Evaluation of
Potential Best Management Practices
-
Drip Irrigation

Prepared for

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EVALUATION OF

POTENTIAL BEST MANAGEMENT PRACTICES

-

DRIP IRRIGATION

Table of Contents

INTRODUCTION **4**
- HOW DRIP/MICRO-IRRIGATION WORKS 4
- WETTED SOIL PATTERN 4
- DRIP/MICRO-IRRIGATION SYSTEM COMPONENTS 6
- EMISSION DEVICES 6
- EMITTER PLACEMENT 6

POTENTIAL FOR WATER SAVINGS **8**
- APPLICATION EFFICIENCY 8
- WATER SAVINGS EVALUATIONS 11

BENEFITS OF DRIP IRRIGATION **12**
- RUNOFF REDUCTION 12
- EXTREME SOIL TYPES AND TERRAIN 12
- REDUCED OPERATING COSTS 12
- ENERGY CONSERVATION 12
- CHEMICAL APPLICATION 12
- IMPROVED TOLERANCE TO SALINITY 13
- IMPROVED PLANT QUALITY AND GROWTH 13

DISADVANTAGES AND BARRIERS **13**

MARKET TRANSFORMATION **15**
- PUBLIC PERCEPTIONS 15

CONCLUSIONS **15**

WORKS CITED **17**

APPENDIX A **18**

List of Tables

TABLE 1. DRIP SYSTEM WETTED AREA RANGES BY SOIL TYPE. 5
TABLE 2. DRIP/MICRO-IRRIGATION SYSTEM COMPONENTS. 6
TABLE 3. EMISSION DEVICE TYPES AND DESCRIPTIONS. 7
TABLE 4. GENERAL IRRIGATION SYSTEM EFFICIENCY RANGES. 9

List of Figures

FIGURE 1. WETTED SOIL PATTERN SHAPES BY SOIL TYPE. 5
FIGURE 2. AFFECT OF SYSTEM EFFICIENCY ON VOLUME OF WATER USED. 10
FIGURE 3. AFFECT OF SYSTEM EFFICIENCY ON PERCENTAGE OF WATER LOST. 10
FIGURE 4. AFFECT OF SYTEM EFFICIENCY ON PERCENTAGE OF WATER LOST WITHIN THE 35% TO 85% RANGE. 10
FIGURE 5. ILLUSTRATION OF ROOT INTRUSION AND AN EXAMPLE OF THE USE OF A COPPER SHIELD WITHIN THE EMITTER. 14

INTRODUCTION

Micro-irrigation allows for efficient irrigation, resulting in savings of water and power, and a reduction in chemical needs. Micro-irrigation is not a new irrigation practice, it has been around since the late 1960's and was initially utilized as an agricultural irrigation best management practice for areas with harsh climates and limited water supplies. The use of micro-irrigation accelerated with the advent of polyethylene tubing. In today's market, drip irrigation is now used extensively in both agricultural and landscape irrigation. The term micro-irrigation includes: drip emitters (point source, drip line, and multiple outlet) and micro-spray. When the drip line is buried it is termed sub-surface drip irrigation (SDI).

This Potential Best Management (PBMP) report will refer to drip and micro-irrigation synonymously, and call out differences where appropriate. Bubblers, which is often considered a component of micro-irrigation, is not included in this PBMP as is categorized as a sprinkler by the American Society of Agricultural and Biological Engineers. Additionally, this report will only focus on those emitters designed for use within landscape irrigation system, excluding emitters that are used exclusively for agricultural irrigation.

HOW DRIP/MICRO-IRRIGATION WORKS

Drip/micro-irrigation typically has a lower application rate than conventional spray and rotary irrigation. Many drip systems are designed to apply irrigation slowly over a long duration as opposed to conventional sprinklers that may apply the same amount of water within a much shorter watering window. For that reason, the conventional sprinklers are often referred to as high-volume irrigation. It should be noted however, that the drip system is not actually low-volume, but is low-application (or precipitation) rate irrigation.

WETTED SOIL PATTERN

When water is applied to soil at a single point, there are two forces that act upon the movement within the soil. Forces of gravity move the water downwards, while capillary action moves the water radially outwards. Figure 1, illustrates the basic wetting pattern shapes for clay, loan, and sand soil types. Although the illustration in Figure one depicts an example of SDI, the wetted pattern is the same as on-grade emitter placement.

For most soils, the wetting pattern will be somewhere between clay and sand. The specific wetted pattern varies per soil type and application rate. Further, water movement can be affected by the composition of the topsoil, permeability of the subsoil, and compaction within the soil profile. For landscape plants, a wetting area of 75% of the root zone is acceptable to provide adequate coverage to for proper root development and to meet the plant-water needs.

Since modifying the application rate can alter the shape of the wetted pattern, a decreased application rate can minimize the horizontal zone under the emitter. This can be beneficial in clayey soils, to promote deeper water penetration and reduce ponding and runoff. Contrarily, sandy soils benefit from an increased application rate and a wider zone of saturation.

Table 1. Drip system wetted area ranges by soil type.

Soil Type	Emitter Flow Rate (gal/hr)	Wetted Area Diameter (ft)	Wetted Area Area (ft^2)
Sand	0.5	2 to 3	3 to 7
	1.0	3 to 3.5	7 to 10
	2.0	3.5 to 4	10 to 13
Sandy Loam	0.5	3 to 4.5	7 to 16
	1.0	4.5 to 5	16 to 20
	2.0	5 to 5.5	20 to 24
Loam	0.5	3 to 5	7 to 20
	1.0	5 to 6	20 to 28
	2.0	6 to 7	28 to 38
Clay Loam	0.5	4 to 6	13 to 28
	1.0	6 to 7	28 to 38
	2.0	7 to 8	38 to 50
Clay	0.5	5 to 7	20 to 38
	1.0	7 to 8	38 to 50
	2.0	8 to 9	50 to 64

Source: Irrigation Association (2007)

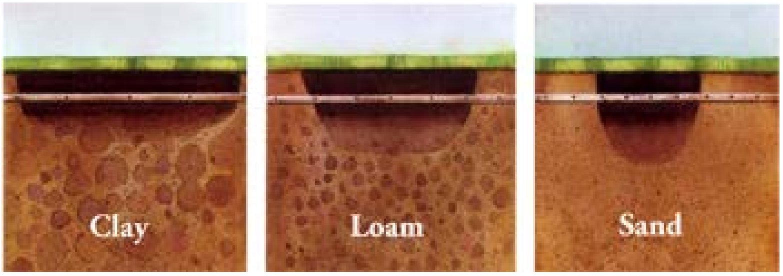


Photo credits: Netafim

Figure 1. Wetted soil pattern shapes by soil type.

Drip/Micro-Irrigation System Components

Drip/micro-irrigation systems have a number of specific components necessary for proper design and functionality. Table 2 lists general components and the purpose for each. For detailed description of the design criteria of these components, refer to the Irrigation Association's 2014 Landscape Irrigation Best Management Practices[1].

Table 2. Drip/micro-irrigation system components.

Component	Purpose
Emission device	Applies water to the plant
Drip tubing	Tubing from which emitters are either attached or imbedded
Drip laterals	Used when there is significant distance the water must travel without the need for an emitter (optional)
Pressure regulator	Used to increase uniformity or lower pressure to an acceptable range
Filter	Used to keep particulates out of drip line
Flush valve	Provided for routine flushing and cleaning of system
Control valve	Should be selected based on flow of the drip zone
Back flow preventer	Helps prevent air build up in piping and water flowing back into system

Emission Devices

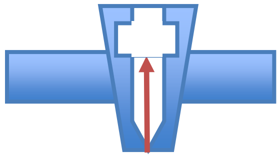
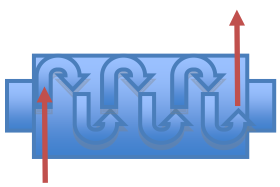
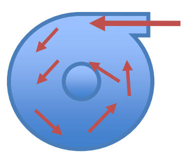
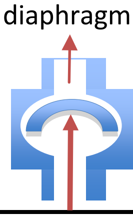
The emitter is how the water leaves the drip line and applies water to the irrigated area. Drip emitter types can be categorized based on the water flow through the emitter, as described in Table 3. Emission devices have specific application rates and should provide accurate and reliable performance that is unchanged over time. However, since drip systems operate low pressures, a small pressure variation can have a significant impact on the flow output.

Emitter Placement

Emitter placement will determine whether salts are pushed away from the root zone or concentrated within it. Salts will tend to be concentrated at the perimeter of the wetted zone. Therefore it is best to place the emitter near the center of the root zone, rather than between root zones of multiple plants, and upslope when applicable. Design details are outlined in Appendix A.

[1] Available at: http://www.irrigation.org/uploadedFiles/Standards/BMPDesign-Install-Manage.3-18-14.pdf

Table 3. Emission device types and descriptions.

Emitter Type	Water Flow	Advantage	Disadvantage
Orifice	Pressure and discharge controlled by diameter of orifice – basic type of turbulent flow 	Can be pressure or non-pressure compensating. Can be effective an inexpensive for small areas	Clogging, attention must be paid to elevation differences and friction loss
Laminar Flow	Water moves in a slow and smoothly at a low velocity 	Reliable and inexpensive	Pressure sensitive, susceptible to clogging, flow rate will vary with water temperature
Turbulent Flow	Water moved rapidly and irregularly at a higher velocity 	More resistant to clogging due to higher flow velocities and less pressure sensitive than laminar flow, flow rate unaffected by water temperature	More pressure sensitive than vortex
Vortex	Water moves in a vortex, or whirlpool, pattern, with low pressure in center 	Less pressure sensitive than turbulent flow	Small orifice may easily clog, requires high quality filtration
Pressure Compensating (laminar/turbulent flow)	Utilize the inlet pressure to modify the flow path, size, shape, or length. Typically with an elastometric disc or diaphragm 	Able to deliver accurate and constant flow rate of a wide range of inlet pressures	Performance may deteriorate over time based on the elastometric/diaphragm material used

POTENTIAL FOR WATER SAVINGS

Drip irrigation is touted as having much higher efficiencies than spray or rotary sprinklers. The high efficiency results from four primary factors:

- The water is slowly applied directly to the root zone
- Only the root zone or the partial root zone is irrigated, as opposed to sprinkler irrigation where the entire field area is wetted
- Soil and plant surface evaporative losses (including water lost to wind) are minimized or eliminated
- Water lost to surface runoff and deep percolation is minimized or eliminated

Additionally, a drip/micro-irrigation system can apply water beneficially with its ability to tailor the water placement and delivery rate to the changing needs of the landscape. The size of the root zone and subsequent water needs varied as a plant matures. Both the placement of the water as well as the application rate is more easily adaptable when using a drip/micro-irrigation system versus a convention solid set system.

For these reasons, drip irrigation is one of the primary factors resulting in the reduction of irrigation water use in turf conversion landscapes. In Turf Removal Programs administered by water agencies, irrigation upgrades, which is typically a conversion to drip irrigation, is a requirement for rebate eligibility.

APPLICATION EFFICIENCY

Irrigation system efficiency varies based on irrigation method, equipment, and design. Applied water can be lost primarily from evaporation, runoff, or drainage. Evaporation can result from water droplets irrigated into the air, from wet leaves, or from the soil surface. A major source of lost water results in runoff from the surface of the landscape. And finally, water can be lost by deep percolation through the soil profile. Basic system efficiencies are listed in Table 4.

Micro-irrigation has less opportunity for losses through transmission. It is applied directly to the root zone with a small wetted soil surface area, reducing evaporative losses. Applying water at a slower rate, reducing ponding and the subsequent flow from the landscape area minimizes runoff, whereas overspray can potentially be eliminated. Deep percolation can be minimized through proper scheduling.

Increasing system efficiency will result in water savings by reducing the excess water needed to achieve adequate water within the root zone. The common practice to compensate for system inefficiencies is to apply more water. When scheduling irrigation, a *run time multiplier* is utilized.

Table 4. General irrigation system efficiency ranges.

Irrigation System Type	Efficiency[a]
Drip/Micro-Irrigation	80 to 95
Landscape Spray Systems	40 to 65
Landscape Rotor Systems	50 to 75
Brass Rotor Systems	60 to 85

Adapted from: Irrigation Association (2007).

As system efficiency decreases, the amount of water need for irrigation use increases. Water Savings due to an increase in Irrigation Efficiency can be calculated by the following equation:

$$WS = 1 - (IE\ initial\ /\ IE\ final)$$

where, WS = Water Savings (%)
IE = Irrigation Efficiency (%)

The effect of the irrigation system efficiency is illustrated in Figures 2 and 3. As the efficiency decreases, the volume of water applied increases, resulting in a negative expontial curve. Therefore, the percentage of Water Lost, or supperfluous application, as a result of inefficeincey can be calculated for any Irrigation Efficiency with the resulting equation:

$$WL = -1.854\ \ln\ (IE) - 0.2168$$

where, WL = Water Lost (%)
IE = Irrigation Efficiency (%)

Here, the givens (area, etc.) will not effect the Water Savings therefore this can be universal within the truncated 35% to 85% Irrigation Efficiency range Figure 4. The range minimum is 35%, below this efficiency it is recommended to fix major issues requireing potential redesign/installation. Beyond the 85% efficiency range, the impact potential savings my not significant.

For example, an irrigation zone with stationary spray heads assume an initial irrigation efficiency of 40%. If the irrigation efficiency can be increased to 85%, by replacing the spray heads more efficient irrigation equipment, drip-irrigaiton, this would result in a 53% water savings.

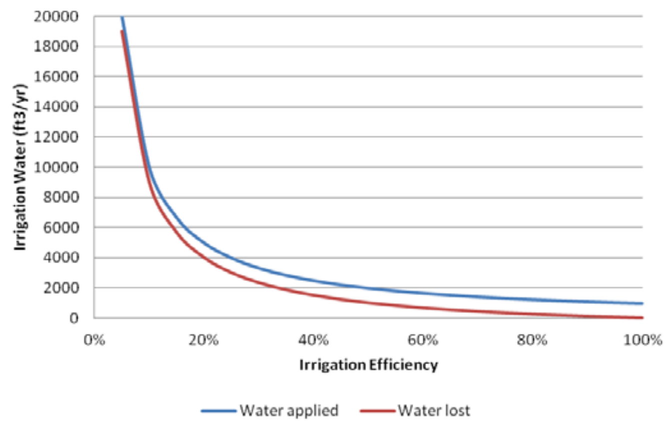


Figure 2. Affect of system efficiency on volume of water used.

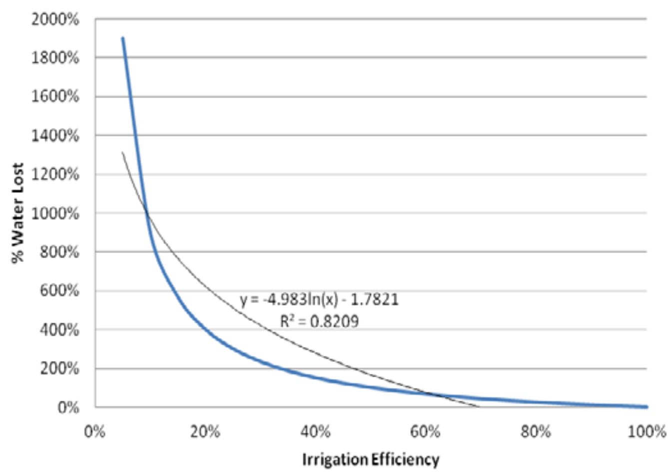


Figure 3. Affect of system efficiency on percentage of water lost.

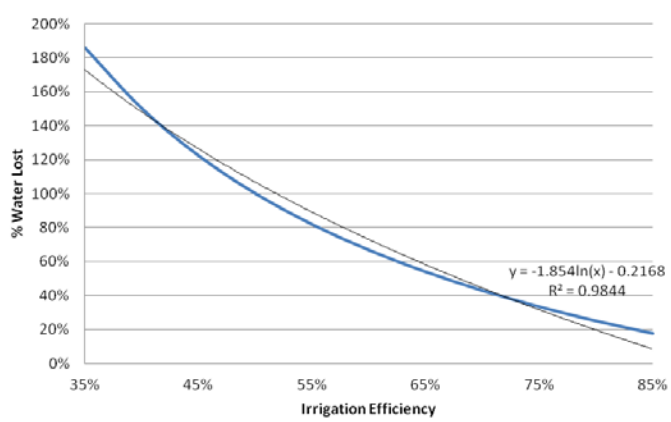


Figure 4. Affect of sytem efficiency on percentage of water lost within the 35% to 85% range.

This analysis does not take into account the sub-surface redistribution (movement of water within the root zone) into account, which is often not considered. Redistribution, where there is no canopy interference, occurs from lateral movement prior to infiltration and or horizontal redistribution within the soil (Dukes, et al., 2006). In addition, canopy interception can also contribute to the redistribution of water (Mateos et al., 1997; Stern and Bresler, 1983; Mecham, 2001). When catch can DU_{lq} varied from 0.30 to 0.80, sub-surface volumetric water content DU_{lq} varied from 0.50 to 0.80 (Dukes et al., 2006). Therefore, encouraging the movement of water within the soil can alleviate the effect of mild inefficiencies. Highlighting the importance of controlling irrigation application, which is easily achievable with drip irrigation.

WATER SAVINGS EVALUATIONS

Most of the water savings research for drip irrigation is focused on agricultural uses. Where, the amount of water saved is compared to production yield. Lamm and Trooien (2002) reviewed 10 years of SDI research on corn in the Great Plains and reported that water savings of 35% to 55% compared to traditional forms of irrigation. Automation of SDI systems based on soil moisture sensors[2] may further improve water use efficiency (Dukes and Scholberg 2001).

The American Water Works Association study on residential end uses of water concluded the following homes with: in-ground irrigation systems used 35% more water than houses without these systems, automatic timer controls incorporated into the system led to 47% more water used, but drip irrigation systems only used 16% more water than homes which did not irrigate the area with in-ground irrigation (Mayer et al. 1999).

Decreasing the amount of water consumed by a domestic irrigation system without causing stress or reduced quality to the turfgrass and landscape is possible. In a 30-month study on homes monitored in Central Florida, residential landscapes where categorized into based on turfgrass percentage, utilization of micro-irrigation, and irrigation scheduling (Baum 2005; Haley 2007). The treatment group consisted of an irrigation system designed according to specifications for optimal efficiency including a landscape design that minimized turfgrass and maximized the use of climate appropriate plants irrigated with micro-irrigation. Irrigation runtimes were adjusted seasonally. The control group consisted of existing irrigation systems and typical landscape plantings, where the homeowner controlled the irrigation scheduling.

On average, the treatment group homes consisted of 65%[3] landscape bedding that was irrigated with micro-irrigation; contrasting with the control group homes where typically less than 25% of the irrigated area was ornamental plant material an the entire landscape area was irrigated with sprinkler irrigation.

The conclusions showed that the homes with micro-irrigated areas required less water than if those areas were sprinkler irrigated. The treatment homes with both the adjusted controller run time settings and the incorporation of micro-irrigation in the bedding areas used 41% less

[2] More information on the savings potential of soil moisture sensors is available in that PBMP report.
[3] Some of the treatment group landscapes had as little as 5% to 15% turfgrass

irrigation water than the control group (based on sub-metered monthly water use data over the 30-month period). This would yield a weekly water savings of 1,440 to 1,800 gal per week based on irrigating twice weekly for the homes included in this study.

BENEFITS OF DRIP IRRIGATION

Runoff Reduction

As a result of the low-application rate of drip irrigation systems, water is applied slowly allowing it to be absorbed rather than quickly result in surface runoff yielding a number of benefits:

- Dry-weather stormwater runoff reduction
- Reduction in the transmission of pollutants
- Reduction in sediment transference
- Reduction of the spread of disease organisms by water movement[4]

Extreme Soil Types and Terrain

The infiltration rate of tight clay soils is very low, and since the application rate is low, it allows for water to be applied more slowly so the water can be absorbed, minimizing ponding and runoff. On the other end of the spectrum, very fine sandy soils have an infiltration rate too high to allow for adequate water storage. In this case, drip irrigation can allow for water to be applied frequently in small quantities, minimizing deep percolation. For these same reasons, properly designed drip systems can conquer irregular, rolling, or steep sloped terrain.

Reduced Operating Costs

Low-application rate systems will often result in an overall less expensive system to run (lower capital and operating costs) due to more efficient utilization of pumps, filters, and pipelines. Consequently, these system components can be sized for lower flow rates and pressures and therefore have a longer performance life.

Energy Conservation

Not only will the low-application rate reduce operating costs, the lower operating pressure means a reduction in the pumping head requirements, which will result in pumping energy savings. The increased efficiency as compared to convention irrigation also means less water is pumped, yielding a further reduction in energy.

Chemical Application

Chemigation and Fertigation can be applied through drip irrigation directly to the root zone. Improved control over chemical and/or fertilizer placement will provide increased efficiency, yielding a reduction in:

[4] Disease is also controlled as a result of the improved chemigation management potential with drip irrigation.

- Chemical and/or fertilizer loss to leaching
- Chemicals and/or fertilizers runoff
- Chemical and/or fertilizer costs
- Weed growth

Improved Tolerance to Salinity

Drip irrigation maintains higher moisture levels with the root zone[5], reducing plant sensitivity to saline water and soil conditions. Soil salinity builds up as the soil dries out. When soil have a higher concentration of salt, it is more difficult for the plant to absorb water from the soil, which will hinder plant heath and growth. This can be an issue for high pH calcareous soils (IA 2007), which are often found in arid regions of the country.

Frequent applications of water at the root zone push the salts to the perimeter of the wetted area. Using drip irrigation as a process to prevent the combination of harmful soil salinity levels and maintain soil moisture is referred to as *micro-leaching*.

Improved Plant Quality and Growth

Following traditional irrigation practices, plants extract that water in the root zone within the soil from the range of field capacity (FC) to the permanent wilting point. As the soil moisture decreases, it becomes more difficult for the plant to extract water from the soil and the plant consumptive water use and moisture stress increases. As moisture stress increases, physiological changes within the plant inhibit growth. Ideally, the soil moisture level is maintained slightly below FC to attain optimum health, growth, and aesthetic quality.

Since drip irrigation more precise application of water, maintaining the controlled soil moisture levels is easily achieved. The slow regular, uniform application of water results in even growth, resulting in quality consistency, and a favorable (and controlled) root zone environment. Since drip is typically applied at or below the surface, damage due to water contact with foliage is minimized or eliminated. Wet foliage can lead to disease organisms, which are often spread through conventional overhead irrigation practices.

DISADVANTAGES AND BARRIERS

Although there are no serious disadvantages of drip/micro-irrigation, there are a few common preconceived barriers to the use of line- and point-source irrigation.

Every irrigation system requires on-going maintenance. However, drip/micro-irrigation is notoriously considered high maintenance. This is partially due to the landscape maintenance practices surrounding the components. Surface systems in particular are susceptible to vandalism. For example, string mowers ("weed whackers") can dislodge or slice ¼" vinyl tubing.

[5] The rate of soil drying and the elements that influence the drying of the landscape edge may be significantly different than the middle areas of an irrigation zone.

Another issue arises from children or pets running through landscape beds can displace the position of a point-source emitter.

Depending on the advancement of the emitter material or chemigation practices, drip may be susceptible to root encroachment (subsurface uses), insect, and/or rodent damage, algae growth, and UV damage (surface uses), particularly soft tubing components. An advancement to root intrusion has been the addition of copper shield within the embedded emitter as a non-chemical remedy (Figure 5). Advancements to the polyethylene material and the inclusion of copper within the emitter has increased design life and reduced related maintenance issues.

Photo credits: Rain Bird

Figure 5. Illustration of root intrusion and an example of the use of a copper shield within the emitter.

Another maintenance issue that burdens drip is the potential for clogging at very small openings. Implementing best practices to minimize clogging include filtration and periodic flushing of the system.

All irrigation systems should have a recommended operating pressure, and drip systems operate at the lower range of the pressure spectrum. Consequently, drip systems require pressure regulation more often than conventional components. New advances in technology have helped to overcome this barrier. Emitter design can provide a consistent flow over the entire lateral length of the line, ensuring increased reliability for the range of pressures.

Although drip irrigation can be very efficient, since water and nutrients are delivered directly to root zone, mismanagement is still an issue. Improper management can lead to over-irrigation and excessive nutrient losses due to leaching. Salt has the potential to accumulate at the perimeter of the wetted area. Irrigation water should be assessed to determine its suitability for irrigation and if water treatment is required. Testing for water quality, particularly when using a non-potable water source, should identify the chemical characteristics of the water and will address possible problems with soil salinity and plant vigor from the use of the water. See Appendix A for water quality testing and recommendations.

Dust buildup can occur as well. Dust that collects on foliage, which is often washed down with overhead sprinklers, is not when using drip irrigation. In regions with infrequent precipitation events, dust buildup can be minimized by occasional spaying (via hose), blowing, or wiping of leaf surfaces. This issue is more of a barrier than true disadvantage.

Finally, a purely psychological barrier to the use of drip irrigation is the notion that is isn't working because the end-user cannot see it in action, as opposed to sprinklers that popup, obviously spray, and often leave an reminder of functionality by means of overspray or runoff onto adjacent hardscape.

MARKET TRANSFORMATION

As will any device that does not need to adhere to a standard, there is the potential for inferior products to be sold in the marketplace under the same name. This has been the case with some drip/micro-irrigation components. There are several industry issues such as the lack of basic minimum product design, performance requirements, and uniformity among testing methods for common performance factors.

To resolve these issues, in May 2010, the International Construction Code initiated projects to develop an American National Standards Institute (ANSI) consensus product standard for landscape irrigation sprinklers and emitters. The new International Green Construction Codes and Standards will have specific references to irrigation and cite these new standards.

The American Society of Agricultural and Biological Engineers (ASABE), ANSI accredited standards developer, is working in partnership in developing this new landscape irrigation standards which includes has retained micro-irrigation (drip and micro-spray) as its own section within the standard. The Landscape Irrigation Sprinkler and Emitter Standard process should be complete during 2014. The United States Environmental Protection Agency (USEPA) WaterSense program is also participating in this process. For irrigation products, WaterSense labeling criteria is typically based on such standards.

Benefits to water use efficiency that will result from the new standard include consistent, more accurate test results, better information for designers and installers regarding product choices, improved durability, and a means for inspection, verification, and quality control in the field. The standard may also require pressure regulation within the products.

PUBLIC PERCEPTIONS

Many contractors and homeowners are reluctant to install micro-irrigation components. The micro-irrigation is perceived to require more maintenance and can be more costly to install (additional components). However, the majority of the homeowners study homes surveyed with the micro-irrigation incorporated into their systems were quite pleased with the results (Haley 2008). Additionally, once the landscape plants became established the micro-irrigation equipment was almost unnoticeable (Baum 2005; Haley 2007).

CONCLUSIONS

Micro-irrigation or drip systems are generally more efficient than conventional sprinklers because they slowly deliver water directly to the root zone, minimizing the water lost to wind, runoff, evaporation, or overspray. Using an irrigation system with a higher level of efficiency, when properly managed, has the potential for sizable water savings. By applying water directly to the root zone rather than the entire landscape area, the wetted area of the landscape footprint is reduced. Additionally, for landscape plants, it is acceptable for the wetted area to be 75% of the root zone.

Although the water may be applied to the plants more effectively, the plant-water needs do not drastically reduce. Care must still be taken to ensure the water is not applied in excess of the plant-water requirement. Drip irrigation applies water at a slower application rate; the volume of water can be the same if over a longer period of time.

As with other types of irrigation systems, the layout, design, and management is extremely important for realizing water savings. To ensure benefits of drip irrigation, the following criteria should be implemented:

- The drip/micro-irrigation system should include the following components:
    - Pressure regulator
    - Filter
    - Flush valve
    - Back flow preventer
- Use separate drip/micro-irrigation zones where practical with differing plant water requirements, root zone-depths, and slope.
- Separate above-grade drip/micro-irrigation zones from SDI zones
- For line-source drip irrigation, provide emitter and row spacing guidelines based on soil type and site conditions
- Where soil texture, tilth, or slope is likely to induce runoff, provide for mini-basins to mitigate run-off.

A note on SDI in turfgrass areas: SDI in large turfgrass areas may result in a reduction of aesthetic appearance as a result of insufficient design of lateral line spacing and soil type. However, SDI works well in small turfgrass strips (width less than 4 feet). SDI in these areas can be utilized to eliminate runoff and overspray which is a common result of sprinkler irrigation in small strip applications.

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APPENDIX A

Recommended water quality tests to be completed before designing or installing a system when using a non-potable water source.

1.	**Electrical Conductivity (EC),** a measure of total salinity or total dissolved solids, measured in dS/m or mmho/cm.
2.	**pH,** a measure of acidity, where a value of 1 is very acid, 14 is very alkali, and 7 is neutral.
3.	**Cations** include Calcium (Ca), Magnesium (Mg), and Sodium (Na), measured in measured in meq/L, (milliequivalent/liter).
4.	**Anions** include Chloride (Cl), Sulfate (SO4), Carbonate (CO3), and Bicarbonate (HCO3), measured in meq/L.
5.	**Sodium Absorption Ratio (SAR),** a measure of the potential for sodium in the water to develop sodium sodicity, deterioration in soil permeability and toxicity to crops. SAR is sometimes reported as Adjusted (Adj) SAR. The Adj. SAR value better accounts for the effect on the HCO3 concentration and salinity in the water and the subsequent potential damage to the soil because of sodium.
6.	**Nitrate nitrogen (NO3 - N),** measured in mg/L (milligram/liter).
7.	**Iron (Fe), Manganese (Mn), and Hydrogen Sulfide (H2S),** measured in mg/L.
8.	**Total suspended solids,** a measure of particles in suspension in mg/L.
9.	**Bacterial population,** a measure or count of bacterial presence in # / ml, (number per milliliter)
10.	**Boron*** measured in mg/L.
11.	**Presence of oil****

* *The boron test would be for crop toxicity concern.*
** *Oil in the water would present a concern of excessive filter clogging. It may not be a test option at some labs and could be considered an optional analysis.*

Source: Lamm and Rogers (2012).