REVERSING YIELD LOSS BY MANAGING DISTRIBUTION UNIFORMITY

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Abstract: Poor System Distribution Uniformity (DU) has been shown to negatively impact crop yields in numerous studies conducted over the past several decades. By managing DU and utilizing other tools for identifying uneven application of water across a field, these yield losses can be reversed. Performing DU analysis along with physical and visual inspections of the system components is the first step. Taking corrective action to restore the DU to at, or near design performance is the next step. Research shows that correcting pressure variations and/or remediating systems to eliminate plugging have the greatest impact on improving DU.

Managing your DU through ongoing maintenance and periodic inspections is the key to reversing yield losses permanently. Don't let poor DU be a silent killer of your yields and profits, take control of your system by managing your DU and maintaining your micro irrigation system with straightforward process described here; measure, remediate, maintain, and measure again.

I have never met a grower who does not agree with the statement, "Water and inputs directly affect yield." No water equals no crop, and not enough water equals not enough yield. Truth is that yield improvement is the biggest reason why growers install micro irrigation in the first place. However, it is surprising how few users of micro irrigation are regularly measuring the effectiveness of their irrigation systems. Most users are turning systems on for a set number of hours and assuming that the water and inputs are reaching the crop. Some use moisture monitoring to verify that water is getting where it is needed. More and more growers now also have flow meters to measure the volume of water applied. But when was the last time you had a Distribution Uniformity (DU) test performed to ensure even application of water across your field?

Data from numerous studies over the last few decades establish a direct link between yield loss and low DU. Furthermore, several studies document the decline of DU in an average system over time. Lack of maintenance, poor water quality, inadequate filtration, system design, or system operation can all lead to DU decreases. Poor DU is a silent killer of yields and therefore profits. There is a clear opportunity here to reverse yield losses by measuring DU and also other qualitative factors to determine overall irrigation system performance.

So what is DU (distribution uniformity)? It is the measure of how uniformly water is applied to the area being watered. There are several methods for measuring DU, but the most widely accepted method today is published by the ITRC of Cal Poly in San Luis Obispo (Burt 2004: Burt et al. 1992). In this method the Global or System DU is calculated by mathematically combining several Component DU values together and is expressed as a fraction between 0 and 1. (We frequently see people convert this number to a percentage and discuss a DU of say 85%, but officially it's a fraction of 1, ie 0.85.)

The four DU Components are pressure differences, unequal drainage, unequal application rates or unequal spacing, and "other" causes which are any factor that would cause flow rate differences at identical pressures like plugging, wear, or manufacturing variation. Unfortunately simply measuring the flow rates of emitters across a field does not tell you whether the differences are due to pressure variation

or other causes like plugging or wear. In an ITRC study performed on 329 fields researchers found that 45% of the non-uniformity was due to pressure differences, 52% was due to "other" causes such as plugging. Only 2% of the variation was due unequal application rates (emitter spacing) and 1% due to unequal drainage. Therefore the ITRC Rapid Technique (Burt 2004) requires measurements of pressure differences in the field and the "other" causes of flow rate differences not related to pressure such as plugging, wear, and manufacturing variation. Each component is calculated using the lowest 25% of readings divided by the average of the total. This results in a designation of "lower quartile" or DU_{lq}. The global or system DU of the lower Quarter is calculated as:

$$DU_{lq\Delta q\ global} = DU_{lq\Delta p} \times DU_{lq\ Other}$$

Management of your DU is important to determine whether every portion of your crop is receiving the same amount of water and nutrients. Using the ITRC rapid procedure will enable you to determine whether or not the DU deficiency is due to uneven pressures in your system or another factor like plugging. It is one of the few quantitative measurement tools available that allows a grower to understand the uniformity of water and input applications; and it has been tested extensively and proven to be accurate when performed correctly.

DU testing needs to be performed frequently enough to ensure that any changes in system performance can be identified and corrected. Once a year is probably a minimum, but there are growers who perform DU analysis weekly or monthly. Most commonly we see a test at the beginning of the season, a few weeks after the hottest portion of the season begins, and at the end of the season.

If you get a lower than desired DU number at any time, take corrective actions to improve your system performance. Approximately half the time a low DU is due to pressure differences ($DU_{lq\Delta p}$) throughout the field, and half the time it is due to "other" ($DU_{lq\ Other}$) problems, primarily plugging.

Pressure differences may be an original system design problem and may be costly to repair. However, these pressure differences can also be due to simpler problems such as:

1. Poorly functioning pressure regulating valves
2. Plugging at the riser screens resulting in uneven line pressures
3. Poor pumping performance out of the well due to plugging or lack of maintenance.
4. Inadequate discharge pressure out of the supply pump.

These types of pressure problems are all correctable and many of them are not particularly costly to remedy, especially when compared to the yield losses they can cause.

If the DU deficiencies in your system are caused by DU "other" such as plugging, there is corrective action available as well. Please note that on rare occasions, "other" sources of non-uniformity may be due to wear on the emitters or sprinklers from chemigation with abrasive products like gypsum, or due to manufacturing variation. However, most commonly we see these DU losses caused by plugging in two key categories, microbiological plugging, and mineral or chemical precipitation. Additionally on buried tape (SDI), root intrusion can also be a source of emitter plugging.

Once plugging has occurred and it has decreased your DU, the system must be remediated in order to correct the issue. The type of remediation performed depends on the nature of the foulant that is plugging your system. If the foulant is microbiological (see Figure 1), you will need to remediate with a biocide, typically, bleach, chlorine dioxide, Peracetic acid, hydrogen peroxide, copper, or ozone. If the foulant is mineral in nature most likely an acid will be needed to dissolve the mineral back into solution and flush it from your system. We see sulfuric acid, nitric acid, N-phuric, and citric acid as well as some designer

safe acids being used commonly. If you have root intrusion, both bleach and sulfuric acid have proven to be effective if applied timely and properly. Again, the nature of the foulant (stuff plugging up your system) must first be identified. Here are some tools we use to identify foulants:

1. Inspect riser screens
2. Inspect filtration devices
3. Flush out the hoses and capture the water in a plastic bottle to look for foulants
4. Cut out sections of tubing and dissect for inspection
5. Shave down emitters to inspect emitter pathways.
6. Destruct and inspect sprinklers and button emitters for inspection
7. Dig up sections of SDI (buried drip tape) and inspect for foulants or root intrusion

The remediation procedure, including choice of chemistry that will have the greatest efficacy and be most cost effective, can be somewhat complex. Also the concentration used, the length of application time, and the number of applications necessary can vary from location to location. There are some basic process steps however:

1. When performing a remediation, flush the system completely ahead of time to remove any loose foulant that will increase the chemical demand and decrease the efficacy.
2. Startup the system and get the selected chemistry flowing immediately at the correct dosage range (do not exceed lablel application rates if using a biocide as they are considered pesticides and must be applied at or below label rates.) If using an acid follow the micro irrigation system manufacturer's specifications on the desired pH range and exposure time; typically not less than 2 pH, but not more than 3 pH. Recommended exposure times vary. (see Netafim Drip Irrigation System Maintenance Handbook, 2014)
3. Next open up the individual lines to speed the delivery of the full concentration of chemistry to the end of the system and measure for proper residual at the furthest point.
4. Close the lines again to bring the system up to full pressure, now the remediation has actually begun and all emitters should be seeing the same concentration of chemistry.
5. Run for the desired length of time, typically two hours, shut down the system and allow it to soak overnight.
6. Flush the system and repeat the entire remediation procedure one more time.

Using the good old 80/20 rule, this procedure is effective most of the time if using the right chemistry at the right dosage. However, we have seen systems that needed continuous biocide dosing for 72 hours in order to restore the DU to desired ranges. Some systems need to be remediated multiple times before the DU is restored. Unfortunately every system is different, every foulant is different, and there is no such thing as a silver bullet that works every time. If you find that you have plugging issues in need of remediation, we highly recommend working with a reputable company that you trust to assist in your efforts, or to provide a turn-key solution.

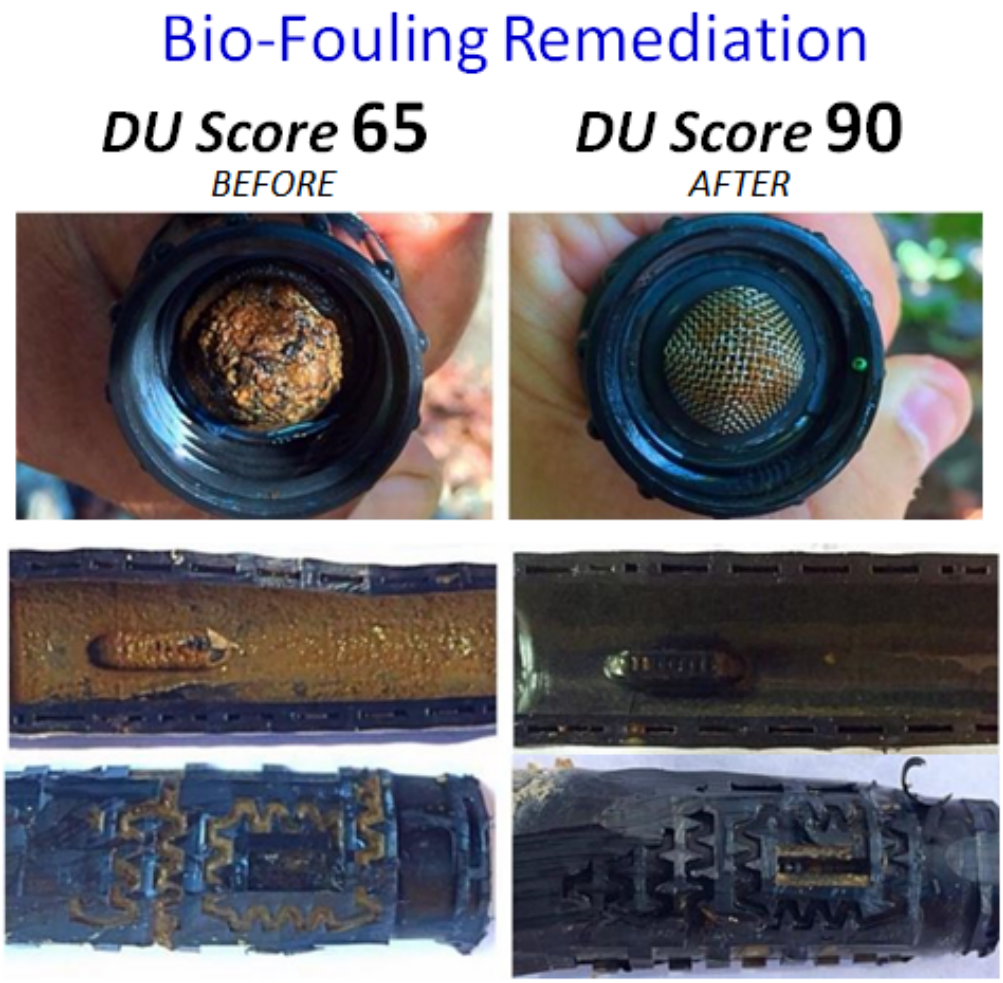

Figure 1

Once you have invested in restoring your DU to acceptable ranges, you will want to maintain that system performance over time in order to maximize your yields. Therefore system maintenance is incredibly important ongoing. Regular periodic flushing is one of the simplest and most underutilized tools to ensure good performance. Here are a few key items to check routinely:

1. Flush the entire system, mains, sub-mains, laterals, and individual lines in that order.
2. Check and clean riser screens and ensure that they are performing correctly and free from plugging.
3. Keep your filters clean and ensure proper back flushing and performance.
4. Check pressure regulator valves for proper performance.
5. Spot check system pressures to ensure that they are consistent and gauges are functioning correctly.
6. Maintenance: sprinkler, emitter types, and / or nozzle sizes must match.
7. Maintenance: fix breaks and leaks immediately.
8. Perform moisture monitoring to ensure water is being delivered as you expect
9. Use vegetative density analysis like NDVI to identify areas with poor plant vigor
10. Walk the fields and look for signs of plant stress

System maintenance using chemigation to prevent plugging before it occurs can be highly effective if properly managed. Again, the nature of the foulant causing the plugging must be known; is it

microbiological, or chemical / mineral? Also note that sometimes it is both! Once the foulant is identified and the proper chemistry and dosage rate has been selected, a maintenance program can be set up. Typically this involves a simple chemical metering pump, a flow switch, pressure switch, or flowmeter to activate the chemical pump automatically every time you irrigate.

Unfortunately like any piece of equipment, these systems need regular maintenance and calibration in order to be effective in preventing plugging and maintaining high DU and yield. Also required dosage and choice of chemistry can change as water quality, ambient temperature, or other factors change on your property. A good service company can be essential to help ensure the success of your maintenance program and maintaining adequate DU to ensure yield losses are permanently reversed.

It is an established fact that water and inputs drive yield, and therefore lack of water and inputs, or uneven application of water and inputs result in yield losses. In order to identify the uneven application of water, we use a tool called Distribution Uniformity (DU) analysis. This tool allows a grower to determine whether water is being uniformly applied across a given area, and identify whether the cause of uneven distribution is due to pressure differences or "other" causes like plugging. Growers can also use qualitative inspections like inspection of filters, riser screens and emitter or hose destruction and inspection to identify the foulants that can cause plugging. Walking the fields and inspecting plant vigor, use of NDVI, inspection of wetting patterns, and soil moisture sampling can all lead to the identification of non-uniform water application.

Once a low DU has been discovered and the cause identified, corrective action can be taken. If the cause is uneven pressures an Irrigation specialist may be able to help identify the mechanical problems and offer a solution for corrective action.

If the cause of the low DU is plugging and the foulant has been identified, remediation through chemigation is usually effective at restoring the DU to acceptable levels. One you got it up, keep it up! Regular physical maintenacnce of your filter systems, flushing of your system and lines, and pressure checks make a huge difference. A chemical maintenance program can be a very effective tool at maintaining high DU numbers if properly applied.

You must inspect what you expect, regular DU checks, physical inspections of qualitative factors and moisture monitoring are the keys to ensuring that we all reverse yield losses by maintaining high DU.