrigation systems can be adjusted by raising or lowering the height of the nozzles above the crop surface and/or adjusting the water pressure. Recheck water distribution using the cup tests.

   Notice: Don’t forget that distribution will change dramatically as the crop grows higher and intercepts the water at different levels. Rather than waiting until you notice dry spots or actual growth differences in your crop, try some “pre-crop” checks with the cups raised to different levels. This will provide you with data to know when to raise the booms or sprinklers as the crop grows in height.
4. Other Corrective Measures. If the coverage is still not acceptable, try installing different nozzles. Last and most drastic would be to change the spacing of the nozzles or the type of system being used.

   Note: Changes being considered for a solid set system can be tested using a small “model” system of two supply lines with four nozzles. Test the water distribution of the trial system the same way you tested the production system

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BLANK IRRIGATION SYSTEM TEST RECORD

IRRIGATION SYSTEM TEST RECORD

Test number _____
Nursery _____
Name of nursery
House or bed _____
Name or code of shelter
house, seedbed,
polybag bed, etc. _____
Irrigation system _____
Type of system i.e. (Solid
set or traveling boom) _____
Nozzles _____
Make and model _____
Spacing _____/_____
Distance between
lines/nozzles
Type _____
Rectangular or triangular
Location of grid _____
Specific location of grid layout
(Example: waterline #4,
between sprinklers #8 and #9).
Collection container _____
Type of container
(i.e. 4 oz. plastic Dixie cup)
Inside diameter of top _____ mm
Duration of test _____ min.
Length of time water collected
Wind _____
Speed and direction of wind during test
System pressure _____
Technician _____
Name of person(s) performing test
Date _____ Time _____