Master Gardener

Sonoma County

Calculating Drip Irrigation Schedules

The biggest challenge in drip irrigation is accurately determining how much and when to water. Fortunately, UC websites contain a goodly amount or research-based help and advice. What follows is a summary of the scientific method of determining watering schedules for automatic controller-driven drip irrigation systems. There are some concepts to understand, and a bit of math to do—it will seem obtuse and daunting at first. But hang in there—it's all logical and makes sense. Once you get the drift, and do a couple of examples for your own garden, you'll have a method for efficiently irrigating your plants using the least amount of water possible.

What determines water needs?

The amount of water needed by any given garden zone is influenced by soil type, exposure and the plants' 'thirstiness'. Soils vary greatly in their rate of percolation--sandy very fast, loamy medium, and clay very slow. The effect is that the denser the soil, the more the water spreads laterally as it's percolating. Therefore the spacing of drip emitters depends on soil type--closer together the sandier the soil, farther apart, the more clay. Watering frequency is also influenced by soil type.

Plant water needs have been both empirically and scientifically determined. Plants are well defined in groups: no supplemental water, drought tolerant, low water, moderate water, and regular water. This is familiar to most home gardeners. Those needs have further been scientifically quantified by the plant's Evapotranspiration--abbreviated ET. This is the combined water lost from both transpiration from plant leaves and evaporation from soil and wet leaves. It's also sometimes known as crop or plant water use

Water needs are further influenced by location, exposure, wind, and weather. Clearly a sunny, south facing windy hillside will lose more water than the same plant in a shady, sheltered spot.

Three-step system

There are three steps to determining a watering schedule for a drip irrigation system:

Step 1: Finding water requirement per day or month for the garden section.
Step 2: Determining how many emitters to use, or how much emitter line
Step 3: Determining the watering days and times of your system

Step 1

A term known as Reference ET has been calculated for all locations in California for every month of the year—this is abbreviated ET^{o} and is the amount of water needed by the reference crop to survive. The reference crop is tall fescue grass, which is a thirsty plant, requiring regular water. ET regions number 1-18 and range from the coastal fog belt to the arid dry of the deserts. Coastal Sonoma County--Petaluma-Sebastopol and west is Zone 1; the Santa Rosa plain and Sonoma Valley are Zone 5, and the northeast corner of the county zone 8. (The zone map is at http://wwwcimis.water.ca.gov/cimis/images/etomap.jpg)

Further, a study by UC called WUCOLS—which stands for Water Use Classification of Landscape Species—determined the percentage of the reference ET--the species or crop factor--needed by all normally available landscape plants. With these two pieces of information, we can calculate how much water any given plant type needs, each month, in the region our garden is in.

The California Irrigation Management Information System (CIMIS) is a network of over 120 automated weather stations throughout the state. These stations provide data—temperature, humidity, wind, evaporation—to central computers in Sacramento that in turn provide daily ET^{o} information for all regions. So how can we use all this detailed scientific information? Since we know our plant types, we can multiply the crop factors for those plant types by the reference ET information for our area to come up with the amount of water needed, in a given month, by a particular type of plant.

There are a couple of other factors that 'tweak' the equation: the efficiency of the irrigation system—since we're dealing with drip, that will always be 90%; the planting density—whether total coverage, half coverage, sparse; and a microclimate or exposure factor—whether the zone is in sun, shade, windy, exposed or protected. Details are in the table below:

Crop coefficients

Crop coefficients, or species factors range from 0.1 to 0.9 and are divided into four categories:
Very low < 0.1 (10% of ET^{o})
Low 0.1 - 0.3 (10-30%)
Moderate 0.4 - 0.6 (40-60%)
High 0.7 - 0.9 (70-90%)

Planting Density

The planting density factor ranges in value from 0.5 to 1.3.
This range is separated into three categories:

Low—sparse	0.5 - 0.9
Average—moderate coverage	1.0
High--complete coverage	1.1 - 1.3

Exposure Factor

The microclimate or exposure factor ranges from 0.5 to 1.4, and is divided into three categories: Average is open field, low-moderate wind, part sun. Higher winds and greater exposure take a higher factor, and a protected, shady location would use a lower factor.

Low	0.5 - 0.9
Average	1.0
High	1.1 - 1.4

Applying Step 1, finding water requirements, involves looking up the ET^o for the zone and month, applying the crop or species coefficient for the plants involved, applying the planting density factor, applying the exposure factor, applying the efficiency factor (90%) and then converting the reference ET inches per month to gallons per month. The conversion factor from inches of rain or water, in which ET is measured, to gallons of water is .623

For our example we'll use an illustration zone: a mix of drought tolerant and low water natives and Mediterranean plants, including *ceanothus, rhamnus californica, teucrium fruticans, achillea*, prostrate rosemary, and *euphorbia characias*. The part-sun garden area is roughly 15 x 20 feet, or 300 square feet, and the new plantings were spaced such that we have about 40 plants total. These are all generally low-water plants, and thus have a low crop coefficient average of .2 to apply to reference ET—in other words, 20% of reference. (These factors are obtained from the table on the Zone map referred above).

Our bed was of average density (not actually when first planted, but based on mature sizing). The crop coefficient is .2 – the middle of the range for low water use). Exposure factor is slightly lower than average due to some shade - .9. Zone 5 reference ET for July is 6.51 inches and irrigation efficiency, as always for drip, is .9

The formula is:

$$\frac{ET^o \text{ x crop coeff. x density x exposure factor x planted area}}{\text{Irrigation efficiency}} \text{ x .623}$$

$$= \frac{6.51 \times .2 \times 1.0 \times .9 \times 300}{.9} \times .623$$

$$= 390.6 \times .623$$

= **243 gallons per month**
or around **60 gallons per week**

It’s easy to see that if we were planting thirstier plants in full sun, the water requirements would go up substantially.

Step 2

Now that we know how much water this garden area needs, step 2 involves designing a drip system to provide that water to the planted area correctly for the exposure and soil type of the zone. For simplicity we'll assume that we'll provide two 1/2 gph emitters (lower flow for denser soil) to each plant (a single emitter is fine for a small plant initially, but doesn't allow for growth and even water spacing.) Thus, with 40 plants, we'll have 80 1/2 gph drippers, and each hour that the system is on will provide 40 gallons of water (a gallon per plant). An alternative would be to run 80 feet of emitter line that contains emitters every 1 foot, for the same total of 40 gallons per hour.

Step 3

Thirdly, we combine the information from the first two steps to figure drip controller timing--when to turn on, how often, and how long to run each time. One of the biggest benefits of drip is that it puts small amounts of water, slowly, so it has a chance to penetrate, and runoff or overspray waste is never an issue. But plant selection and soil type affect your watering schedule. Some plants prefer to be continually damp, and some to dry out between waterings.

We need about 240 gallons per month. Our drip design provides 40 gallons per hour. The section is in part sun, so too long between waterings is not advisable. Further, the soil is fairly dense, which means it's going to retain water for a while. Thus we wouldn't want to water a tiny bit every day, nor would we want to water only once or twice per month. So it seems logical to set our drip to run, say, every six days, or roughly five times per month. If it runs for 75 minutes, we'll be putting out about 50 gallons per watering cycle, or pretty close to the right amount at 250 gallons per month. Or, if our soil were less denser, and we felt that it wouldn't retain water quite so long between cycles, we might set for every 4 days, seven times per month, for 50 minutes--total water 245 gallons per month. As detailed and complex as these calculations seem, there are still a lot of assumptions involved, and in the end, you still need to pay some attention to your system, your plants and your soil to determine if the right amount of water is getting to them.

So, let’s summarize:

- The formula takes into account all the factors about this garden bed, and deduces that we need about 240 gallons per month in the middle of the summer.

- We design a layout using emitters or emitter line that provides a known amount of water per hour of irrigation—in this case 40 gallons per hour.

- We use our knowledge of soil and plant type to arrive at a logical watering schedule that provides the needed weekly amount of water—every five days (six times per month) for an hour and a quarter.

These calculations were done with July ET^{o} --about the hottest time of the year. Obviously May and September, and even June and August will probably need less water. UC Irrigation studies have shown that irrigation controllers should be adjusted at least monthly for the summer irrigation period. These studies demonstrate that monthly adjustment, versus set-at-the-season-beginning and leave-til-late-fall can produce water savings of *up to 40-50%.* They conclude further that weekly adjustment, if you are so inclined, can result in even more savings. The simplest way to adjust is to look at the reference ET for the month, compare it to July, and reduce (or increase) watering time accordingly.

For example, our July ref ET was 6.51 inches. August is 5.89. 5.89/6.51 =.9, or 90% so you could reduce the 75 minute watering time above by 10 percent, to 67 minutes. September and October would take similar quick calculations to re-figure the new watering times. Once a month controller adjustment seems a reasonable price to pay for 40-50% water savings.

Now, what happens when we get a heat wave of plus 100-degree weather mid July for two weeks? We clearly need more water for optimum plant health. Modern controllers have made this easy--they have a simple override setting that allows the set program to be increased or decreased by a certain percentage. The set program is by definition the 100% level, so that hot spell might be compensated for by increasing the override by, say, 20-30 percent for those two weeks. Conversely if there was a cool, cloudy spell, you might decrease to 80% for that period.

Clearly doing drip right requires some care and attention by the gardener, but remember, we're talking about both optimizing our expensive plants' health, and minimizing the use of expensive water.

Finally, there is a way of automating these weather-driven changes with newer technology. The ET information from the CIMIS system plus weather data is packaged by makers of the newest ‘smart’ irrigation controllers and transmitted to the controllers by radio signal. The controller makes all the same calculations we just went through, integrates weather data down to a very small area (e.g., it knows if there is some rain in Glen Ellen, but not in Sonoma) and adjusts the water schedule on a daily basis for optimum plant health and water savings.

The new WaterWise Demonstration Garden that Master Gardeners installed in Sonoma has one of these controllers that was donated to the project by local Petaluma company Hydropoint. It was fascinating to learn from the company rep how to program it, and see that it accounts for plant density, plant type, root depth, amount of slope, and even plant placement on slope. Then it overlays that daily ET and micro-zone weather data to change the watering program daily. If the temperature spikes 25 degrees, it gets a boost. If there’s a summer thundershower over Sonoma, it skips a day.

These type of connected smart controllers are more expensive initially, as you’d expect, and there is a small monthly charge after the first year for the daily data feed. But a number of studies have shown that the water savings from maximum efficiency of irrigation far outweigh these additional costs, and the payback is short.

For a UC study of smart controllers, to go
http://groups.ucanr.org/CLUH/files/66789.pdf

For a detailed guide on calculating water needs and application in the landscape, as well as the complete crop coefficient table go to
http://www.owue.water.ca.gov/docs/wucols00.pdf